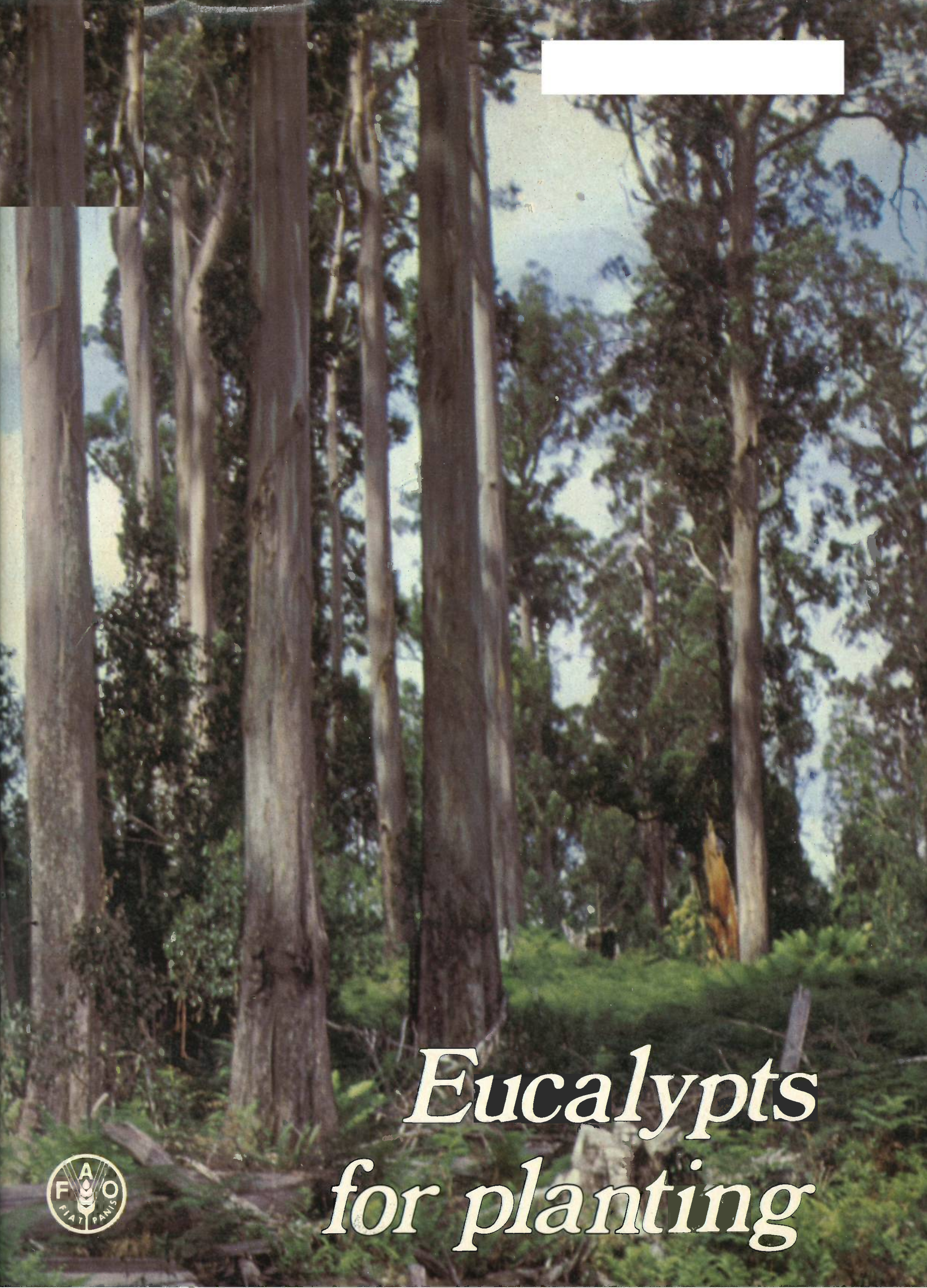


Eucalypts for planting

Like its companion work, *Poplars and willows,* this new edition of *Eucalypts for planting* is the product of the collaboration of many specialists. Its aim is to present the information gathered on the genus *Eucalyptus* since the first edition appeared in 1955. The eucalypt is increasingly considered by researchers and planners to be the most important tree available to man's exploitation, for its climatic adaptability, its relative ease of establishment and its wide-ranging usefulness.

Cover: Natural mixed eucalypt stand, Tasmania

L.D. Pryor

EUCALYPTS FOR PLANTING

Eucalypts for planting

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome 1979

The designations employed and the presentation of material in this publication do not imply the expression of any opinion whatsoever by the Food and Agriculture Organization of the United Nations concerning the legal status of any country, territory, city or area of its authorities, or concerning the delimitation of its frontiers or boundaries. Mention of product brand names does not imply their recommendation by FAO. The views expressed are those of the authors.

P-32
ISBN 92-5-100570-2

Originally published in 1955 as *Eucalypts for planting*
FAO Forestry and Forest Products Studies, No. 11

The copyright in this book is vested in the Food and Agriculture Organization of the United Nations. The book may not be reproduced in whole or in part, by any method or process, without written permission from the copyright holder. Application for such permission, with a statement of the purpose and extent of the reproduction desired, should be addressed to The Director, Publications Division, Food and Agriculture Organization of the United Nations, Via delle Terme di Caracalla, Rome, Italy.

© FAO 1981
Printed in Italy

Foreword

The first edition of *Eucalypts for planting*, written by André Métro and published by FAO in 1955, has been in constant use in many countries over the past two decades. In that period there have been major developments both in the area of eucalypt plantations established and in planting techniques. The area of plantations reported has increased fivefold and now amounts to at least four million hectares, spread over more than ninety countries outside the natural area of distribution of the genus in Australia and the East Indies. Eucalypts are of increasing importance to the developing world, of which eighty countries have reported their interest in the genus. They have many uses, for sawnwood, pulpwood, wood-based panels, poles and posts, as well as for environmental and amenity planting. They have an especially important role to play in the production of renewable fuelwood resources, for which they provide an excellent combination of specific gravity and volume production. The adaptability of one or other species of eucalypt to a wide range of climates, from semi-desert to cold temperate or alpine, is one reason for their remarkable success as exotics.

The expansion in planting and development in techniques in the last 25 years have led to a nearly complete rewriting of the book. FAO was fortunate in obtaining the services of Dr. M.R. Jacobs, like A. Métro a eucalyptologist of world reputation, as main author of the new edition. As acknowledged in the text, many other individuals have made valuable contributions, but the major source of new information remains the country reports, received in response to the FAO questionnaire on eucalypts which was sent to member countries. I hope that the new book will play as useful a role as its predecessor in the series of publications on afforestation prepared by FAO's Forestry Department.

Information is of limited value without the means to use it. One important development which has been made possible through the service provided by the Seeds Section of the Division of Forest Research, CSIRO, Canberra (and by its predecessor in the Forestry and Timber Bureau), is the reliable provision of source-identified seed of a large variety of Australian eucalypt provenances for testing in other countries. The choice of species and provenances to be collected for the international programme has been determined on the advice of FAO's panel of experts on Forest Gene Resources, and it has been possible to extend the speed of collection and the range of provenances collected by means of financial support from FAO's Regular Programme.

Eucalypts for planting will, it is hoped, aid foresters to know "the right tree to plant on the right site, using the right treatment." A continuation and expansion of eucalypt seed provision will enable them to make effective use of their knowledge.

E. Saouma

Director-General
Food and Agriculture Organization
of the United Nations

Acknowledgements

FAO acknowledges with thanks the valuable contributions made to this monograph by foresters throughout the world. Many national forest departments, institutes and individuals supplied detailed information and illustrative material.

FAO is especially grateful to the Government Printer, the Forestry and Timber Bureau and the Division of Forest Research, CSIRO in Canberra for permission to make use of published material in *Forest Trees of Australia* by Hall, Johnston and Chippendale and the Forest Tree Series of leaflets, FTB leaflet No. 114 by N. Hall on climate, G.M. Chippendale's *Eucalyptus buds and fruits* and *The use of trees and shrubs in the dry country of Australia* by Hall *et al.*; also to CSIRO and the Bureau of Meteorology in Melbourne respectively for material from *The Australian environment* and climatic maps.

Volume and yield table data were kindly supplied by a number of institutes and individuals, as indicated in Appendixes 2 and 3. Other contributions or sources acknowledged with thanks are those of Professor Pryor and Dr. Brooker; the Wattle Research Institute, Pietermaritzburg; New Zealand Forest Products; Dr. Cheney, Dr. Gibson, the International Potash Institute, Bern; Dr. Dale and Dr. Poynton and the Department of Forestry in Pretoria. Among the photographs particular mention should be made of the series which were specially taken by the Centro di Sperimentazione Agricola e Forestale, Rome, to illustrate the author's account of growth habits in Chapter 2; of the series depicting bark characteristics supplied by the Division of Forest Research, CSIRO, Canberra (Chapter 3); and the colour photos provided by Professor Pryor, Dr. Johnston, Dr. Boland and the Forests Commission, Victoria.

These acknowledgements would not be complete without recognition of the inestimable contribution of Mr. R.L. Willan, technical editor, indexer and general coordinator for the preparation and publication of this work.

Readers are reminded that several comprehensive national or regional accounts of eucalypts have appeared in recent years, notably those by de la Lama Gutiérrez for Spain, Goes for Portugal, Hillis and Brown for Australia, and Poynton for southern Africa.

NOTE ON NOMENCLATURE

The practising forester has to live with frequent changes in botanical nomenclature. An important plantation taxon which has recently been affected by name changes is the *E. globulus* complex. Four taxa, previously considered as separate species, are now considered as subspecies of *E. globulus* (Kirkpatrick, 1974; Chippendale, 1976), as follows:

Name included in Chippendale, 1976	*Previous names*
E. globulus Labill. ssp. *bicostata* (Maid. *et al.*) Kirkp.	*E. bicostata* Maid. *et al.* *E. stjohnii* (R.T. Bak.) R.T. Bak.
E. globulus Labill. ssp. *globulus*	*E. globulus* Labill. *E. globulus* Labill. var. *compacta* L.H. Bail.
E. globulus Labill. ssp. *maidenii* (F. Muell.) Kirkp.	*E. maidenii* F. Muell.
E. globulus Labill. ssp. *pseudoglobulus* (Naudin ex Maid.) Kirkp.	*E. pseudoglobulus* Naudin ex Maid. *E. stjohnii* (R.T. Bak.) R.T. Bak. *E. globulus* Labill. var. *stjohnii* R.T. Bak.

In the present work, names used by reporting countries have been retained, as, for example, in Chapter 4; while the new nomenclature has been adopted in Chapter 3 (Systematics) and Chapter 14 (Species monographs). The old nomenclature is also retained in certain of the drawings in Appendix 7, which are reproduced from Blakely's "*Eucalyptus* buds and fruits" (1968). This accounts for the nomenclatural inconsistency.

Contents

Figures

PHOTOGRAPHS

Colour plates

GRAPHICS

1. The natural environment

The eucalypts are usually regarded as Australian trees. The great majority of the many species and subspecies are endemic to the Australian continent and closely adjacent islands. Nevertheless, several occur naturally in the land mass of Papua New Guinea to the north of Australia and certain species occur in some of the islands of the eastern part of the Indonesian archipelago, such as Timor, the Lesser Sunda Islands, Flores and Wetar. One important species, *E. deglupta*, follows the line of active volcanoes which extends from New Guinea through Sulawesi (Celebes) and the Moluccas up to the island of Mindanao in the Philippines.

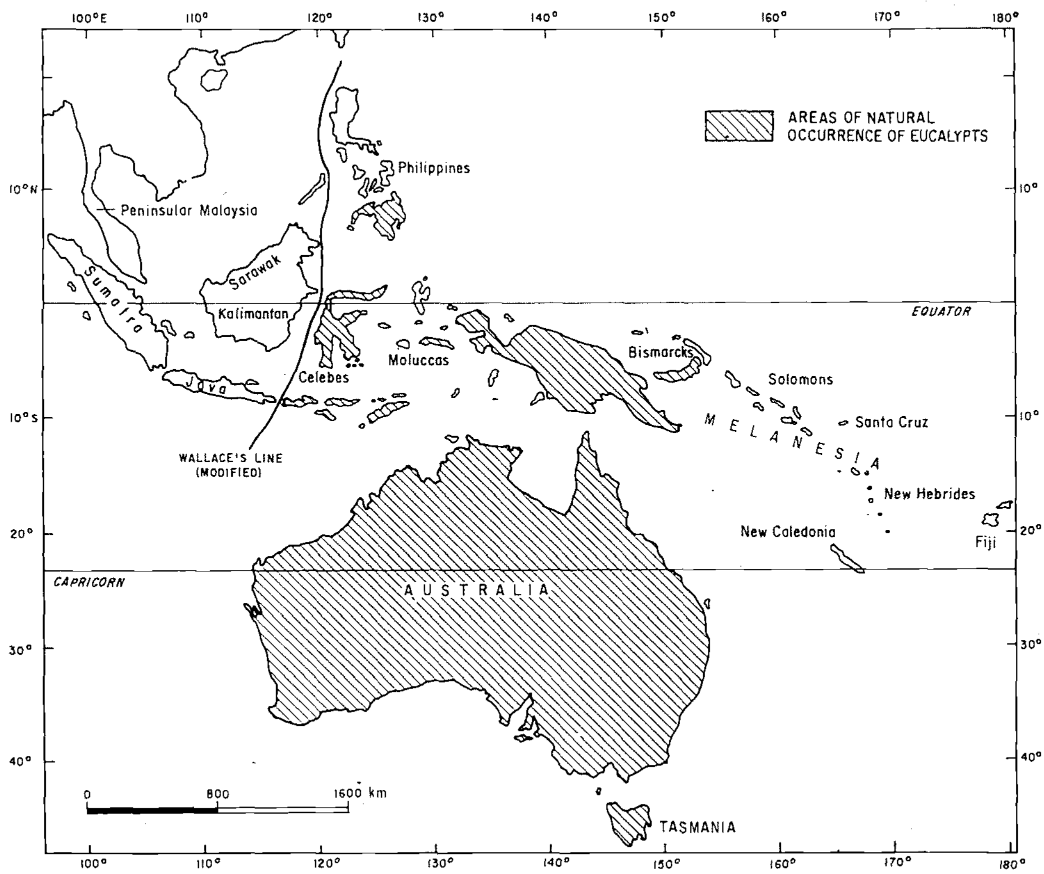
Of the species found outside the territorial limits of Australia, two, *E. deglupta* and *E. urophylla*, have not been recorded from Australia. These two are important as possible "eucalypts for planting" in the lower latitudes of the world. They are good species and tolerate lower latitudes than any found in Australia, where the northernmost point is 10°41′S.

Limits of natural occurrence of the genus

The natural occurrence of the eucalypts is nearly always to the east of "Wallace's Line", a hypothetical but very practical division separating what A.R. Wallace called Indo-Malayan and Austro-Malayan life types, whether animals or plants (Wallace, 1913). This line, as drawn by Wallace in 1869, passes between Bali and Lombok, through the Makassar Strait with Sulawesi on its eastern side and Borneo to the west, then northeast through the Celebes Sea and the southern islands of the Philippines, leaving Mindanao on its western side. In Mindanao occurrences of *E. deglupta* are found to the west of the line as drawn by Wallace. Recent studies have suggested that Wallace was incorrect in drawing his line east of Mindanao. The amended line is shown in the Times Concise Atlas of the World (1973) as going west of Mindanao. The known natural occurrence of all eucalypts lies east of this amended line, with the possible exception of *E. alba* in north Bali (Martin and Cossalter, 1975-76).

The eucalypts, then, are essentially Austro-Malayan trees with a natural latitudinal range extending from 7°N to 43°39′S. The majority of present-day species and of the best natural stands of the most widely planted species occur south of the Tropic of Capricorn. Nevertheless, recent trials have demonstrated that provenances growing north of the Tropic of Capricorn are of increasing importance in low-latitude countries.

I Natural distribution of the genus *Eucalyptus*



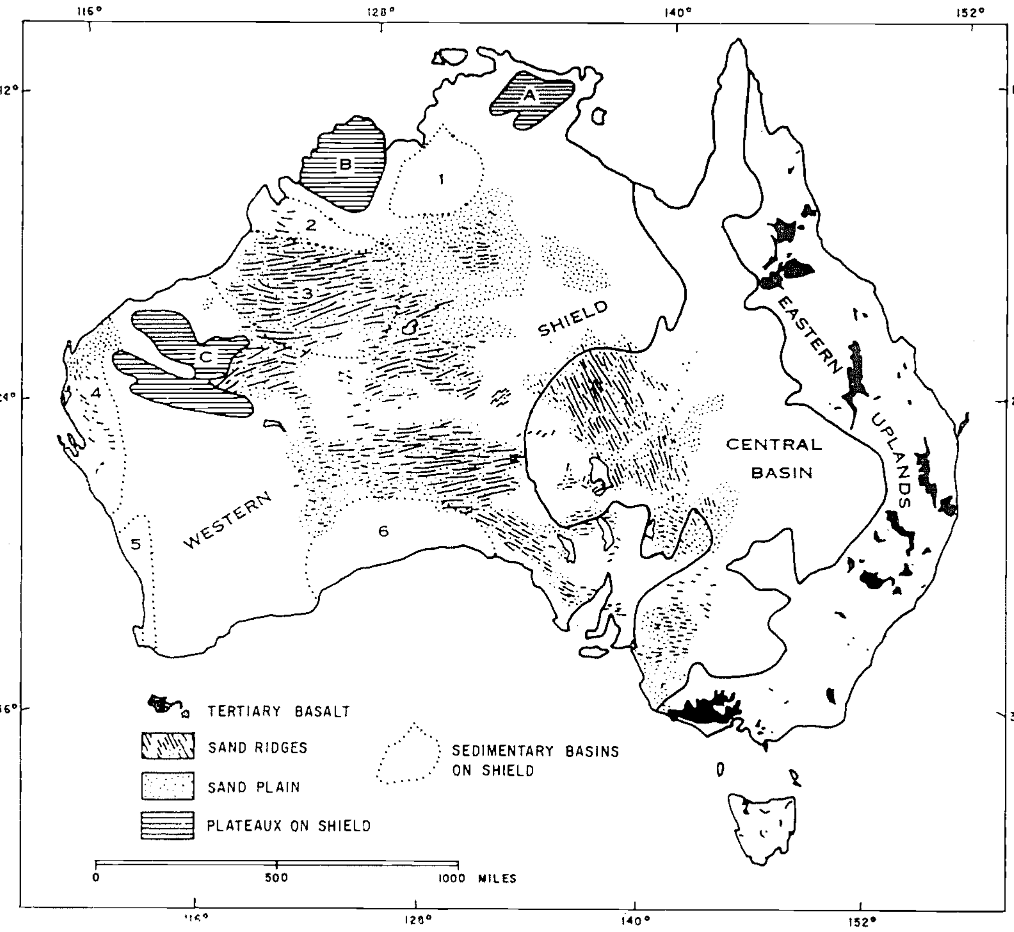
The Australian land form

The continent and adjacent islands which make up the Commonwealth of Australia cover an area of 7.7 million km^2, about the same area as the United States of America, excluding Alaska and the Hawaiian Islands. The basic features of the continent (Leeper, 1970; see Figure II) are the Western Shield, largely an extensive plateau of ancient granites and gneisses between 300 and 600 m in altitude; the Central Basin; and the Eastern Uplands which form an unbroken belt of higher ground from Cape York in Queensland (latitude 10°41′S) to the southernmost tip of the continent at Wilson's Promontory in Victoria (latitude 39°8′S). The main continental mass is separated by Bass Strait from the island state of Tasmania, essentially a southward extension of the Eastern Uplands.

The Eastern Uplands are between 150 km and 350 km wide and the crests of the mountain ranges are usually between 600 m and 2 000 m in height. The highest peak is Mt Kosciusko, in the state of New South Wales, with an altitude of 2 211 m.

Between the Eastern Uplands and the Western Shield lies the Central Basin, mainly under 200 m in altitude but with a few ranges protruding from it, such as the Flinders, the Mt Lofty and the Musgrave Ranges in South Australia and the Macdonnell Ranges in the Northern Territory.

The Eastern Uplands create a watershed between rivers which flow into the Pacific Ocean on the eastern side of the continent, into the large Gulf of



II The Australian land form.
(A, Arnhem land; B, Kimberley Plateau; C. Hammersley Ranges. Sedimentary basins: 1, Ord-Victoria; 2, Fitzroy trough; 3, Canning; 4, Carnarvon; 5, Perth; 6, Eucla)
After Leeper, 1970

Carpentaria to the north, to the southern Indian Ocean in the south or into land-locked depressions in the Central Basin. These uplands are of great importance in intercepting, and causing rainfall from, air masses which blow over or into the continent from east or west. The main continuous belt of high forest country in Australia lies along and to either side of the Eastern Uplands. Most eucalypt species of importance to countries outside Australia occur naturally along this belt.

On each side of the Eastern Uplands, and on the northern and western side of the Western Shield, there are alluvial valleys and lower reaches of streams which may be up to 200 km from the coast. The total area of alluvial (and aeolian) deposition resulting from the gradual weathering of the older land masses represents approximately one third of the continental area or more than 2 million sq km. An appreciable proportion of inland Australia has a surface of blown sand.

Climatic fluctuations in Australia have been accompanied by changes in sea level. When the sea-level rose, large areas of the Central Basin were flooded. When it fell, both Tasmania and New Guinea were either united with or less widely separated from the main land mass. The Eastern Uplands experienced some uplifting during the Tertiary Period and there was some vulcanism in different parts of the continent at that time.

The coastline of Australia changed appreciably with the rise and fall of sea-level. Substantial areas of the continental shelf which are now under water were previously exposed. Localities which are now close to the coast were then well inland, sometimes 200 kilometres or more. This influenced the continentality of their climates.

Australian climatic conditions

The Australian continent extends over about 35° of latitude, and a similar distance from east to west. More than one third of it is north of the Tropic of Capricorn, the northernmost point being Cape York in Queensland at a latitude of 10°41′S. The remaining and larger part extends southward in the subtropical and temperate zones to the southern tip of Tasmania at about latitude 43°39′S, the southern limit of arboreal vegetation. Macquarie Island, administered by Tasmania, is at latitude 55°S but is treeless.

The Australian climate is influenced by several factors, but the main one is the sequence of large rotating air masses which move over the continent from west to east at an average speed of about 800 km per day (Leeper, 1970). In the southern hemisphere, these air masses rotate in an anti-clockwise direction around high-pressure centres and are called "highs" or "anti-cyclones." Between successive highs, wedges of low pressure or air masses rotating clockwise around low-pressure centres enter the system, both from the southern oceans and from northern tropical seas to the northeast and northwest. These "lows" or large "cyclones" are very important factors in bringing rain.

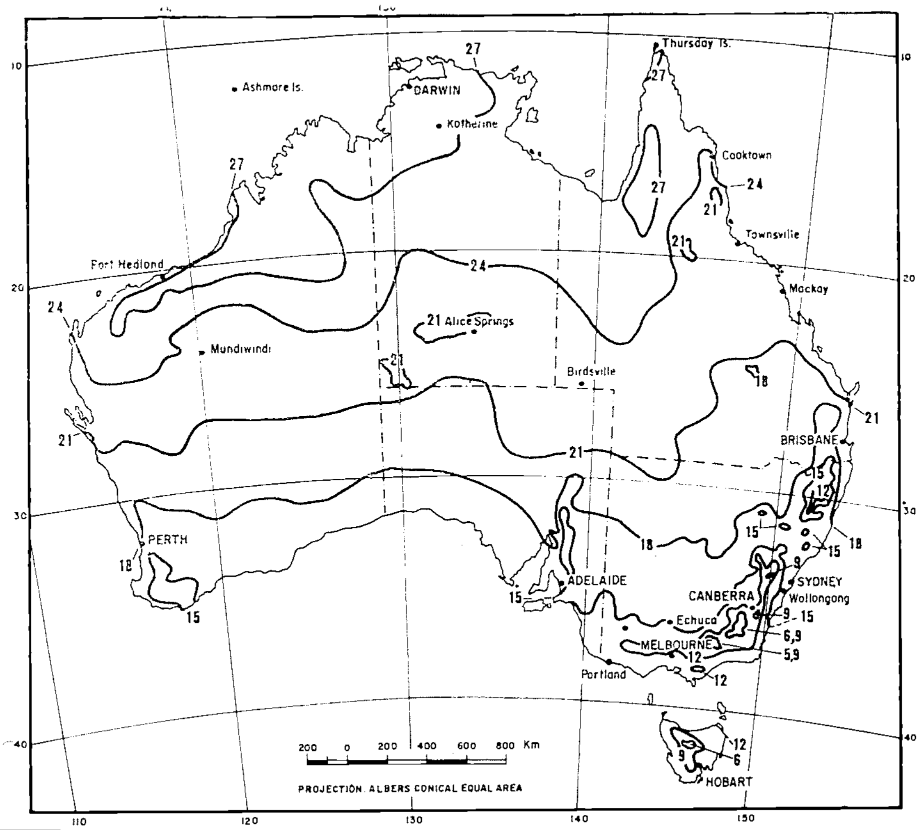
In the tropical parts of Australia the southeast trade winds bring rains to the eastern ranges and coast. During summer, intense tropical cyclonic storms occasionally develop over the seas to both the northeast and the northwest of the continent. The path of these storm-cyclones is irregular and unpredictable but, when they approach or cross the northern coastlines, they bring heavy rains and sometimes cause severe damage.

The centre of Australia is dry and has few clouds. It heats up relative to the region near the coast, particularly the southern seaboard. When winds from the rotating air masses, whether "highs" or "lows", blow over the continent, they become warmer and bring warm or hot conditions to the seaboard.

As a result of the effects of varying topography on these air masses, Australia has a complex series of zones of low and high rainfall, as well as uniform, summer and winter rainfall. These seasonal rainfall zones are of great importance to the distribution of tree species and vegetation types. The zones are shown on the map in Figure IV, and climatic data for one or more localities in each zone are given in Appendix 1 (for examples of comparative climodiagrams, see Appendix 8).

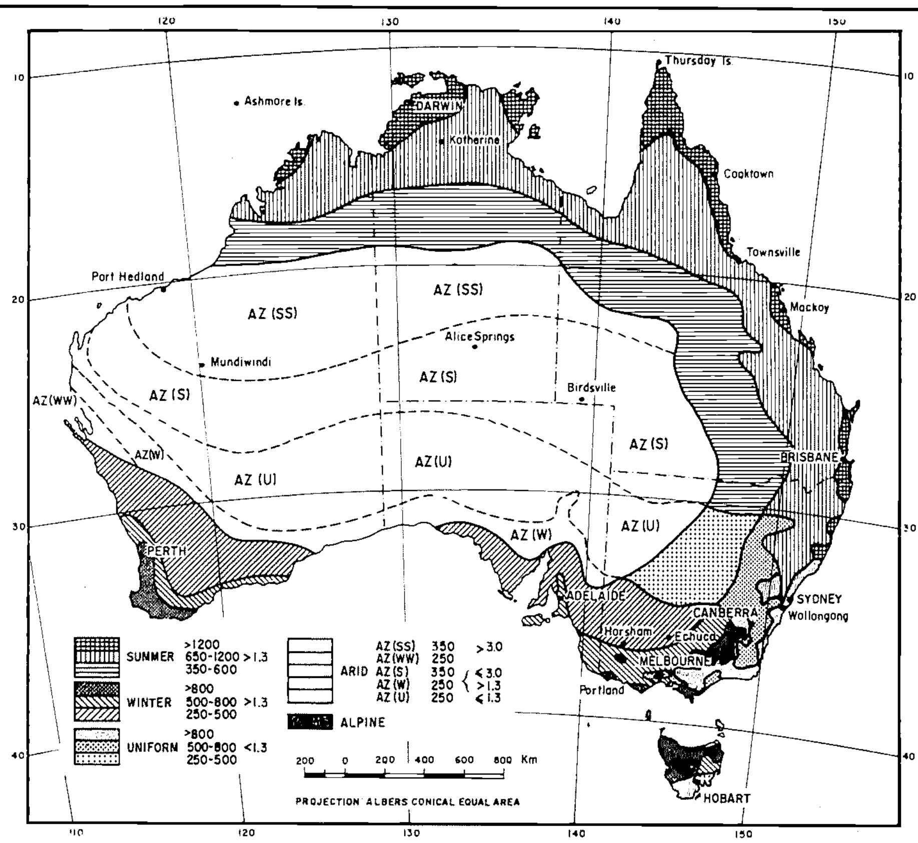
ZONES OF SUMMER RAINFALL

The zones of summer rainfall (SR) include the areas which receive the greatest amount of rainfall but, because they have the highest evapotranspi-



III Mean annual temperatures (isotherms in degrees Celsius)

Courtesy Director of Meteorology, Australia



IV Seasonal rainfall zones

Courtesy Director of Meteorology, Australia ration, much of it is lost. Figure IV shows that, north of Taree (latitude 32°S), most of northeastern New South Wales, all of Queensland and the Northern Territory, and most of Western Australia north of latitude 30°S are in the zone of summer rains, including the arid-zone parts of this vast area. Many eucalypt provenances and species of high potential for planting in tropical and subtropical countries will come from these zones. The rainfall of the summer-rainfall zones is much more variable than that of the winter-rainfall zones, and over most of it the species have become adapted to long dry seasons.

The wettest section of the summer-rainfall zone (i.e., SR > 1 200 mm) occurs in four separate areas. The easterly area is the somewhat discontinuous belt along the northeastern coastline north of Taree, New South Wales. This is the region affected by the southeast trade winds blowing against the Great Dividing Range (particularly north of the Tropic of Capricorn). An area of over 5 000 km^2 in northwest Queensland near Cairns receives more than 2 500 mm of rainfall annually as a result of this influence (Leeper, 1970). The other three areas of the SR > 1 200-mm zone are on the northeastern and northwestern sides of the Northern Territory peninsula and a small section of the Kimberley Ranges of Western Australia. These are influenced by monsoon rains, usually coming from the northwest but sometimes from the northeast.

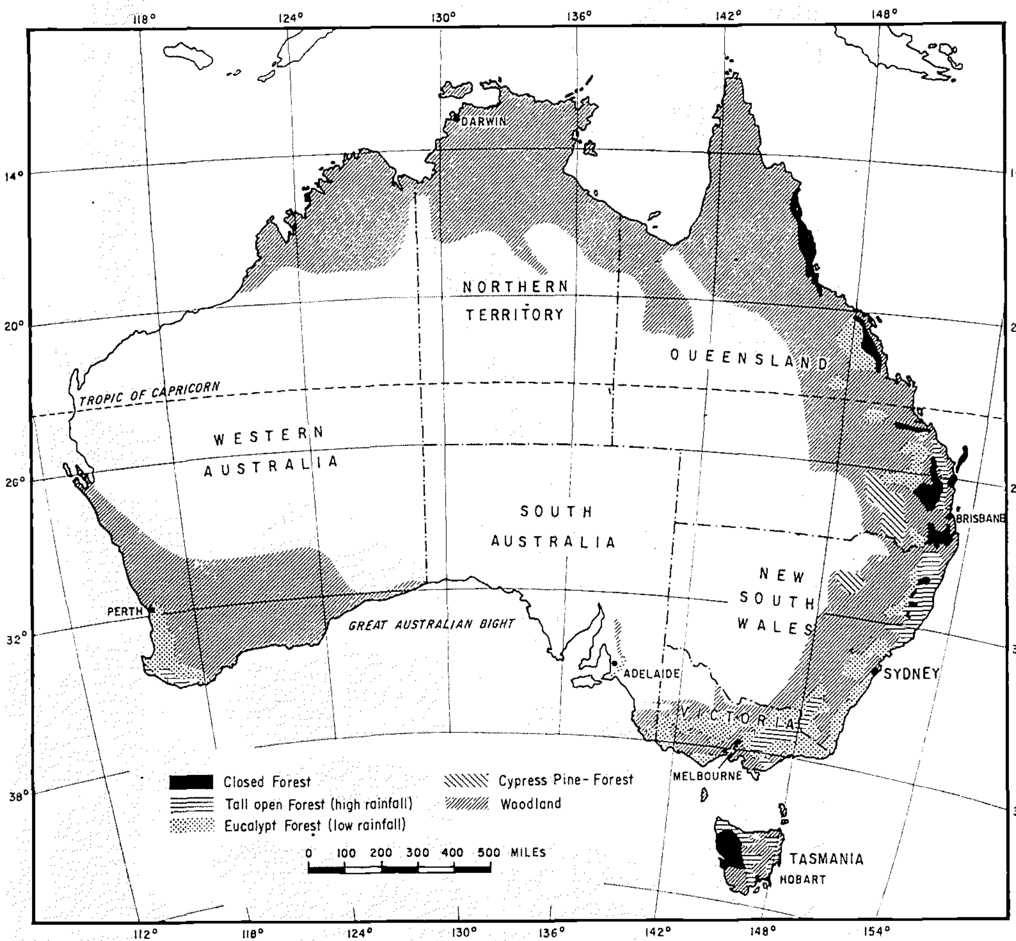
The second section of the summer-rainfall zone (SR 600-1 200 mm) lies mainly inland of the wettest section and covers a strip of an average width of 200 km, from central New South Wales to Derby in Western Australia. This is fairly good open forest or woodland, with some agriculture and potential for pasture improvement. It contains several provenances of eucalypts which are of interest to other countries for planting.

The third section of the summer-rainfall zone (SR 350-600 mm) is again a belt of an average width of 200 km, inland of the second section in Queensland, Northern Territory and Western Australia. Most of it is managed for grazing. Rainfall varies considerably from year to year. It contains much woodland but few eucalypts recommended for planting.

The huge arid sections of the summer-rainfall zone, AZ (SS) < 350 mm and AZ(S) < 350 mm, cover the north-central part of Australia. This is difficult country, but the trees that do grow on it sometimes interest nations that have similar conditions.

Zones of uniform rainfall

The zones of uniform rainfall (UR) as shown in Figure IV are somewhat complex in pattern, particularly in New South Wales. They occur where both the cyclones or "lows" moving from west to east in winter and the rain-bearing storms from the Pacific Ocean to the east and southeast have an influence on the rainfall pattern. The two sections, UR > 800 mm and UR 500-800 mm, cover much important forest and agricultural land in New South Wales and eastern Victoria. Many eucalypt species discussed in this book come from these sections. They are also important in southern Tasmania.



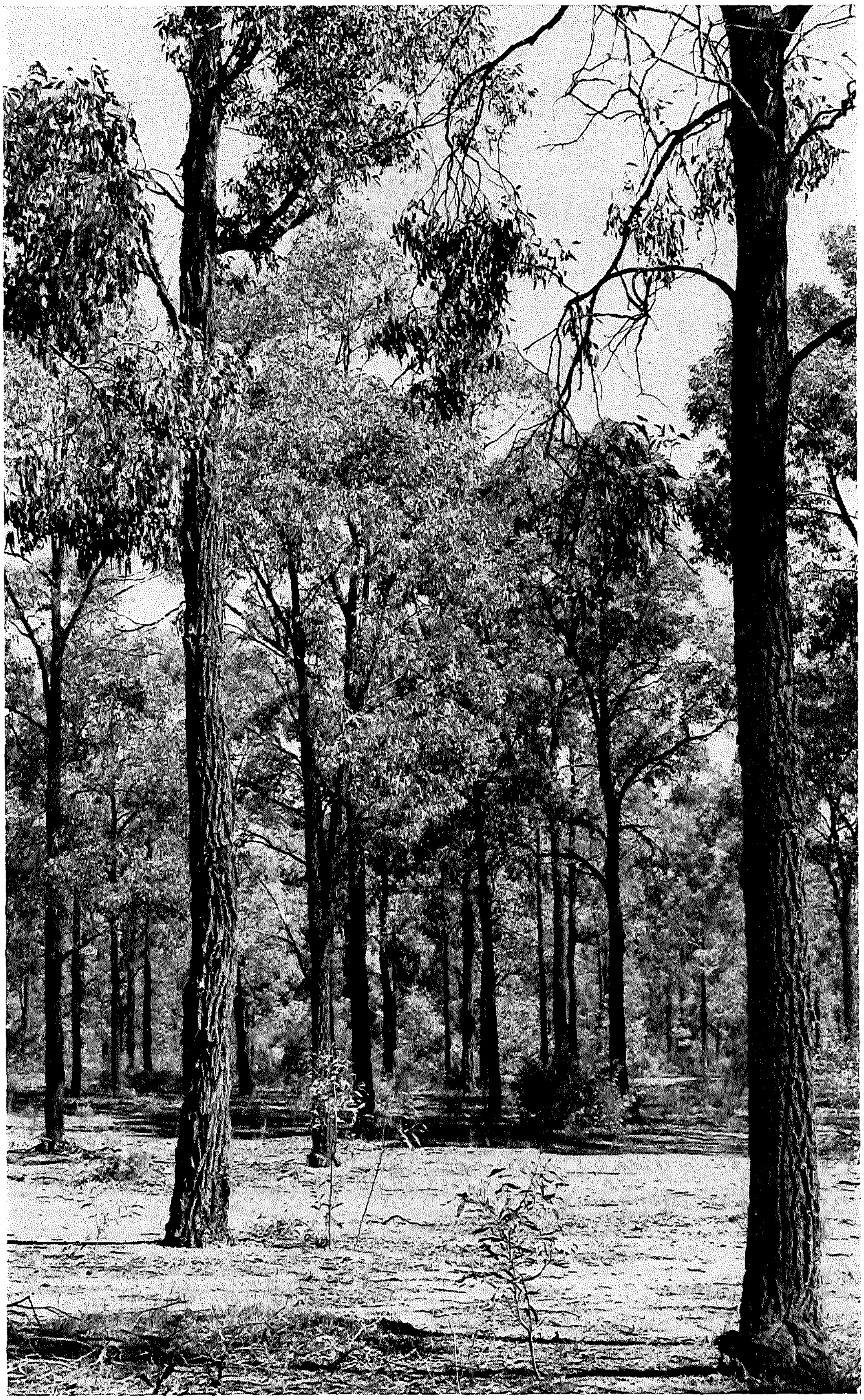
V Principal forest and woodland areas of Australia

After Hall, Johnston & Chippendale, 1975

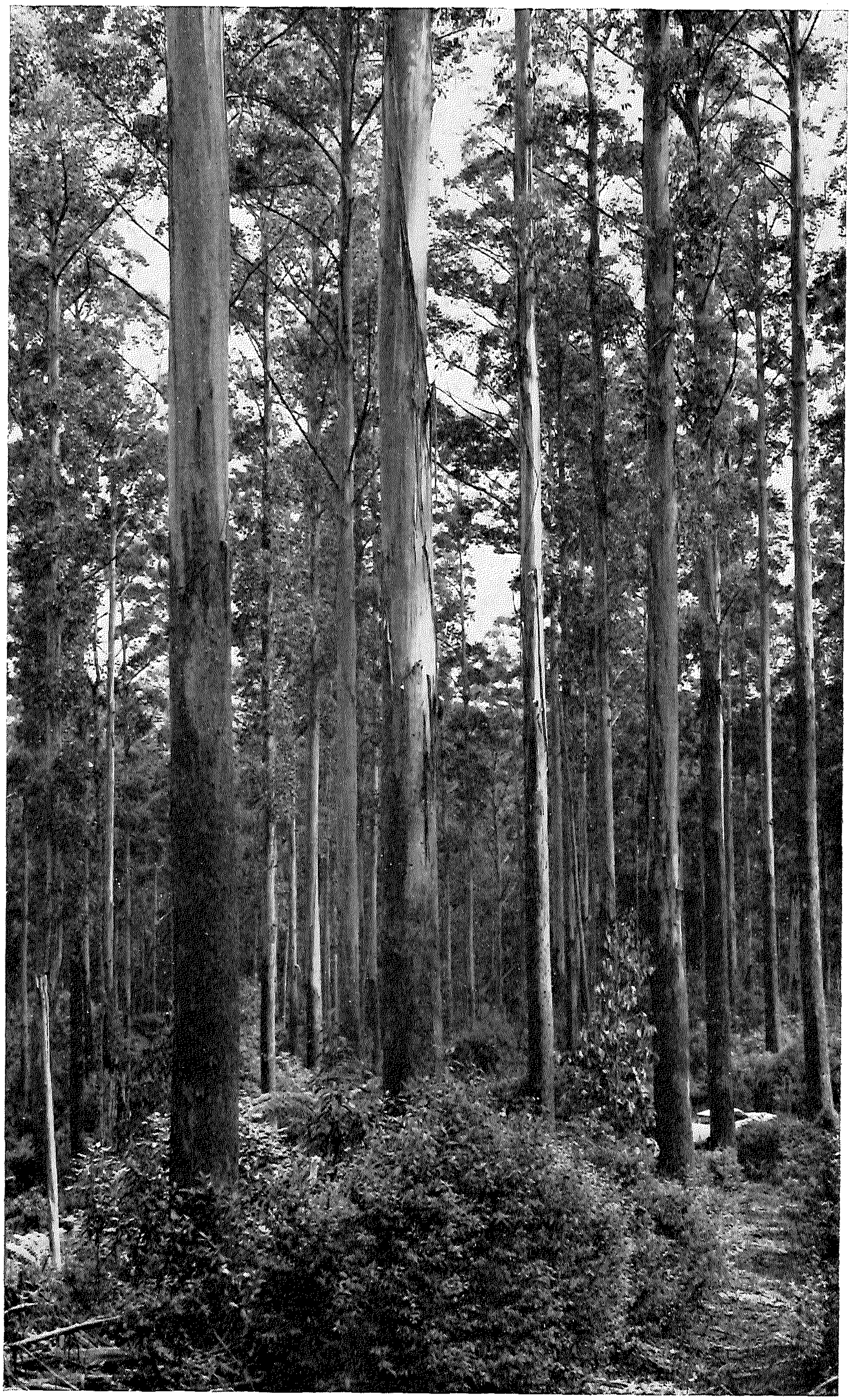
Zones of winter rainfall

The zones of winter rainfall (WR) are important in the four southern states — Western Australia, South Australia, Victoria and Tasmania — with a substantial intrusion into the southern part of New South Wales inland from the Great Dividing Range. The cyclonic winter air masses — "lows" — move north from the southern oceans and then eastward across the southern part of the continent, but are usually pushed south again as they reach New South Wales and Victoria. They are most important to Australian agriculture because they provide the most reliable wet seasons.

The wettest zone of winter rainfall (WR $>$ 800 mm) covers the important forest region of far southwest Western Australia, a small section of the Mt Lofty Ranges in South Australia, and important forest regions in Victoria, Tasmania and the south of New South Wales, inland from the Alpine Zone.



1. Woodland of
E. sideroxylon,
Rushworth,
north central
Victoria
Forests Commission, Victoria



2. Natural regrowth of *E. regnans* after the fires of 1939. Age 35 years, top height 60 m, maximum height 100 m. Powelltown, Central Highlands, Victoria. Annual rainfall 1 125 mm
Forests Commission, Victoria

Table 1.1 Structural forms of vegetation in Australia

Life form and height of tallest stratum [1]	Projective foliage cover of tallest stratum [1]			
	Dense (70-100 %)	Mid-dense (30-70 %)	Sparse (10-30 %)	Very sparse (< 10 %)
Trees [2] > 30 m	Tall closed forest [4]	Tall open forest [5]	Tall woodland [3]	Tall open woodland [3]
Trees 10-30 m	Closed forest [4]	Open forest [6]	Woodland	Open woodland
Trees 5-10 m	Low closed forest	Low open forest	Low woodland	Low open woodland
Shrubs [2] 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 [3]
Hummock grasses 0-2 m	—	—	Hummock grassland	Open hummock grassland
Herbs (incl. moss, ferns, hemicryptophytes, geophytes, therophytes, hydrophytes, helophytes)	Closed herbland	Herbland	Open herbland	—
	Closed tussock grassland	Tussock grassland	Open tussock grassland	—
	Closed grassland	Grassland	Open grassland	—
	Closed herbfield	Herbfield	Open herbfield	—
	Closed sedgeland	Sedgeland	Open sedgeland	—
	Closed fernland	Fernland	Open fernland	—
	Closed mossland	Mossland	Open mossland	—

[1] Isolated trees (emergents) may project from the canopy of some communities. — [2] A trees 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. — [3] These formations are rare in Australia. — [4] Formerly called "Raisi forest". — [5] Formerly called "Wet sclerophyll forest". — [6] Formerly called "Dry sclerophyll forest".

The zone WR 500-800 mm covers a narrow zone in southern Western Australia, southern South Australia, Victoria, southern New South Wales and northeastern Tasmania. This is some of the best Australian farming land and has useful species of eucalypt.

The zone WR 250-500 mm is usually 100 to 200 km wide and covers good grazing land in Western Australia, South Australia, Victoria and New South Wales. Apart from provenances of *E. camaldulensis*, eucalypts from this zone are not much used for planting.

ALPINE ZONES

The alpine areas of Australia are limited to the States of New South Wales, Victoria and Tasmania. There are substantial areas which are under snow for several months of the year. In odd protected spots a little snow has lain throughout the year for at least the past 20 years; it is possible that under screes it has lain for centuries. The tree line is about 1 300 m in Tasmania and 2 000 m on the mainland. The alpine eucalypts are of interest for planting on special sites of limited extent. Figure III shows mean annual temperature zones in Australia.

Australian soils

About 90 percent of the whole complex of the Australian vegetation is dominated by the genus *Eucalyptus*. Is it the soils or other factors which have enabled the eucalyptus to thrive, regenerate and diversify over such a large area? Are there any special characteristics in the soils?

Most physical types of soil are found in Australia, developed from the wide range of parent rocks. By and large the soils are old and well leached (Leeper, 1970). The forest soils have a fairly low pH; they are likely to be deficient in phosphorus and also nitrogen, in spite of numerous tree species, shrubs and herbs of legumes under the dominant eucalypts. The soils are frequently high in aluminium, manganese and iron, but low in the minor elements: copper, zinc, molybdenum and boron. They are usually low in free carbonates even when calcareous rocks are present in the parent material. The majority of the eucalypts were adjusted to these soils before clearing for agriculture commenced. At that time the high evapotranspiration of the forest prevented rapid leaching of salts from the soil complex, in which salts were present but not in dangerous amounts. Clearing for agriculture led to movement of salts to the lower levels of the soil catena and an accumulation which is sometimes dangerous to agricultural crops and natural vegetation. This led in turn to the identification of eucalypt species which could tolerate soil salinity and these have been important in some planting countries.

As is usual in forests, generations of leaf-fall led to an accumulation of plant nutrients in the upper layers of natural Australian forests. One characteristic in which Australian soils differ from the soils of the continents in the northern hemisphere is that the worms and other soil fauna in Australian forest soils are not as quick-acting as those of the northern hemisphere. The lower horizons of the Australian soils are less regularly enriched.

Although there are certain characteristics common to many Australian soils and the microfauna and microflora in them, there is also enormous variation. Different species of eucalypt are adapted to the different combinations of edaphic factors which occur. Some of these problems are discussed in Chapter 13 — "Choice of species."

Australian forest types

The classification of Australian forest types in this chapter follows the vegetation classification used by Specht in "The Australian Environment" (Leeper, 1970); see Table 1.1. The distribution of the main forest and woodland areas is shown in Figure V. The classification is based on:

1. *The life form and height of the tallest stratum*, with four main divisions — (*a*) trees; (*b*) shrubs (woody plants less than 8 m tall, usually multi-stemmed); (*c*) hummock grasses; (*d*) herbs. Eucalypts are prominent in the first two of these divisions.

2. *The projective foliage cover of the tallest stratum.* This may be (*a*) dense (70-100%), including closed forest and closed scrub; (*b*) mid-dense (30-70%) including open forest and open scrub; (*c*) sparse (10-30%) including woodland and shrubland; (*d*) very sparse ($<$ 10%) including open woodland and open shrubland.

CLOSED FOREST

The closed forests or rain forests are found in well-watered areas from Cape York in Queensland (lat. 10°41′S) to the south of Tasmania (lat. 43°39′S). In the tropics and subtropics they contain a wide variety of Indo-Malaysian trees but the eucalypts do not form a significant element in them, although they occur at the frequently rather sharp transitional zone at the edge of the closed forest.

In southern Australia the main elements of the cool-temperate closed forests are "Antarctic" species such as *Nothofagus* which are also typical of high-rainfall areas of New Zealand and Chile. The eucalypts play an important part in the development of the cool-temperate closed forests of southern Australia. Periodic major forest fires may kill all the aerial parts of all the trees in these forests. Then follows a sequence of seedling acacias and eucalypts, such as *E. regnans*, *E. delegatensis* and *E. nitens*, under which the closed-forest species gradually develop. The subterranean parts of the closed-forest species are not necessarily killed by the fire and they sprout from quite large stumps. The eucalypts grow to 60 or 70 m or more in height and the understorey of closed-forest species to perhaps 30 m in height. Ultimately the closed-forest species replace the eucalypt overstorey. *E. delegatensis* goes out in a few decades, *E. regnans* may last 200 years while *E. nitens* appears to tolerate the closed-forest species better than the other two. Ultimately "In the heart of the rain forest the eucalypt is not to be found" (Métro, 1955). Yet in the heart of the southern closed forest may be found huge fallen trunks, sometimes 2 m in diameter, which prove to be *E. regnans* and which once reared over the closed forest to a height of at least 30 m.

Open forest

The open forest and woodland formations of Australia are the realm of the eucalypts. The genus dominates them to the extent that more than 90 percent of the wood volume of the natural forest is eucalypt wood.

Open forest is divided into (*a*) tall open forest; (*b*) open forest; and (*c*) low open forest. The trees of the tall open forest have a dominant height of at least 30 m, frequently 60 m, with boles at least half the tree height, and a dense understorey of small trees, large shrubs, tree-ferns, etc. The term "wet sclerophyll forest" is frequently used to describe this type. Tall open forest is found in areas with at least 900 mm of rain per year along the east coast of Australia and the far southwest of Western Australia. In the southeast of Australia it may be a stage in the succession to a closed-forest association after catastrophic fires.

Open forest has a dominant height of between 10 and 30 m; it is usually dominated by eucalypts and the eucalypt and understorey species change with dominant height and with latitude. It is subject to fairly frequent burning, but the eucalypts are rarely killed by this. The term "dry sclerophyll forest" is frequently used to describe this type. It may be subdivided according to the type of understorey.

Low open forest has a dominant height of 5-10 m. In some areas the eucalypts may co-exist with other tree species such as the native conifer, *Callitris* (cypress pine).

Specht's woodland and open-woodland types are usually dominated by eucalypts, but occasionally by trees of other genera, such as *Callitris, Casuarina, Melaleuca* and *Acacia*. The trees have rounded crowns and the length of the tree bole is usually less than the depth of the crown. Woodland and open-woodland communities cover a vast area in all States of the mainland of Australia. They grade into open forest at their moister limits and into scrub or shrubland types at the drier.

Mallee eucalypts are characteristic of large areas of open-scrub formation in different parts of Australia. The usual present occurrence of mallee is on sandy soils in rather dry climates, but large areas of the Australian wheat-belt were developed by clearing mallee scrub in the 250- to 500-mm rainfall zones. The "mallee" plant form is one in which several stems, each like the eucalypt "crown unit" described in Chapter 2, grow from a large subterranean lignotuber. The stems live on for 20-30 years; when they are killed or die naturally they are replaced by new shoots from the lignotuber. The lignotuber, or "mallee root" as it is called, is not a root but an underground stem structure. It may live on for 200-300 years. Mallee roots cleared in creating the wheat-belts provided an important source of household fuel for the cities of Melbourne, Adelaide and Perth.

The mallee form, although characteristic of inland sandy areas on the Australian mainland, is also seen in the alpine areas of New South Wales, Victoria and Tasmania, where *E. pauciflora* and other alpine species develop it, and on the wet heathlands of southern Tasmania, where some species of eucalypts such as *E. vernicosa* develop it.

Local empirical terminology

The morphological diversity in the genus *Eucalyptus* which has resulted from this variety in the Australian environment has been popularly simplified by the use of the word "gum" to describe every kind of eucalypt. Nevertheless, eucalypt users, planters and foresters have distinguished various categories which they have identified empirically with highly descriptive names according to outstanding characteristics.

Many of the names refer to bark characteristics, which are described in Chapter 3. Other names which are commonly used are as follows:

> "Ashes", such as *E. delegatensis*, are so called because the wood resembles that of *Fraxinus* spp., or true ashes.
>
> "Boxes" are those species with hard white fine-grained wood remotely resembling true box (*Buxus*). Their bark, moreover, is unmistakable, persistent, fibrous, fine in texture and light in colour, as *E. gomphocephala.*
>
> "Peppermints" are those species whose leaves contain particularly fluid juices rich in piperitone with a very characteristic smell, such as *E. dives.*
>
> "Bloodwoods" are species of the subgenus *Corymbia* in which there is a tendency for substantial cavities in the wood to accumulate kino. This substance bleeds from the trunk, particularly when it is cut.
>
> The first eucalypts called "mahoganies" had dark, reddish wood like true mahogany (*Swietenia* spp.). Later, other species with bark characteristics similar to the "mahoganies" were given names such as "white mahogany" and so on.
>
> The "blackbutts" include several unrelated eucalypts with a rough stocking of bark, blackened by bush fires, on the base of the trunk with smooth bark above it.

This local empirical terminology undeniably has its drawbacks as can be seen from the example of the "Blue gum" — the name applied in Tasmania to *E. globulus*, in New South Wales to *E. saligna*, in Queensland to *E. tereticornis*, in South Australia to *E. leucoxylon.*

Since the botanical affinities and general qualities of these species differ widely one from another, it is advisable to use the modern botanical nomenclature when studying the eucalypts and their behaviour, whether in their district of origin or in reforested areas elsewhere. This is outlined in Chapter 3.

2. Growth characteristics

Thanks to inheritance from precursors and the course of evolution in recent millennia, the eucalypts have developed growth characteristics which have made them a major factor in the perpetuation of a woodland resource under the difficult environmental conditions of their homeland. They also possess growth characteristics of vigour and aggression which enable them to assist the rapid establishment of a substantial forest resource in many countries of the middle and lower latitudes of the world. Between the first world *Eucalyptus* Conference, held in Rome in 1956, and the second one, held in São Paulo in 1961, the annual volume of saleable *Eucalyptus* wood produced in countries outside Australia surpassed that produced within Australia (Fairbairn, 1967) — in spite of the fact that 95 percent of the volume of the native forests in Australia consists of various species of eucalypts. Between 1961 and 1975 the volume of *Eucalyptus* wood being produced annually in plantations established outside Australia had increased to about nine times the volume harvested annually in Australian natural forests (Forwood Conference, 1974). This astonishing growth achievement justifies the theme "Eucalypts for planting" — the title of this book. In the countries where they have been planted on a major scale, the eucalypts have been given the opportunity to take advantage of the growth mechanisms they have developed. It is, therefore, desirable to outline some of these mechanisms, to point out those which have been vital to the persistence of the genus, and to emphasize those which make it such a valuable source of raw material when planted in good soils in mild climates.

The Australian continent and adjacent islands, including New Guinea, have been separated from other major land masses of the world for a long time. Evolution in relative isolation has taken place in both plants and animals during this period. Evolution in isolation has undoubtedly saved many animal life forms, particularly marsupials which would have proved easy victims to highly efficient carnivorous mammals which developed in other land masses. Many plants of Australia have developed survival mechanisms which are very successful when they are introduced to other countries with comparable climatic conditions.

Australia is a dry continent. On most occasions much of it appears brown and arid. It is likely that a woodland fire would extend actively in some part of the continent during the warm part of every day in every recent century. In spite of its dryness, the continent has a generous covering of a wide variety of trees and more than 90 percent of this tree cover consists of various species of eucalypts.

The eucalypts owe their dominance in Australia to their ability to survive as individuals or as species in localities where periods of extreme fire danger are certain to develop at frequent intervals. The danger of severe fire damage exists during dry periods and droughts. Thunderstorms which produce lightning strikes may occur in these dry periods and they have resulted in innumerable small fires and periodic catastrophic fires in recent geological times. The major fires would severely damage or destroy the aerial parts of trees even in moist forest types. Successful species need defensive growth mechanisms to permit them to survive in the face of this danger. The eucalypts possess such mechanisms. It should be stressed that most parts of Australia have been subject to fires for a long time quite apart from human activities.

Australia was first occupied some forty thousand years ago by nomadic hunters. There was more than one invasion, but all took place during the Stone Age, when neither agricultural nor urban civilizations had developed. The nomadic hunters had undisturbed occupancy of the continent between their invasions and the European colonization of two centuries ago, and although their culture remained relatively static during this long period, they lived in harmony with their environment. They used fire regularly to help hunting and other activities, and this use of fire favoured the eucalypts which had developed effective mechanisms for living with fire. The hunters did not cause the development of the defensive mechanisms of the eucalypts, but trees which possessed them were favoured by the habits of the hunters.

Colonizing ability

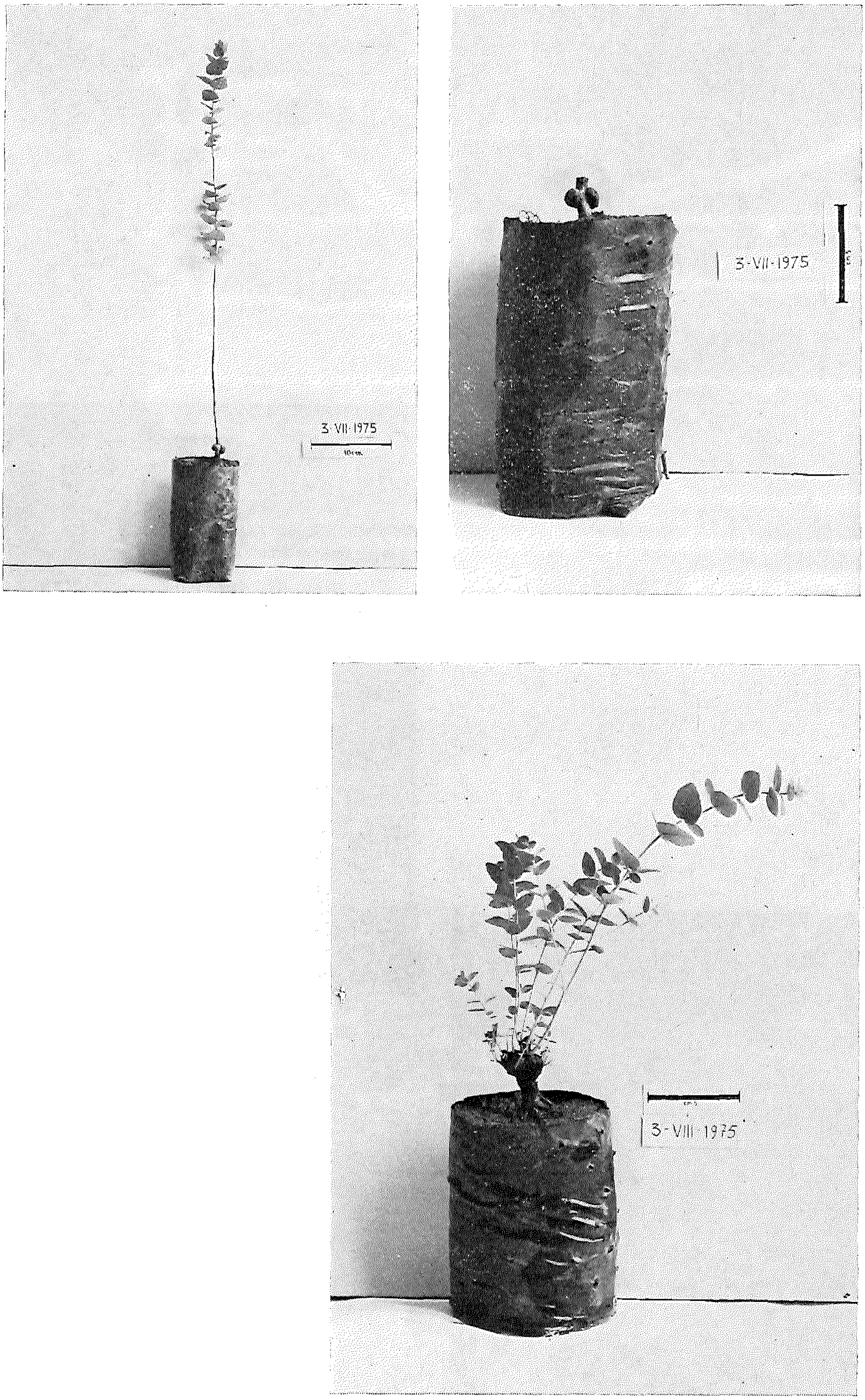
Of first importance in enabling the eucalypts to become so predominant in a difficult homeland is their ability to colonize bare ground without shelter. Most species of the genus have very small seed with little reserve material in each seed, but the seeds are produced in great numbers. Even when they fall upon ground bared by fire, flood or volcanic action, a small fraction, sometimes as little as one in a million, manages to survive under the protection of some object which shelters it. This is enough to assure the survival of the species and the woodland.

The small seed of the eucalypts has become part of the diet of ants and other small insects (and some birds). Most seed that falls to the ground in Australia is collected by insects. The majority of the tiny seedlings which manage to emerge from the remaining seed are killed by desiccation or frost; but some survive.

Defensive growth mechanisms

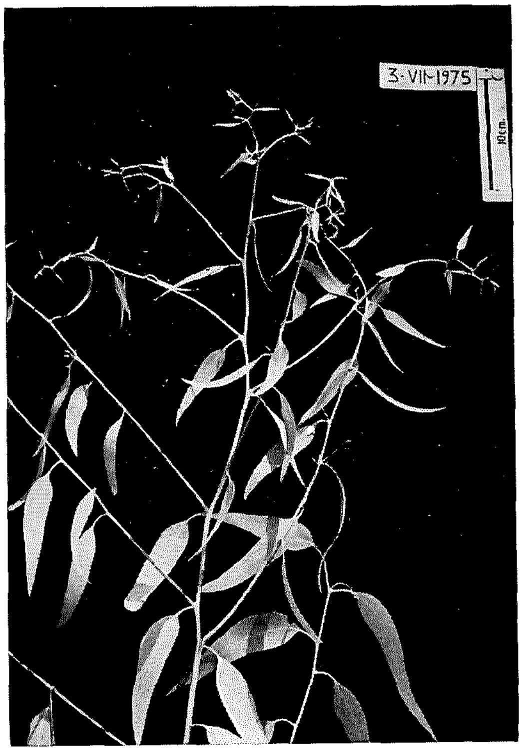
SUBTERRANEAN PROTECTIVE ORGANS

Many plants from several families have developed subterranean protective organs. These enable the individual to produce new shoots if the aerial part of the plant is destroyed by browsing, fires or other accident. The great majority of the eucalypts have developed a very effective subterranean protective organ known as a "lignotuber," illustrated in Figure 3.

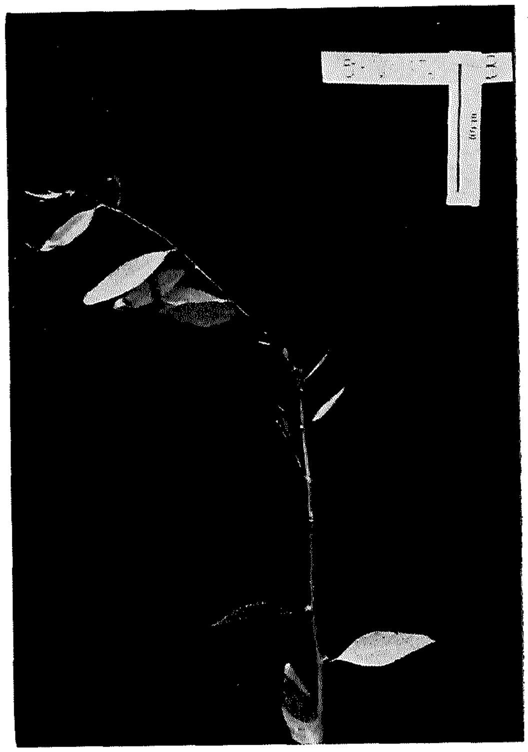


3. Young lignotubers on seedling of *E. globulus*, grown in black polythene bag *(left)*, showing capacity to produce new shoots within one month of stem being cut back *(right* and *below)*

Centro di Sperimentazione agricola e forestale, Rome

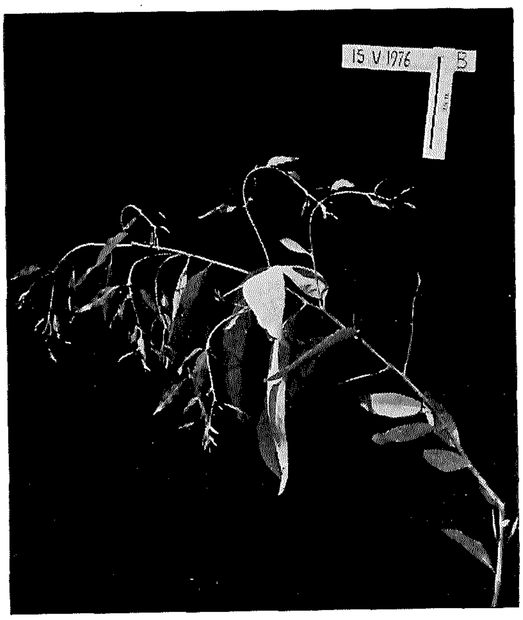


4. Close-up of young *E. camaldulensis* showing indefinite shoots and naked buds
Centro di sperimentazione agricola e forestale, Rome



a)

5. *(a) and (b),* Rapid extension of eucalypt lateral shoot within one month
Centro di sperimentazione agricola e forestale, Rome



b)

The lignotubers of eucalypts develop at an early stage of the seedling as small protuberances in the axils of the cotyledons and sometimes the first few pairs of leaves. These protuberances coalesce around the stem and then fold downward over the junction of stem and root and bury themselves in whole or in part in the surface soil (Jacobs, 1955). They have the potential to produce leafy shoots in profusion if the aerial part of the plant is destroyed. They are, therefore, regarded as positively geotropic stem structures. In addition, they are storage organs and accumulate reserve foods.

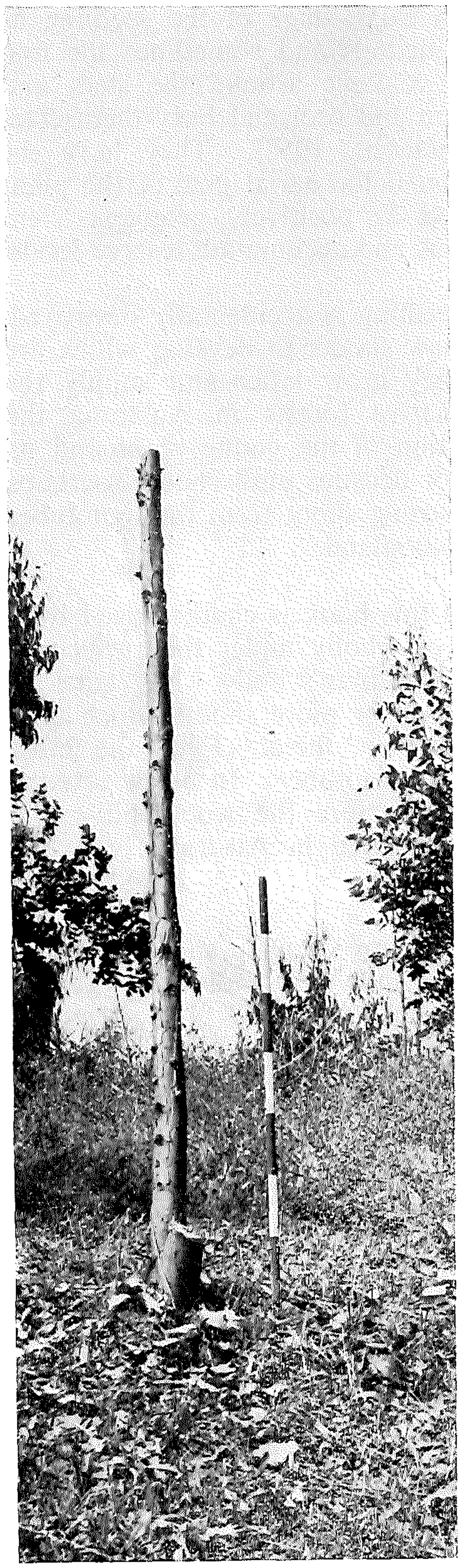
When the aerial part of a young eucalypt seedling is accidentally destroyed, the reserve foods in the lignotuber enable new shoots to develop which are usually stronger than the earlier ones. They grow taller and supply the lignotuber with additional reserves. In native forests in Australia the process of the destruction of the aerial portion of the young plant and its replacement by stronger shoots may go on for decades until chance, perhaps the death of a neighbouring tree, permits a strong shoot from the lignotuber to take its place as a senior citizen of the woodland.

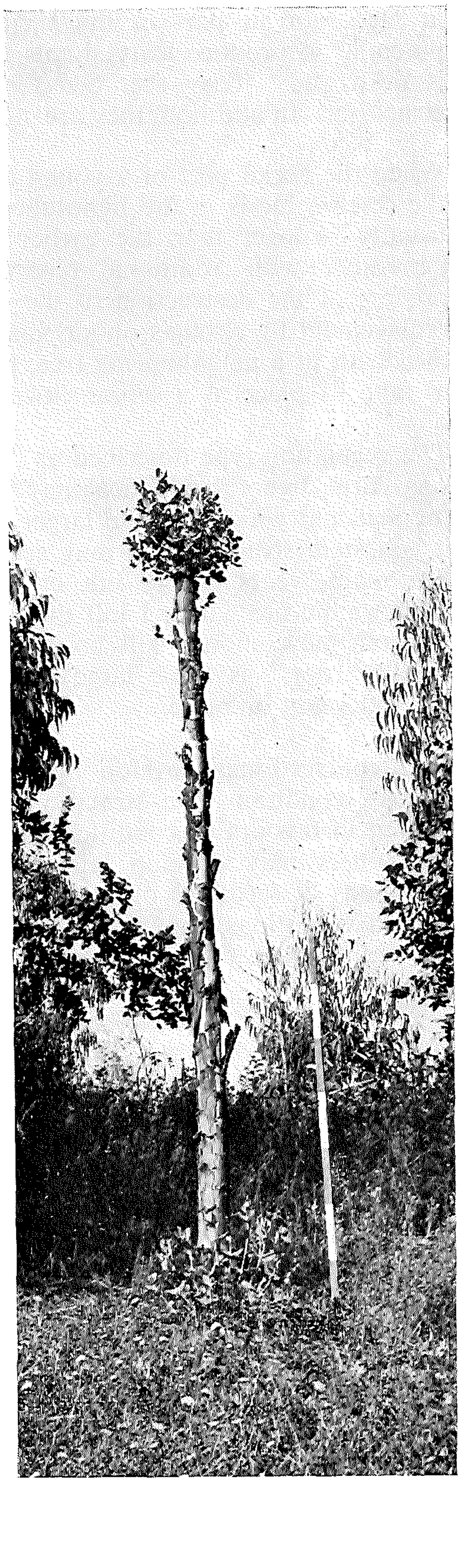
The vegetation type described as "mallee" in this book is characterized by a very large lignotuber which may be partly or wholly under the surface of the soil and which may be larger in size than a man's body. Nevertheless, it is a stem structure and may send up a dozen or more shoots which may live many years before fire or accident destroys them. Even the most catastrophic fire will not kill the subterranean lignotuber. In a few months vigorous new shoots will come from it and restore the woodland. The "mallee root," as these large lignotubers are called in Australia, can live for 200 years or more.

Eucalypt seedlings develop lignotubers at varying growth stages. Under difficult conditions the structures develop within a few months of germination; in favourable conditions in nurseries and well-tended plantations the lignotubers may develop later. In some large nurseries having tens of thousands of seedlings of species which regularly develop lignotubers under natural conditions, many seedlings may be found in which the lignotubers are rudimentary or even absent.

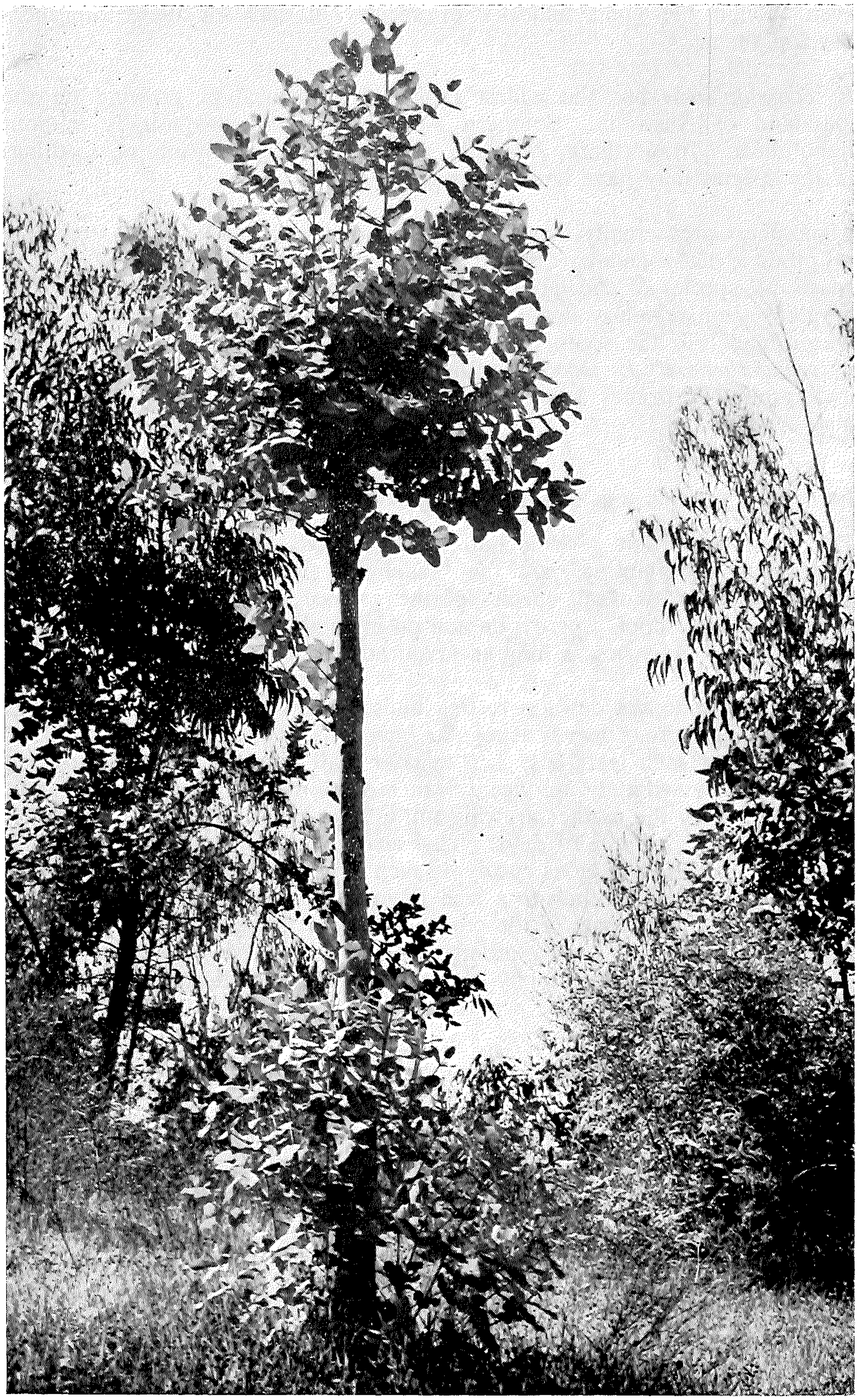
A few eucalypts never or very rarely produce lignotubers: *E. regnans, E. fastigata, E. delegatensis, E. sieberi, E. grandis, E. nitens, E. pilularis, E. diversicolor, E. gomphocephala, E. astringens*, and the southern Australian form of *E. camaldulensis*. These develop a thickened somewhat carrot-like zone at the junction of stem and root, from the top of which new shoots may develop and which also serve as storage organs. The non-lignotuberous eucalypts include some of the more valuable plantation species. Most of them grow naturally in very favourable localities where there would be closed forest or closed scrub and not eucalypt forest in the complete absence of fire. A few non-lignotuberous species such as *E. astringens* grow in fairly dry country.

It is of interest that the non-lignotuberous eucalypts are not confined to any single systematic group in the genus. Species from at least four of the seven subgenera recognized by Pryor and Johnson are non-lignotuberous





6. *Left, right* and *opposite*: rapid production of new shoots after pollarding of main stem
Centro di sperimentazione agricola e forestale, Rome



even though the great majority of species in each of these subgenera develop them.

E. camaldulensis has the widest range of any eucalypt growing on the mainland of Australia. Southern Australian forms are usually without lignotubers. In northern Australia a substantial proportion of seedlings of the species may have lignotubers in certain localities.

Lignotubers are actually stem structures and it is usual for stem structures to produce leafy shoots. Shoots from roots, however, are very rare in nearly all species of eucalypts, but *E. tetrodonta* of far northern Australia develops them regularly if the roots are cut, also *E. pachycalyx* from north Queensland. In the south they are occasionally found from the roots of *E. polyanthemos*. *E. jacobsiana* and a few other tropical species produce underground rhizomes sometimes metres long from which leafy shoots may arise.

Aggressive mechanisms which permit rapid growth

INDEFINITE SHOOTS AND NAKED BUDS

The most important growth habits which give grounds for the theme "Eucalypts for planting" are the "indefinite shoots" and "naked buds" which are features of all species of the genus. These two characteristics permit eucalypt shoots to grow on and on in height or length and to produce new orders of branches as long as favourable conditions for growth persist.

The eucalypts do not develop resting buds. The delicate growing tip goes on producing pairs of leaves at regular intervals. It is an "indefinite shoot." In the axil of each leaf there is a "naked bud" which is another growing tip that can immediately produce a branch of the next order or, should some accident destroy the mother growing tip, take over the task of becoming the main shoot in a matter of days. This character is illustrated in Figure 4. Under favourable conditions eucalypts such as *E. regnans* or *E. grandis* may grow from a small seedling to a tree 10 m or more in height in two years. Each year the upper part of the crown will grow in height by perhaps 5 m and produce four or even five orders of branches. These build up the lower parts of the trunks very rapidly and enable the production of a very large volume of wood per hectare per year.

ACCESSORY BUDS

It was inevitable that the tender terminal shoots and naked axillary buds of eucalypts would become attractive food for other life forms. In the course of time they have become the staple diet of many insects, some mammals and certain fungi, irrespective of whether the individual tree is in the seedling, semi-mature or mature stage. The most significant marauders are insects, sometimes in the larval and sometimes in the mature stage or even both. It is rather strange that the rich bird life of Australia has not developed species which attack the leafy shoots of eucalypts significantly; birds may feed on the nectar in the flowers, the flowers themselves, the fruits and the seeds in the fruits, but rarely the leaves.

The eucalypts have an aggressive replacement mechanism to counteract attack on the tender terminal and axillary shoots. In addition to the naked bud in the axil of each leaf, there is a pad of meristematic tissue at the base of the naked bud which can produce one or even several new axillary shoots if the original naked bud is destroyed. While the original naked bud or the shoot above its axil is growing vigorously, hormones are produced which inhibit the development of new shoots from the pad of meristematic tissue at the base of the naked bud but, if the naked bud or the shoot above it is destroyed, the inhibition is removed and new shoots grow in the leaf axil. These are called "accessory buds". This is a very effective replacement mechanism in Australia, where leaf-eating insects have predators which have evolved with them and keep them under some control. The leaf-eating insects prevent the eucalypts from growing at their maximum rate in Australia, but the accessory buds ensure a reasonable growth, provided the predators of the leaf-eating insects also play their part. If, perhaps because of an abnormal season or other reason, the predators fail to appear in normal numbers, or if the leaf-eating insects breed in abnormally high numbers, certain species of eucalypts may be severely defoliated. They usually recover after a year or two, thanks to the accessory buds and the epicormic buds, described in the next section.

When eucalypts are planted outside Australia in localities which do not have insects that defoliate them, they may produce the remarkable rates of growth of which they are capable. If, however, a leaf-eating insect is introduced from Australia *without* its natural enemies the plantations may suffer much more than natural stands in Australia. This has happened with several insects in Africa, South America and New Zealand. It may be possible to introduce predators of the pests from Australia. Successes and problems in this field are discussed in Chapter 9.

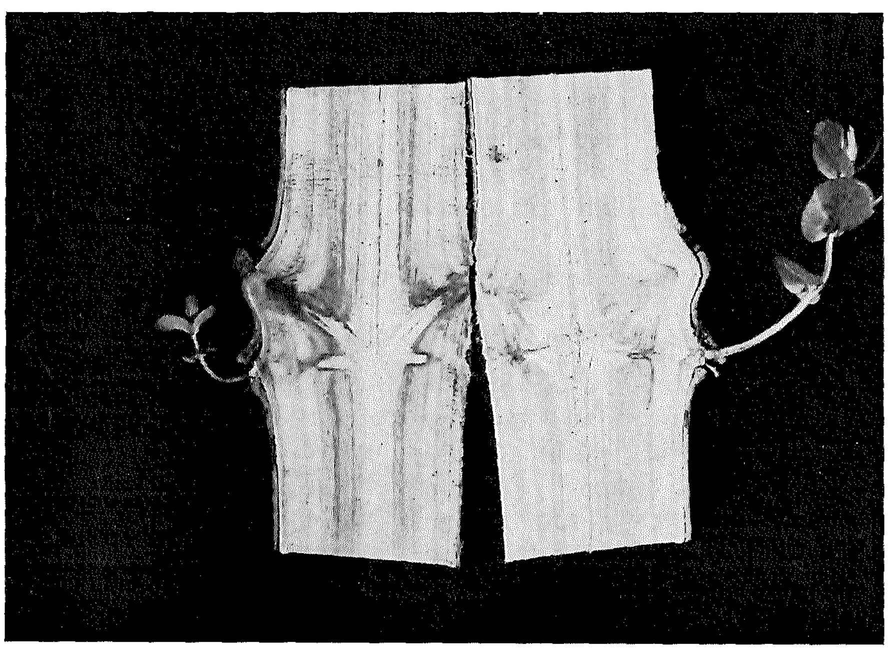
Epicormic buds

The eucalypts have evolved in a climate where fires have occurred at frequent intervals in recent geological time. Sometimes these fires are catastrophic and some of the very best species are killed by them. Most species, however, can refoliate their crowns after defoliation and the destruction of the smaller branches. They can do this thanks to the phenomenon of "epicormic buds," probably more properly called "proventitious buds," which are not restricted to the *Eucalyptus*, but are a very marked feature of it. They are illustrated in Figures 6 and 7.

When the leaf falls, the accessory bud-producing tissue in the axil is not occluded by diameter growth of the stem. Instead, a small shaft of tissue with bud-producing properties grows radially outward as the trunk or branch increases in size. The shafts can be seen on the surface of the wood as small eye-shaped structures a few millimetres long. All are capable of producing new leafy shoots, but if the crown is healthy their potential is held in check by hormones produced in the crown or ends of the branches above them. If fire or other accident destroys the leaves of the crown, the

7. Close-ups of stem *(above)* and stem section *(below)* of *E. globulus*, showing formation of epicormic shoots from base of leaf nodes

Centro di sperimentazione agricola e forestale, Rome



inhibiting factor ceases to operate and the trunk and branches become bearded with new leafy shoots. There is a potential source of new shoots for every leaf that develops as the tree gains height and the branches lengthen — literally many thousands of them on each tree. It is a wonderful growth mechanism.

The shoots from epicormic buds also serve to repair the branches and crowns of all eucalypts even when they are not damaged by fire or other accident.

Because of the nature of their growth, all eucalypt branches must continually increase in length while they are healthy. The ends of very long branches become defective and finally die. The branch may then be regenerated by shoots from epicormic buds situated perhaps several metres back from the tip at places where the branch may be 10 cm or more in diameter. The branch ends die, dry out and finally break off and fall to the ground, particularly in storms.

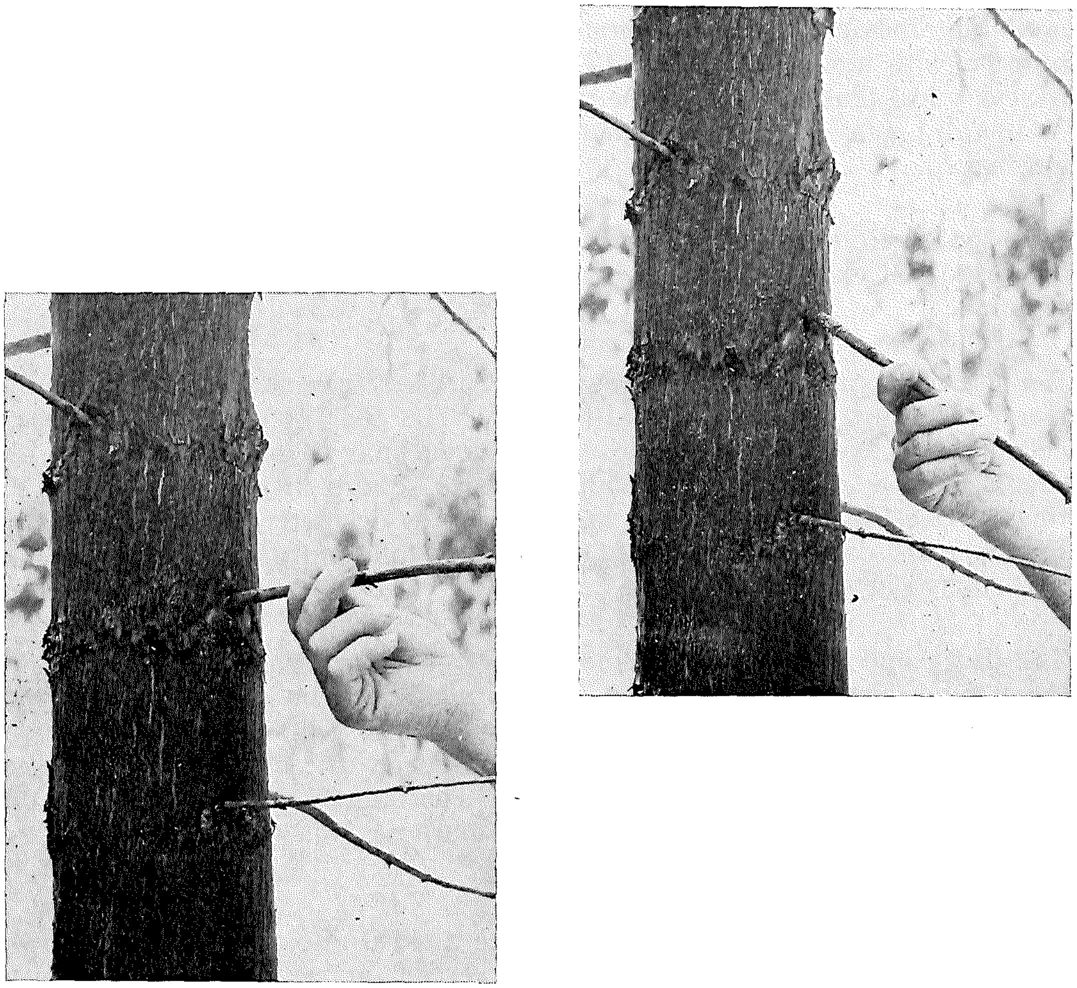
The dying and breaking off of the ends of eucalypt branches have been of great importance to the nomadic hunters who lived in harmony with their environment in Australia for so many thousands of years. The dead branch ends dried out high up in the crowns and once dried would not become thoroughly wetted even in severe storms. The hunters could always rely on dry wood for their fires, both for cooking purposes and warmth.

Structure of the "crown unit"

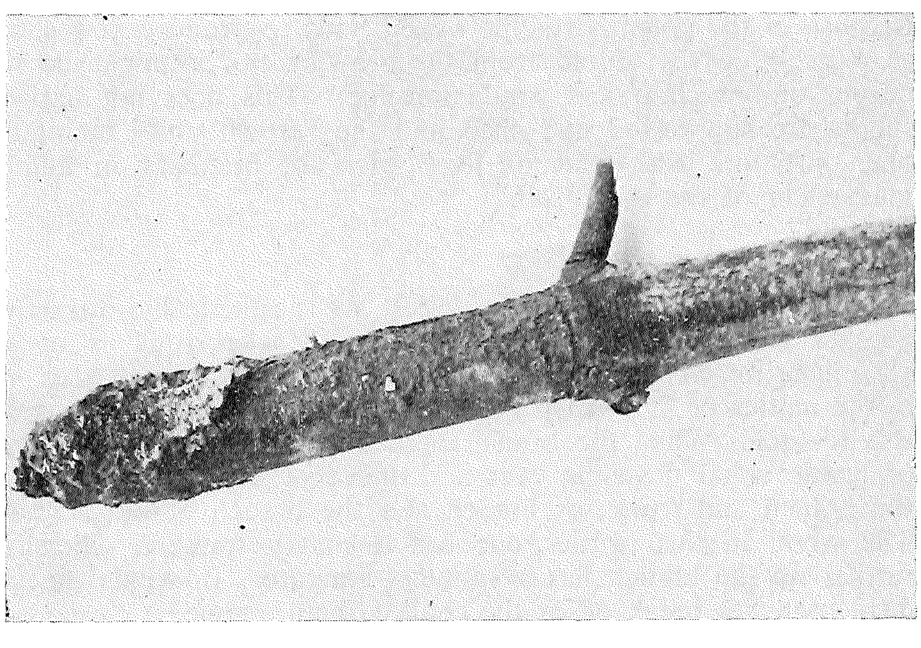
The crowns of very large eucalypt trees are divided into a number of "crown units" which give the trees their characteristic appearance. Each crown unit is something like the crown of a pole-sized plantation tree, perhaps 12-15 cm in diameter at breast height. If such a crown unit is studied it will be found to consist of a main stem and four or five orders of branches, rarely more. The structure of the crown units is very much under control. Because of the potential of the naked buds to produce new shoots as soon as pairs of leaves unfold from the growing tip, it might be thought that dozens of branch orders would develop. This does not happen. Excess shoots are suppressed and shed and the "crown unit" maintains a rather open structure with four or five orders of branches in addition to the main stem of the unit itself.

Branch shed

The clean trunks of eucalypt trees are aesthetically attractive and the absence of branches on the lower part of the trunk is of considerable advantage in harvesting and processing. If not the best trees in the world in the matter of natural shedding of branches, they do rank very highly in this feature. When the branch of a eucalypt becomes moribund, a zone of brittle wood develops over a distance of 2-4 cm from the junction of the branch and trunk, or branch and the branch of the next lower order. The wood in this brittle zone has a chalky fracture, whereas the wood further up the branch has a splintery fracture. In winds the moribund or dead branches break off at the chalky-fracture zone.



8. Branch shed in eucalypts. The branch breaks off inside the stem, at the base of the brittle zone
Centro di sperimentazione agricola e forestale, Rome



9. Close-up of broken branch, showing kino pad secreted around the base of the branch
Centro di sperimentazione agricola e forestale, Rome

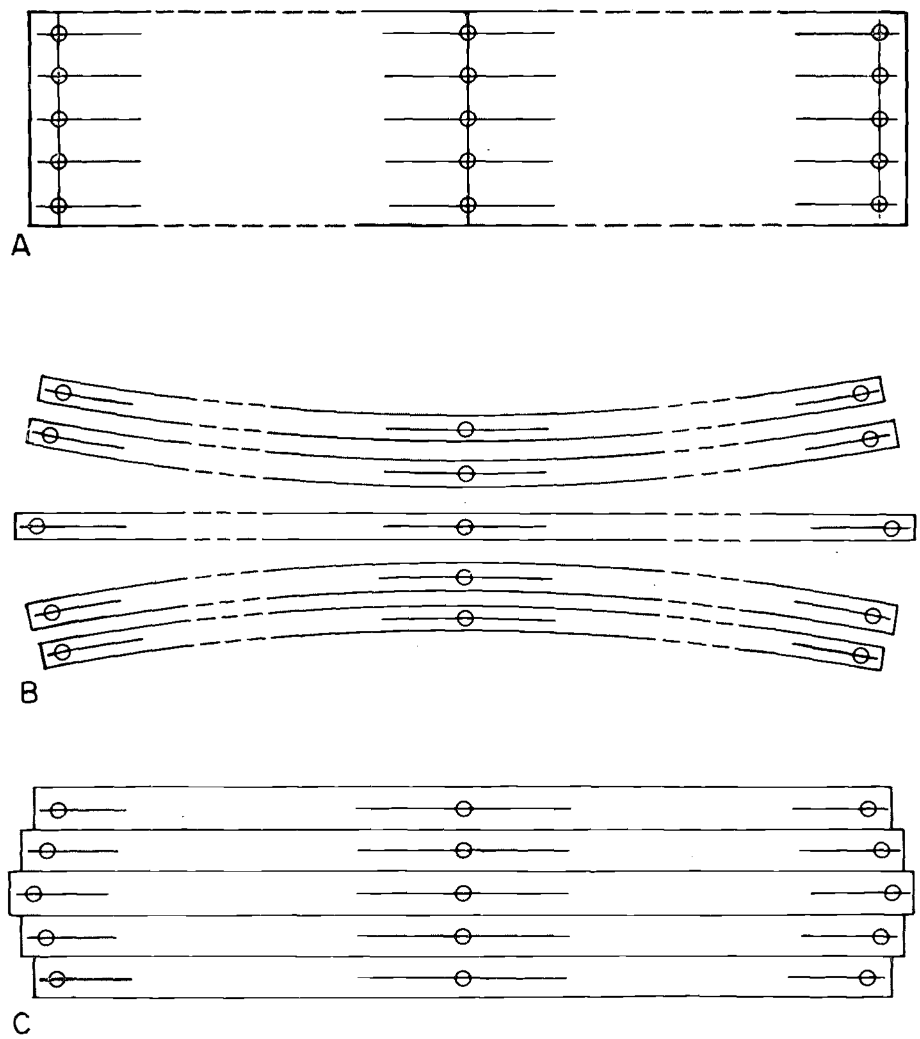
The trunk

The clean trunks of many *Eucalyptus* trees attracted the attention of processors at an early stage of knowledge of the genus. Efforts were made to use the trunks for a variety of purposes both in Australia and in countries outside Australia where the growth mechanisms discussed earlier in this chapter had demonstrated the outstanding rates of growth of which the genus is capable. The popularity of the genus waxed and waned with growers according to their primary object of management. When grown for fuelwood (including charcoal) or pulpwood the genus has never lost popularity. In the pole industry reactions have varied with the species used. In the sawmilling industry there has been widespread disappointment. The reasons for these varying reactions lie in the cellular structure and fibre orientation of the different species, and in the strain gradients which develop in a eucalypt trunk, both in a longitudinal direction and across the cross-section. These characteristics can be studied in papers by Dadswell, 1952; Jacobs, 1938, 1939b, 1945, 1955 and 1965; Boyd, 1950a, b and c, 1972 and 1973a, b; Boyd and Schuster, 1972; Kubler, 1973; and Wilhelmy and Kubler, 1973a, 1973b.

The outer trunk of any green eucalypt trunk is in a state of tension along its longitudinal axis and the inner wood in a corresponding state of compression. The reason behind this behaviour of eucalypt trunks appears to be that, as the trunk grows in diameter, the outer layers shorten slightly between any two points on the stem, in comparison with the inner layers. The shortening is not much in terms of length and it decreases per unit of diameter growth as the tree increases in diameter, but it does lead to severe compression stress in the centre of the stem and to tension stress in the outer layers.

The forces involved are considerable. The average tension stress in the outermost layer of eucalypts is approximately 84 kg/cm^2 (1 200 lbs/in^2; Jacobs, 1938). This outer tension stress is resisted by the inner layers of the stem, resulting in a longitudinal strain gradient across any diameter. The inner layers become compressed and the innermost layers are crushed beyond the elastic ability of wood to resist longitudinal compression. Compressive stresses greater than 140 kg/cm^2 (one ton/in^2) can be demonstrated in the centre of young eucalypt poles 15 cm in diameter. Under these severe forces the cells of the inner wood fail in the course of time and develop large numbers of small compression failures in the cell walls. The phenomenon is known as "brittle heart" in the Australian industry. The traditional allowance for it in stumpage appraisal has been a 20-cm square on the cross-section. This means that in Australian forests eucalypt trees for sawlogs must be grown to a diameter of 20 cm before they start to produce wood which will command a stumpage for the forest owner.

If a eucalypt stem is cut lengthwise, the release of inner compression makes the inside edge of the resulting piece longer out-of-tree than it was in-tree, and the outer wood contracts, becoming shorter out-of-tree than in-tree. A longitudinal piece of wood that was straight in-tree becomes a curve out-of-tree with its convex edge facing the pith, as shown in Figure VI. The radius of curvature of pieces cut from the outside edges of eucalypt



VI The effects of longitudinal growth stresses. Sawing causes curvature in the outer pieces (B). If these are straightened out artificially, the release of tension in the outer pieces causes a decrease in length, whereas the release of compression in the inner pieces (C) causes an increase in length
M.R. Jacobs

trunks of different diameters increases as the diameter of the log increases as shown below (Jacobs, 1955).

Diameter in cm	*Radius of curvature in m*
7.5	18
15.0	37
30.0	76
61.0	137

When very large eucalypt logs are sawn lengthwise the large radius of curvature of pieces cut from them is a nuisance, but not a serious one. They cause waste when it is necessary to prepare long straight pieces from them, but the Australian sawmilling industry has learned to live with this defect, and forest services have given sawmillers a defect allowance to compensate them for it. The conversion of small eucalypt logs to sawnboards presents a bigger problem and must be restricted to short lengths.

The longitudinal forces described above are also present in trees grown for the pole industry. Here their effect depends upon the wood structure and fibre arrangement of different species. Species which have straight fibres are likely to split at the ends of the poles, particularly if they are grown quickly, and this can be an annoying loss. Species with an interlocked grain may split infrequently and may be preferable for the pole industry even if their rate of growth is less than some other species.

End splitting as a result of growth stresses does not affect the pulpwood or fuelwood industries to a significant extent.

In addition to the longitudinal forces in a eucalypt trunk there are lateral stresses and strains which manifest themselves on the cross-section. The two types of growth stresses may or may not be interconnected. Green trunks of all sizes are tangentially compressed at their periphery. That is, the outside rings of cells are pushing against each other, tending to increase the diameter of the trunk. This tangential compression imposes a radial tension on the inner wood and this manifests itself in the star-shaped heart shakes which radiate from the pith and which are a common sight on eucalypt logs when they are cross-cut.

When the centre of a eucalypt tree decays, the trunk tends to swell in diameter along the length that is decayed, because the tendency of the outer laters to expand is no longer checked by adhesion to the inner wood. Because of this tendency, successive measurements to find the increase in diameter at breast height are suspect in the case of large eucalypts. They may not reflect growth in volume along the trunk. This phenomenon is not, of course, confined to the genus *Eucalyptus*, but for mature eucalypts it may have a big influence on sawmilling and on the production of poles and piling.

3. Systematics

Early taxonomic classification

Species of trees described as "eucalypts" in this book were seen by Portuguese, Spanish, Dutch and English adventurers during the late sixteenth, seventeenth and early eighteenth centuries as they sailed their ships among the eastern islands of the Indonesian Archipelago and around the western half of the Australian continent. Some of the trees were commented upon in their journals, but the word "eucalypt" had not come into use at that time.

In the latter half of the eighteenth century science-oriented voyages were made in the southern seas by English and French explorers. The scientists attached to these expeditions had been greatly stimulated by the classification of plants and animals developed by the Swedish scientist Carolus Linnaeus. Linnaeus died in 1778, ten years after the start of the first of three southern voyages of the English navigator Captain James Cook, but Cook's scientists were familiar with the Linnaean method of classification. Between 1768 and 1814 there were major scientific expeditions by Cook and Matthew Flinders, Tobias Furneaux, and the French navigators Jean-François La Perouse, Joseph Antoine d'Entrecasteaux and Nicolas Baudin. These expeditions collected and named many Australian plants. The genus *Eucalyptus* was described and named by the French botanist l'Héritier in 1788 after he had examined specimens of *E. obliqua* collected by Nelson, a naturalist in Cook's third expedition. By 1800, 19 eucalypts had been named, and by 1820, 28, mainly collected by sea explorers near the Australian coast. By 1840, 71 eucalypts had been named and there was still abundant new eucalypt material among the mass of plant specimens brought back to Europe by the various expeditions.

The work of Bentham

This material needed orderly classification and the task of doing it was entrusted to the English botanist George Bentham. Bentham did not see the plants he worked with in the field, but in 1867 he produced a masterly work *Flora Australiensis*, which is still the only comprehensive study of Australian flowering plants. By 1860, 149 eucalypts had been named. Bentham endeavoured to arrange them in orderly related groups and adopted a classification based on their anthers, dividing them into five series, with the fifth series, "Normales," subdivided into nine subseries.

Bentham was assisted in his work by many famous botanists whose names are attached to the descriptions of the 149 species named by 1860, and particularly by the Government Botanist of Victoria, Ferdinand von Mueller, who did a great deal of exploratory work on the plants of inland Australia. In *Flora Australiensis* Bentham expressed the hope that von Mueller would produce a better classification of the eucalypts than was given by his antheral classification, based perhaps on bark and field characteristics that he (Bentham) could not inspect. Ferdinand von Mueller produced many papers and a major book, *Eucalyptographia* (1879-84), on the eucalypts but was not able to produce a better classification than the antheral classification of Bentham. In paying tribute to the work of Bentham it should be remembered that he covered the whole range of plants collected by the several navigators, not only the eucalypts. He brought order into the classification of many genera and families.

The work of Maiden and Blakely

After von Mueller died, Australia was fortunate that J.H. Maiden carried on a major study of the eucalypts. Maiden produced the monumental work, *A critical revision of the genus Eucalyptus* (1904-31), which consisted of a series of beautifully illustrated descriptions of all taxa known in his time, but he did not significantly advance the orderly classification of species. The next advance in this field was by W.F. Blakely, Maiden's assistant, who produced in 1934 *A key to the eucalypts*, in which he described 500 species and 138 varieties. Blakely extended Bentham's antheral classification, using eight Sections with several Subsections, which workers find difficult to apply. Blakely's *Key* is not illustrated, but detailed reference is made in his descriptions of species to the beautiful illustrations in Maiden's *Critical revision.* An aspect of Blakely's *Key* that has been very useful is that he gave each of the taxa he described a number. These numbers have been used by several authors since the *Key* was produced and have served to maintain some order in the identification of taxa. In the decades since the *Key* was first printed, it has been found that some names were incorrectly applied. Moreover, as the years passed International Botanical Congresses adopted new customs in spelling botanical names. These matters made a revision of Blakely's names and numbers highly desirable.

An important aid in the identification and understanding of eucalypts was the development of a card sorting system by R.D. Johnston and Norman Hall of the then Forest Research Institute of the Australian Forestry and Timber Bureau. The edges of the cards permit a very large number of characters to be considered and sorted out for any specimen being examined with the aid of a knitting needle, as is customary with card sorting systems. The cards work well in Australia, but in countries outside Australia the problem of hybrids makes identification more difficult and this problem is getting worse year by year.

In 1965 R.D. Johnston and Rosemary Marryatt produced a paper, *Taxonomy and nomenclature of eucalypts*, issued as Leaflet No. 92 of the Australian Forestry and Timber Bureau. This paper provided a revision of the names and status of the many taxa of eucalypts described by Blakely in his *Key*. The revised names were related to Blakely's numbers. The names listed in Leaflet 92 have been revised by G.M. Chippendale in a paper entitled *Eucalyptus nomenclature* and distributed as Reprint No. 151 by the Division of Forest Research, Canberra. The names as given by Chippendale have been used in this book.[1]

Recent taxonomic research

THE WORK OF PRYOR AND JOHNSON

For many decades there was discussion about the ability of eucalypts to hybridize and whether certain names referred to stable species or to hybrids. Some taxa were regarded as hybrids by field collectors, yet named as stable species by responsible botanists; at other times botanists were reluctant to recognize populations which appeared distinct in the field. Some of the difficulty was caused by clinal variation, where a species population gradually varied from one district to another or from one altitude to another. In any one place the population seemed to be stable. This caused some confusion in nomenclature. Moreover, there was uncertainty whether some eucalypt taxa should be given specific or subspecific rank.

Great help in resolving the relationship of taxa and the question of actual or potential hybrids has been given by several scientists who have experimentally manipulated crossings between eucalypt species and have demonstrated, by sorting out progeny, that certain suspect species were, in fact, of hybrid origin. Early work on this problem was done by R.G. Brett (1938) in Tasmania. This work has been greatly extended since the decade 1940-50 by Professor L.D. Pryor of the Australian National University, his associates and other scientists. This work has shown which eucalypts are likely to hybridize and those between which hybridization is apparently impossible. The work has demonstrated that the potential for hybridization in the genus is enormous. The reason that hybridization is not more prevalent in Australia is that species between which hybridization is likely to take place are separated by considerable distances in a large continent or by different flowering times. Particularly since the Second World War, many countries of the middle and lower latitudes of the world have planted a variety of Australian eucalypts from widely separated localities of natural occurrence within close range of each other. It has become apparent that significant crossing of species is taking place.

Based on extensive research work on ability to manipulate hybridization, and a vast amount of field work throughout the Australian continent and adjacent islands, Professor Pryor and Dr. L.A.S. Johnson of the Sydney Herbarium, New South Wales, have published *A classification of the eucalypts* in which the genus *Eucalyptus* of L'Héritier and the closely related genus *Angophora* of Cau are combined. The classification divides the genus

---

[1] *A note on the words "taxon" and "taxa":* The words "species" and "varieties" have proved inadequate to cover groups of plants that appear to be similar, but about which there is some doubt whether they justify "specific" or "varietal" rank. Recently the word "taxon" (plural "taxa) has been used to cover apparently similar groups of individuals which may be under study.

Eucalyptus of L'Héritier into seven subgenera. The subgenera are divided into sections, series, subseries, superspecies, species and subspecies. The various taxa recognized in the classification are given a code consisting of up to six capital letters. The first letter indicates the subgenus, the second the section, the third the series. Subseries may or may not be made use of in any series. If a taxon is placed in a subseries, the fourth letter of the code indicates the subseries. If a subseries is not used, the fourth letter is replaced by a colon (:). The fifth letter indicates the specific status and a sixth is added when the taxon is regarded as a subspecies. The first letter of the code is the first letter of the name of the subgenus. The subsequent letters occur in some sort of descending alphabetical sequence within the subgenera, sections, etc. but do not suggest the accepted names of the species.

In the index to the code, the code letter groups are related to the nomenclature given in Leaflet 92 (mentioned above) by Johnston and Marryatt, with a few changes required in the light of work done between 1965 and 1971. The Pryor and Johnson classification is neither a key nor a guide to identification. The best available descriptions of *Eucalyptus* species in Australia are found in the third edition of *Forest trees of Australia*, by Hall, Johnston and Chippendale; the extensive subsequent series of two-page monographs on additional species by Hall and other authors; *Eucalyptus buds and fruits*, by Chippendale; and *Eucalypts of the Western Australian goldfields*, by Chippendale.

The subgenera and sections in the Pryor and Johnson Classification and the number of taxa in each section are as follows:

Subgenus	Code letter	Section	Section code letters	Number of taxa
Blakella	B	*Lemuria*	BA	10
Corymbia	C	*Rufaria*	CA	30
		Ochraria	CC	9
Eudesmia	E	*Quadraria*	EA	12
		Apicaria	EF	5
Gaubaea	G	*Curtisaria*	GA	2
Idiogenes	I	*Gympiaria*	IA	1
Monocalyptus	M	*Renantheria*	MA	106
Symphyomyrtus	S	*Equatoria*	SB	3
		Tingleria	SD	1
		Transversaria	SE	17
		Bisectaria	SI	104
		Dumaria	SL	36
		Exsertaria	SN	36
		Maidenaria	SP	68
		Umbrawarria	SQ	1
		Howittaria	SS	1
		Adnataria	SU	79
		Sebaria	SW	1

Hybridization is possible or impossible between different taxa according to their relationship as indicated by the Pryor and Johnson letter codes (Pryor, 1974). Interbreeding between two taxa, of which the initial letters of the letter codes differ, has never been known to occur, either under natural conditions or in any experimental programme. In those in which the first letter is the same, interbreeding can generally occur, with three main exceptions within the subgenus *Symphyomyrtus* (S). In this subgenus, taxa with codes beginning with the letters SU interbreed freely, but cross only rarely with other species with codes commencing with the letter S. The same is true of those with codes commencing with the letters SL, and although there has been little opportunity to make an examination, it may be the same in codes commencing with the letters SB. Within most of the remainder of the subgenus *Symphyomyrtus*, that is, species with codes beginning with the letters SD, SE, SI, SN and SP, interbreeding within and between these groups is not only possible but frequent, both in natural stands and under manipulated conditions. A few species remain isolated and have not yet been found to interbreed with others in the subgenus *Symphyomyrtus* or any other group. These are: SQA:A (*E. umbrawarrensis*), SSA:A (*E. howittiana*) and SWA:A (*E. microcorys*) (Pryor, 1974).

It will be apparent that the potential for hybridization is largely given by the first two letters (that is, the Sections) of the letter codes in the Pryor and Johnson Classification. The full code is shown in the species monographs in Chapter 14.

List of hybrids (recognized in Métro, 1955)

The following list gives the names of taxa discussed in the first edition (Métro, 1955) of the present volume which are now believed to have a hybrid origin. Where possible the probable parents are indicated.

Taxon	Probable parents
E. affinis Deane & Maiden	*E. albens* × *E. sideroxylon*
E. algeriensis Trabut	*E. camaldulensis* × *E. rudis*
E. antipolitensis Trabut	*E. globulus* × *E. viminalis*
E. biangularis Simmonds in Maiden	*E. globulus* × *E. urnigera*
E. bourlierii Trabut	*E. globulus* × *?*
E. cordieri Trabut	Probable hybrid of *E. nortonii*
E. globulus var. *compacta* L.H. Bailey cultivar	
E. gomphocornuta Trabut	*E. gomphocephala* × *E. cornuta*
E. huberana Naudin. (as applied by Blakely)	Quite common in Australia. *E. viminalis* × several related species giving seven-flowered umbels in contrast to the three flowers of *E. viminalis*. Chippendale (1976) states that *E. huberana* Naudin. is now accepted as a taxon.

E. insizwaensis Maiden

E. kirtoniana F. Muell.

E. longifolia var. *multiflora* Maiden

E. maidenii var. *williamsonii* Blakely

E. mcclatchiei Kinney

E. nortonniana Kinney

E. occidentalis var. *oranensis* Trabut

E. oviformis Maiden & Blakely

E. patentinervis R.T. Bak. : Syn. *E. kirtoniana*

E. populifolia Hook. var. *obconica* Blakely

E. trabutii Vilmorin

E. globulus × ?

E. robusta × *E. tereticornis*

E. longifolia × *E. robusta*

E. botryoides × *E. pseudoglobulus*

E. globulus × *E. ovata*

E. pseudoglobulus × *E. maidenii*

Status doubtful

E. pseudoglobulus × *E. tereticornis*

E. robusta × *E. tereticornis*

E. microtheca × *E. populnea*

E. botryoides × *E. camaldulensis*

Further discussion of hybridization can be found in Chapter 7, "Tree improvement."

Botanical characteristics of the eucalyptus

Each eucalypt is distinguished by general habit and dimensions; its bark in the adult stage; seedling, juvenile and adult leaves, and sometimes transitional leaves between these two latter phases known as "intermediate leaves"; young branches; inflorescences; bud shape; stamens; fruits and seeds.

Bark

Since the bark, like the habit of the tree, is a feature which readily strikes the eye, a description is particularly necessary for recognition of numerous species of eucalypts which are otherwise similar.

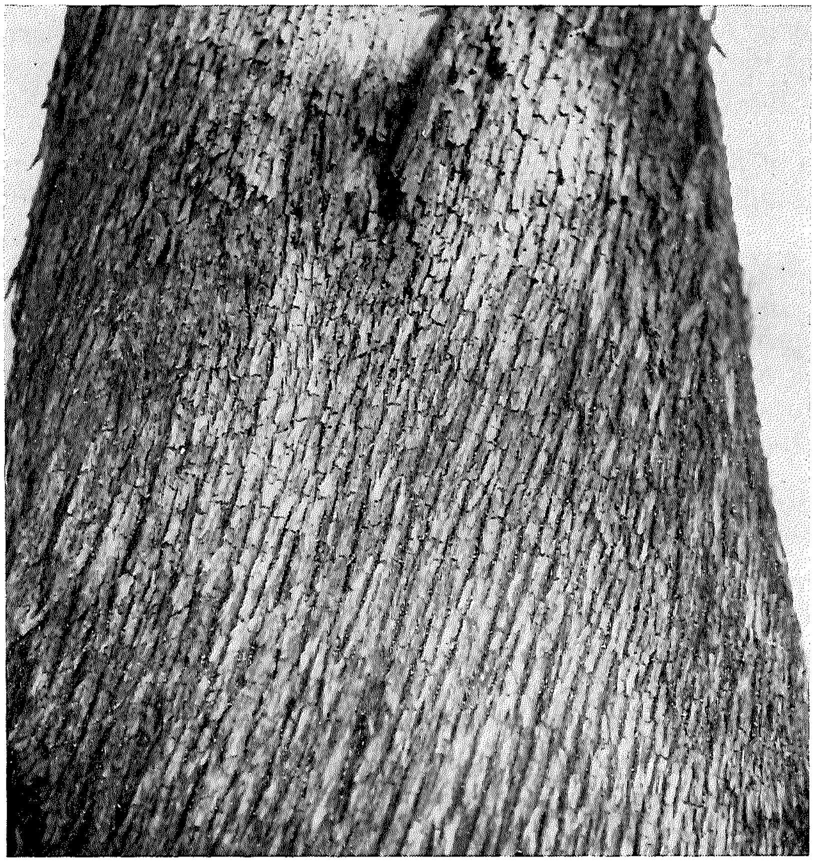
As long as the subero-phellodermal layer on the juvenile branches and their twigs functions uninterruptedly, the primary bark is usually smooth and continuous. When this layer ceases to function, a new layer is formed deep down and is retained for another year or several years. Later, other layers may appear still deeper at various time intervals. These successive layers are distinguishable either over the whole surface, or on parts of the trunk and branches. Moreover, the rhytidome, that is, the complex mass outside the successive generating layers, may vary in colour, texture, and persistence or shedding following renewal of the subero-phellodermal layer.

Generally speaking, the bark on the young branches of a mature tree is smooth, while on the lower part of the trunk, up to a few metres from the ground, the rhytidome becomes more or less persistent and deeply furrowed. Therefore, when describing the type of bark, neither that of the trunk

10. Deciduous bark, *E. globulus*
Division of Forest Research, CSIRO, Canberra

11. Deciduous bark, *E. saligna*
Division of Forest Research, CSIRO, Canberra

12. Ironbark type, *E. crebra*
Division of Forest Research, CSIRO, Canberra



13. Box-type bark, *E. moluccana*
Division of Forest Research, CSIRO, Canberra

base nor of the twigs should be taken into account. Below are listed the types of bark, with the names applied to them in Australia, that are most clearly differentiated.

Deciduous bark

Bark peeling off, when each layer is renewed, in long strips as in *E. globulus* (Figure 10). Peeling off in rather broad plates, as in *E. camaldulensis* and *E. saligna* (Figure 11). Peeling off in very small flakes or scales, as in *E. citriodora* or *E. astringens*.

It is usually difficult to define the colour and surface texture of such barks because they are often characterized by adjoining patches of varying age. While the newer patches are generally shiny and of fine texture with comparatively bright and varied colouring, the old patches, ready to fall, are comparatively dull grey and less smooth.

All species with deciduous bark are grouped together in Australia as "gums."

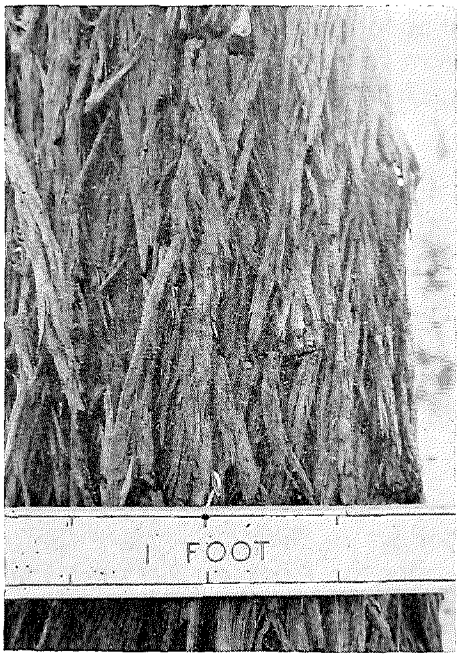
Persistent bark

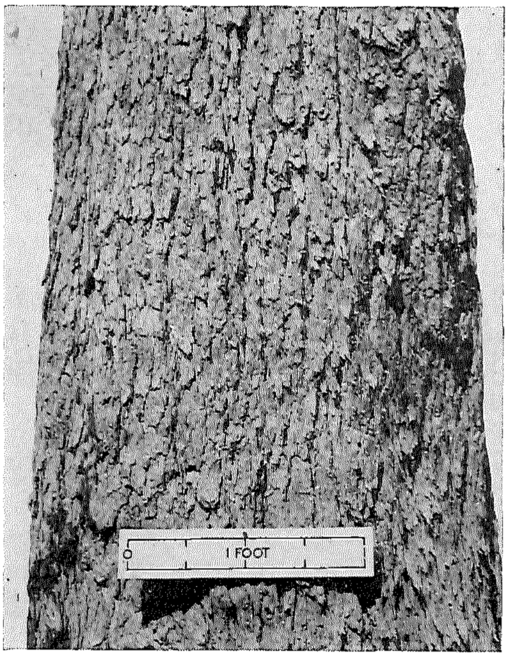
If the subero-phellodermal layer is not renewed in depth, or if for any other reason the external parts of the rhytidome do not strip off periodically from the tree, the bark is called "persistent."

When the bark ages, its surface oxidizes, darkens, becomes more or less pulverulent, and loses its specific characteristics. Such characteristics can only be determined by examining the mature bark, not at the trunk base but at one third of the tree's height.

In grouping certain of the categories now recognized by Australian botanists and foresters, the simplest way is to distinguish between four categories of persistent bark.

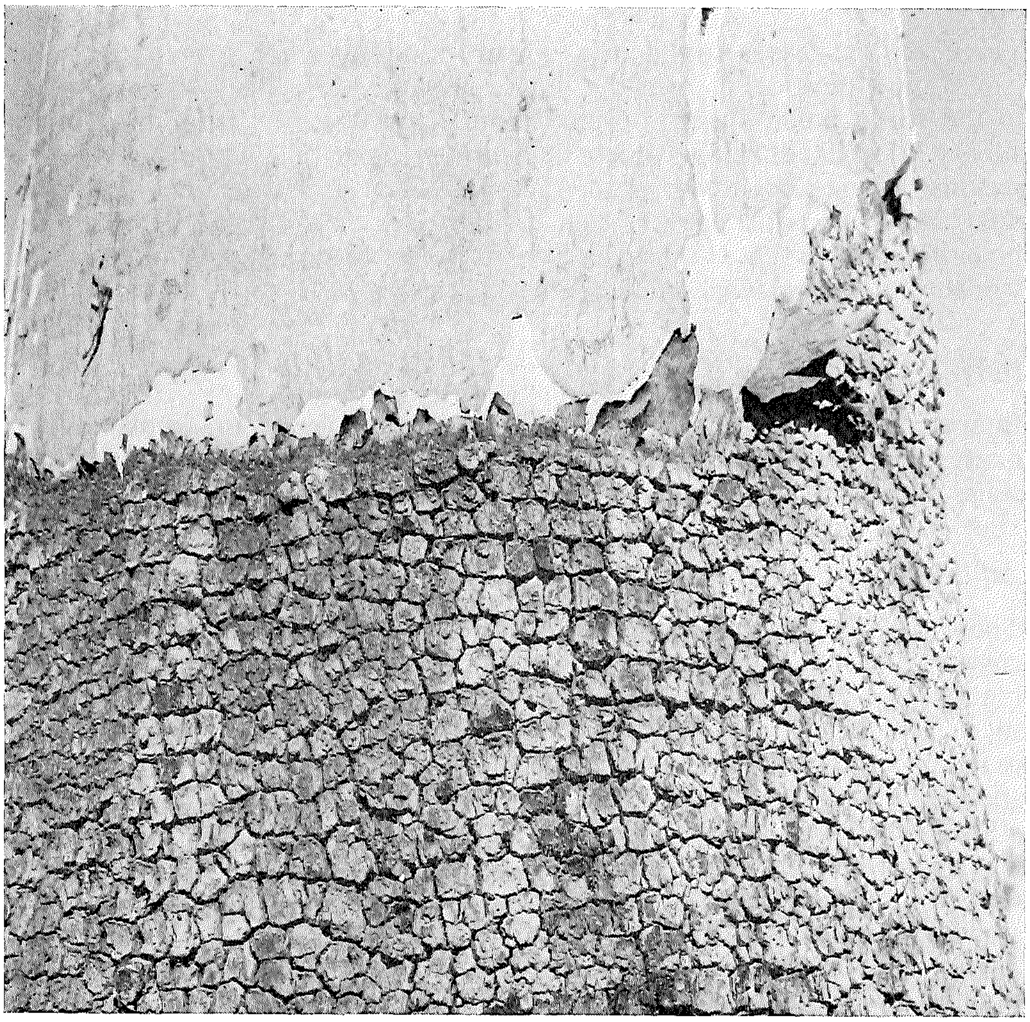
- Ironbark type: this bark is hard, with extremely short fibres, or non-fibrous, breaking up into very small polyhedrons of hard corky texture when crumbled, with deep longitudinal furrows. It is usually dark in colour, sometimes contains inclusions of small masses of gum (kino) rich in tannin (see Figure 12).
- Box type, shortly fibrous: this bark is pale grey, fibrous, finely furrowed or reticulated obliquely on the surface (see Figure 13).
- Long-fibred brown bark: the thick bark is usually more or less dark brown with long or very long fibres, deeply furrowed longitudinally. When the outer layers are peeled off, the long fibrous, often laminated, texture is revealed. This category includes species such as *E. robusta* and *E. botryoides* and "stringybarks" such as *E. obliqua* and *E. globoidea* (see Figure 14).
- "Peppermint" and "bloodwood" types: dull grey to black bark, hard, with shallow irregular furrowing chiefly in two directions, creating an





14. *Left,* Stringybark type, *E. eugenioides*
Division of Forest Research, CSIRO, Canberra

15. *Right,* Bloodwood type of bark, *E. gummifera*
Division of Forest Research, CSIRO, Canberra



16. Tessellated bark type, *E. tessellaris*
Division of Forest Research, CSIRO, Canberra

effect of scales more or less oblong in shape. Examples of these types are *E. elata*, peppermint, and *E. gummifera*, bloodwood (see Figure 15). Another type of bloodwood bark is the tessellated type seen on several tropical bloodwoods (see Figure 16).

Leaves

The leaves of most species of eucalypt vary, sometimes markedly, from the seedling to the mature tree. The leaves are important aids to identification. The system of classifying the various types of leaf used by S.T. Blake (1953) has been followed here.

Seedling leaves

These are the early leaves developed on seedlings in their first year. Pairs of leaves develop from the growing tip on opposite sides of the stem and successive pairs are arranged at right angles to each other, an arrangement known as "decussate."

Juvenile leaves

These are the leaves found in a nursery seedling when four to six pairs of leaves have developed from the young growing tip. They are also common in the forest when shoots develop from lignotubers or from the "reversion shoots" described below which develop on most eucalypt trunks following serious damage by fire or other factors. They are sometimes spectacularly different from adult leaves, e.g., *E. globulus*. It is widely believed that juvenile leaves, such as those seen on seedlings or reversion shoots, reproduce vanished ancestral characters of the species.

Intermediate leaves

Intermediate leaves are frequently larger than juvenile or adult leaves, and many pairs of them may be produced by the growing tip after the juvenile stage and before the more or less stable adult foliage is produced.

Adult leaves (or "mature leaves")

These are the leaves normally produced on the undamaged parts of the crown of mature eucalypts. They are usually coriaceous, often thick, stiff, highly cutinized and rich in sclerenchyma. They are usually alternate, only in a few species are they opposite or sub-opposite. The shape may be regarded as lanceolate in most species. It varies, however, according to species, from almost linear, to narrowly lanceolate, to broadly lanceolate, elliptical, oblong, or even oval and orbicular. They are frequently falcate. Their dimensions vary considerably. In the same species, and sometimes on the same tree, there is an appreciable variation in the shape and dimensions of the leaves. Thus, when the length and breadth of the leaves are given, excluding the petiole, not only the average, but also the extreme dimensions should be indicated.

Reversion (epicormic) shoots

When a eucalypt is damaged by fire or other agency, new shoots develop from the many dormant epicormic buds present on the trunk and branches. These shoots usually carry intermediate or juvenile foliage. They are known as "reversion shoots." While most apparent on damaged trees, reversion shoots are important in enabling a large tree to re-establish its crown when the branches get too long and become mechanically unstable. The ends of the branches die off and reversion shoots develop at positions back along the branch where they are safe from mechanical instability. They soon produce mature foliage. Reversion shoots may be seen at appropriate places in most large crowns.

Opposite and alternate leaves

The vast majority of eucalypt growing tips grow in length between nodes which develop opposite or sub-opposite pairs of leaves, decussately arranged. That is, each successive pair of leaves is at right angles to the previous pair on the stem. In a few species the opposite, decussate foliar arrangement is retained beyond the juvenile stage, when the leaves may be cordate, amplexicaul or connate. In most species the intermediate and mature leaves become alternate. There is then some extension of the shoot between the leaves of each pair developed from the growing point. The length of the internode between the leaves of each pair is shorter than the internode between successive pairs of leaves. It is always possible to identify each leaf pair.

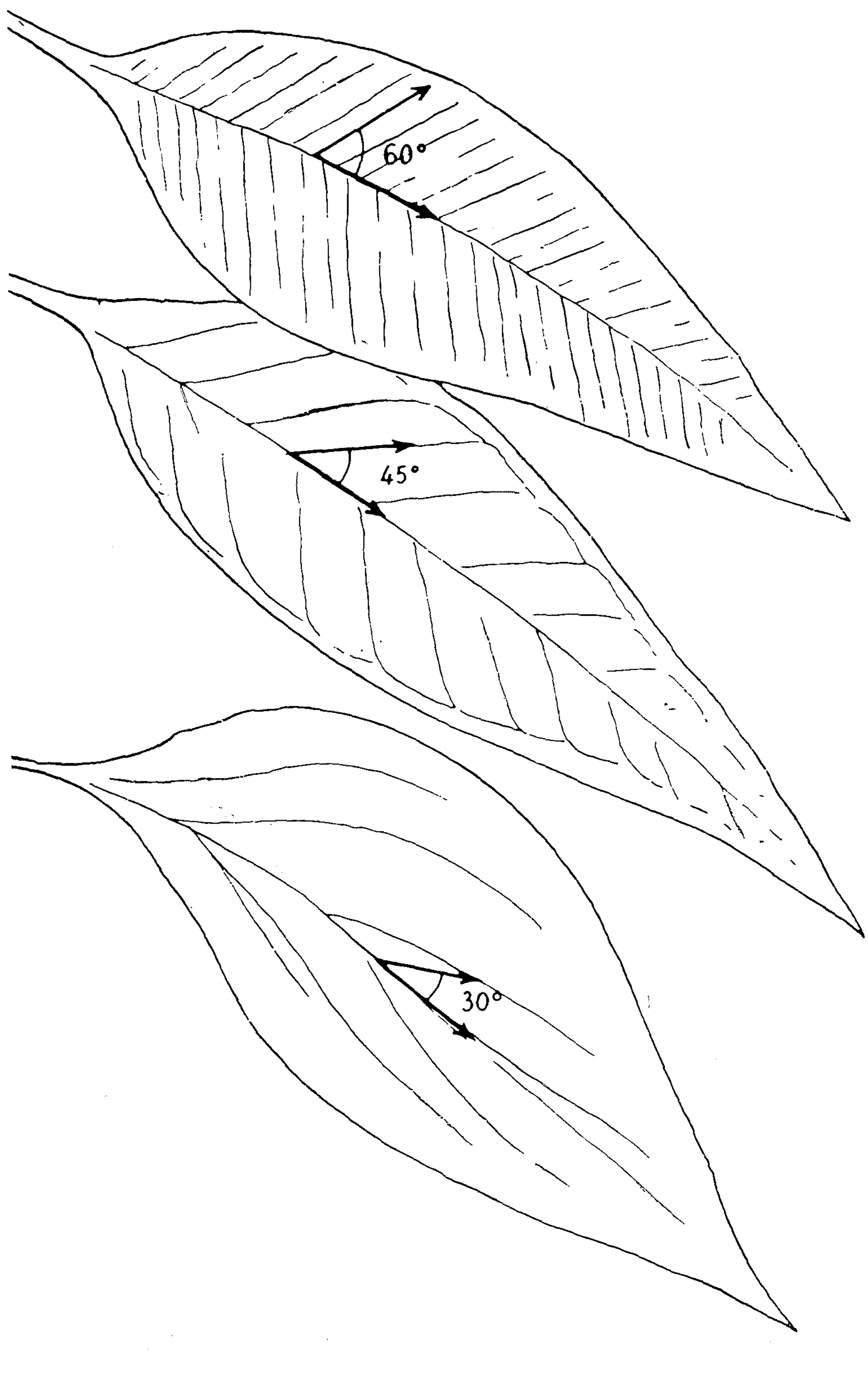
The alternate leaf arrangement is usually accompanied by some twisting of the intermode between each pair and sometimes between the leaves of each pair. This enables the leaves to be ranked on either side of the stem, so that they adopt a posture that intercepts maximum sunlight.

Occasionally, successive nodes of a eucalypt growing shoot may throw off a whorl of three leaves. This may happen on nursery seedlings but more frequently on coppice shoots.

Leaf faces

All eucalypt leaves have an inside and an outside face, representing the way the leaves oppose each other when each leaf pair opens from the growing tip. In some species the two faces are markedly different in colour as the leaves attain their final size; in other species there is little obvious difference between the faces.

The two leaf faces are frequently referred to as "upper" and "lower," because they are most noticeable on shoots where the leaves are ranked on either side of horizontally oriented shoots, thereby effectively intercepting sunlight. In these cases the upper surfaces are darker than the lower surfaces. The upper, darker surfaces were the inside leaf faces when opening from the growing tip.



VII Types of venation in mature eucalypt leaves. *Top:* penniveined; *centre:* oblique; *bottom:* longitudinal

After S.R.F. Rabat (Métro, 1955)

Venation

Leaf venation is a useful guide to the identification of eucalypts. The leaves of most species have a readily recognizable midrib from which the succession of lateral veins diverge and cross the leaf to join an intramarginal vein which follows the contour of the edge of the leaf. The lateral veins maintain a fairly regular "angle of venation" relative to the midrib, particularly in the middle portion of the leaf. The following types of venation can be recognized (see Figure VII).

Penniveined. In this type the lateral veins are fairly numerous, parallel and form an angle of 60° or more with the midrib. The intramarginal vein is usually fine and close to the leaf edge.

Oblique. In this type the angle of venation is less than 60° with the midrib. Lateral veins are less numerous than in the penniveined type, they are frequently anastomosed and the intramarginal vein is somewhat sinuous and comparatively distant from the leaf edge.

Longitudinal. In this type the lateral veins make an angle of 30° or less to the midrib and are sometimes almost parallel to it.

THE INFLORESCENCE

The inflorescence in most *Eucalyptus* species is a dichasial cyme which is considerably contracted, so that the bracts which subtend successive branches of the cyme are brought together in what appears to be a single whorl at the top of the peduncle. Often some or most of these are fused. These fused bracts may appear only as a single pair in many species and then cover the young inflorescence as it first appears and before the buds grow to their full size prior to anthesis. In the subgenus *Corymbia* this process takes a few months, in *Symphyomyrtus* one year and in *Monocalyptus* about two years. Because of the dichasial structure, the flower clusters have precise numbers and show precise orientation. In the few species which have solitary flowers in the leaf axils, such as *E. globulus*, the cymose nature of the inflorescence is not displayed, but in those with other numbers it may be clearly seen. Thus, in the simplest, there is a three-flowered axillary cyme (as in *E. viminalis*) or a seven-flowered flower cluster (as in *E. saligna*), each of which is in accord with the structure of a regular dichasium. As the number of flower buds in each flower cluster becomes greater, precise regularity of the dichasial branching is lost and some of the branches become monochasial. The number of buds in the flower clusters then becomes less precise; they begin to vary within the same species and even within the same individual, especially when numbers exceed fifteen. In the so-called compound inflorescence each cymose cluster behaves as a single unit, these being arranged in accordance with the decussate nature of the normal leafy shoot.

The outstanding feature of each *Eucalyptus* flower is the presence of an operculum which occurs with three variations. The essential nature of this was first recognized by Robert Brown in the early 1800s. In a few species, especially those in the subgenus *Eudesmia,* there is only one operculum present which is surrounded by four small teeth at the top of the hypanthium (in earlier works incorrectly called the calyx tube). These teeth were recognized by Brown as separate sepals, whereas the operculum lying within them is a single structure resulting from the fusion of the four petals. Sometimes there is an indication of the sutures which are the meeting lines of separate petals. In a great many species, particularly those in the subgenera *Blakella, Corymbia* and *Symphyomyrtus*, there are two opercula, an outer one covering an inner. The outer operculum sometimes breaks into separate pieces or it may remain intact, but in either case it is shed before abscission of the inner operculum at anthesis. In the part of the subgenus *Corymbia* comprising the true bloodwoods the outer operculum dehisces imperfectly and usually sheds with the inner at anthesis. In the subgenus *Monocalyptus*, which embraces some 100 species, there is only one operculum present and no sign of calyx teeth. There is some uncertainty as to whether this is made only of fused sepals, or petals, or whether in its derivation it is a more complicated structure resulting from the intimate fusion of petals and sepals.

It is customary to give the name "bud" to what is in reality the flower of the eucalypt up to the time of abscission of the operculum at anthesis. The "bud" comprises operculum, hypanthium and pedicel.

Shapes of opercula

The shapes of the opercula are described in the following terms:

Shape	*Example*
Conical	*E. rudis*
Obtuse conical	*E. cladocalyx*
Acute conical	*E. tereticornis*
Horned or long	*E. occidentalis*
Hemispherical apiculate	*E. amygdalina* or *E. diversicolor*
Rostrate	*E. camaldulensis*
Ovoid	*E. salubris*
Biretta operculum	*E. erythrocorys*
Boss-shaped	*E. globulus*
Flattened	*E. concinna*

It will be found in practice that in the same species, and often on the same tree, the shape of the operculum is variable and can only be described with the help of at least two or three of the above comparisons.

Stamens

The classification of eucalypts established by botanists has been based up to now upon the characteristics of the stamens. Blakely divided the species into eight sections each with several subsections, according to the shape of the anthers. It is practically impossible to distinguish between many of these subsections in the field. In the more recent classification by Pryor and Johnson (1971) the number of sections has been increased to 19.

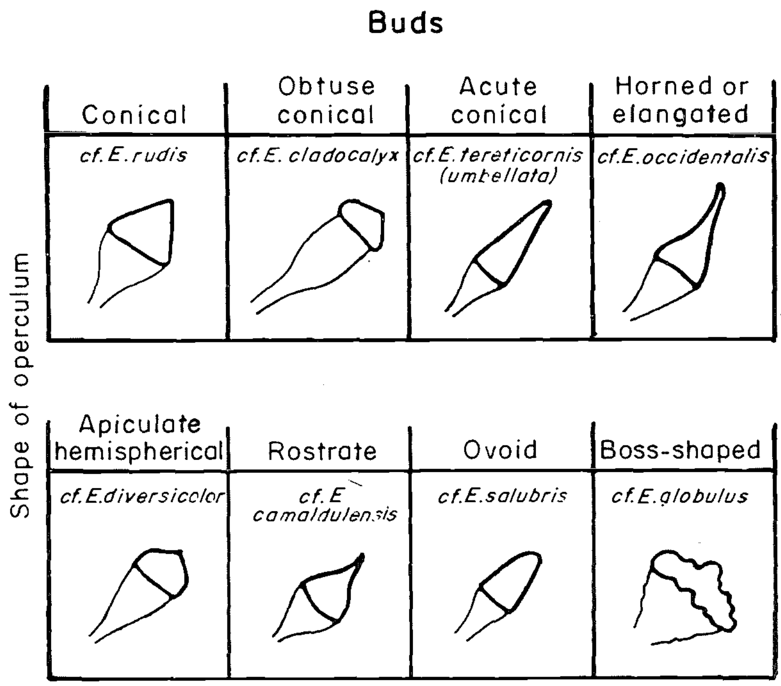
Clearly no attempt can be made here to describe the details of staminal classification. Table 3.1 is intended merely to indicate the range of characteristics to be found of stamens in four of Blakely's principal sections.

While anther characteristics are often difficult to assess, the arrangement of the filaments in the unopened bud is sometimes diagnostic of various groups. This feature can be readily seen immediately the operculum has shed and before the filaments have spread.

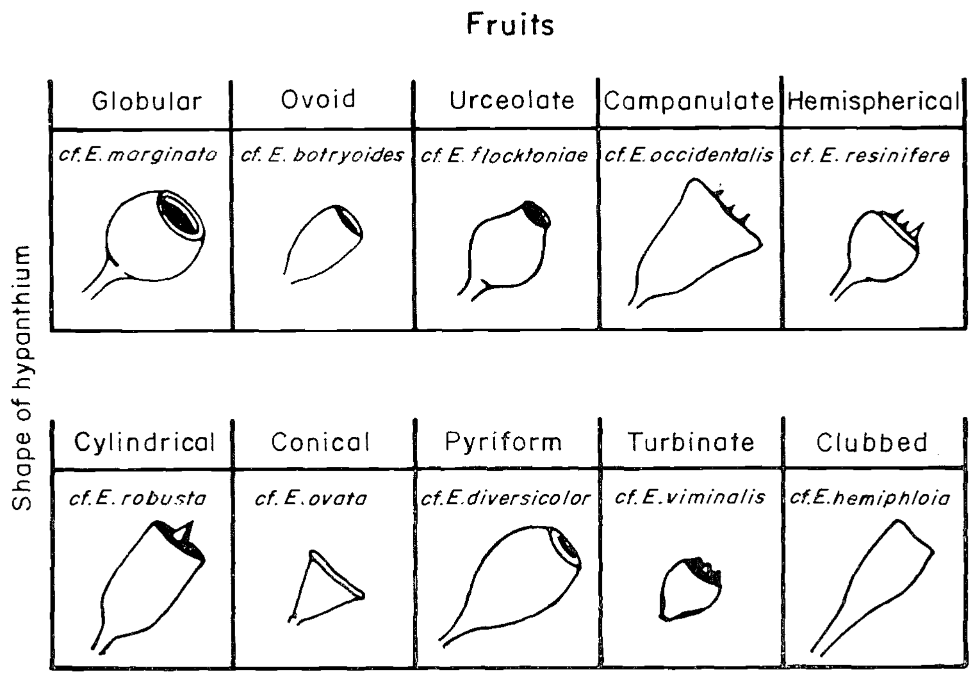
In the series *Cornutae*, e.g., *E. occidentalis*, the operculum is long and conical and all the filaments are accommodated erect and are surmounted by the

Table 3.1 Stamen characteristics

Blakely's section	Fertility	Tip of filament	Shape of anthers	Mouth of sacs	Glands
Macrantherae	Stamens almost all fertile	Subulate	Cordate, oval, oblong, orbicular	Distinct loculi opening into two lobes of auricular shape	Fairly large, situated in the upper half of the commisure, sometimes visible from the front
Renantherae		Subulate	Kidney- or heart-shaped, almost flat	Loculi divergent, sometimes coming together at tip	Very small, or not apparent at upper tip
Porantheroideae	Almost all fertile	Adnate or subulate	Globular or reniform	Fairly distinct loculi opening toward the top or laterally with round pores	Small at the upper tip
Terminales	Numerous filaments without anthers	Adnate or anthers placed obliquely on the filament	Cuneiform, rounded or almost square	Distinct loculi opening in terminal oval slits or round pores	None



VIII "Buds" of eucalypts, showing various shapes of opercula



IX Eucalypt fruits, showing various shapes of hypanthia

anthers. In the red gums *Exsertae*, e.g., *E. tereticornis*, the outer filaments at least are erect and surmounted by the anthers. Exceptions in the red gums are the forms of *E. camaldulensis* with strongly beaked buds. In these the filaments may be completely inflected. In jarrah, *E. marginata*, the filaments are also quite erect and this is the only species of *Monocalyptus* where this condition is seen.

In many species and groups throughout the genus, e.g., all *Blakella, Corymbia, Gaubaea* and *Indiogenes*; some *Monocalyptus*, e.g., *E. sieberi*; and some *Symphyomyrtus*, e.g., *E. leucoxylon*, the filaments are at first erect then strongly inflected with the anthers placed toward the bottom of the bud cavity.

In other species, particularly of the two largest subgenera, the filaments form no recognizable pattern and are variously twisted in bud.

The use of this character in identification is clearly illustrated in the separation of two unrelated ironbark species which look alike and occur together in the field, viz., *E. beyeri* and *E. crebra*. A simple bud dissection shows that *E. beyeri* has inflected filaments and *E. crebra* has twisted filaments.

Fruits

The identification of eucalypt fruits has given rise to a veritable orgy of comparisons with strange objects, and it is well to apply a reasonable check to this. The fruit is formed by the development of the hypanthium and of the lower ovary adhering to it. The upper part of the fruit consists of four segments.

The scar left by the operculum after shedding forms an outside ring called the calycine ring. The next ring inward is the staminal ring. Then follows the disc, the ontogenesis of which has not yet been completely described. Below and inside the disc is the upper part of the ovary which, on maturity, splits and separates into valves.

In some species, the calycine ring which is comparatively prominent in the flower disappears completely as soon as the fruit is formed. In other species, as in *E. leucoxylon*, the ring is fairly well developed but it is fine, and protrudes clearly beyond the disc. In these species, when the fruit ripens, the ring falls or remains partially attached to one side of the fruit. This applies also to *E. melliodora*.

Consequently, a description of the fruit should cover the shape of the hypanthium and of the pedicel of the disc, and the position and shape of the valves.

Shape of the hypanthium proper and the pedicel

The shape of the hypanthium is more or less merged with that of its pedicel. The latter may be truncated or attenuated. The hypanthium proper can usually be classified as globular, ovoid, urceolate, campanulate, hemispherical, cylindrical or conical (Figure IX).

An ovoid or globular hypanthium combined with a long attenuated pedicel produces a pyriform fruit; combined with a short attenuated pedicel, a turbinate fruit. A cylindrical or urceolate hypanthium combined with an attenuated pedicel produces a fruit shaped more or less like a short club.

It must be remembered that the size of fruits may vary considerably according to whether they develop and ripen slowly or, on the contrary, mature quickly.

It is also advisable to be careful with the use of the term "striated." It should be used solely to indicate the striation which appears when the non-sclerous tissue contracts. The term "ribbed" on the other hand is used to indicate that the ribs are clearly visible on fresh specimens.

Shape of the disc

In the flowers or the young fresh fruits, the disc is virtually continuous with the upper part of the ovary. When the fruit ripens and desiccates, the distinction between the two parts becomes increasingly marked and is unmistakable when the valves open. According to whether the ovary evolves into a capsule developed more or less than the hypanthium, so the disc may become protuberant, remain flat, and usually thin, or become depressed. When protuberant, it may be concave, flat or convex. In the latter case it is usually described as "dome-shaped."

Position and shape of valves

The valves may be comparatively short and triangular as in *E. camaldulensis*. In this case they simply represent the upper part of the ovary. Or they may have sharp points formed by the rupture of the persistent base of the style. These sharp-pointed valves may even be continuous and joined together in a single point owing to the persistence of the whole style as in *E. oleosa*. In certain species the valves are fragile and drop off quickly when the fruit is ripe.

Exsert valves. The name "exsert" is given to those valves the base of which is located noticeably at the level of the calycine ring or clearly above it, and when their points project beyond the whole fruit, as in *E. camaldulensis*.

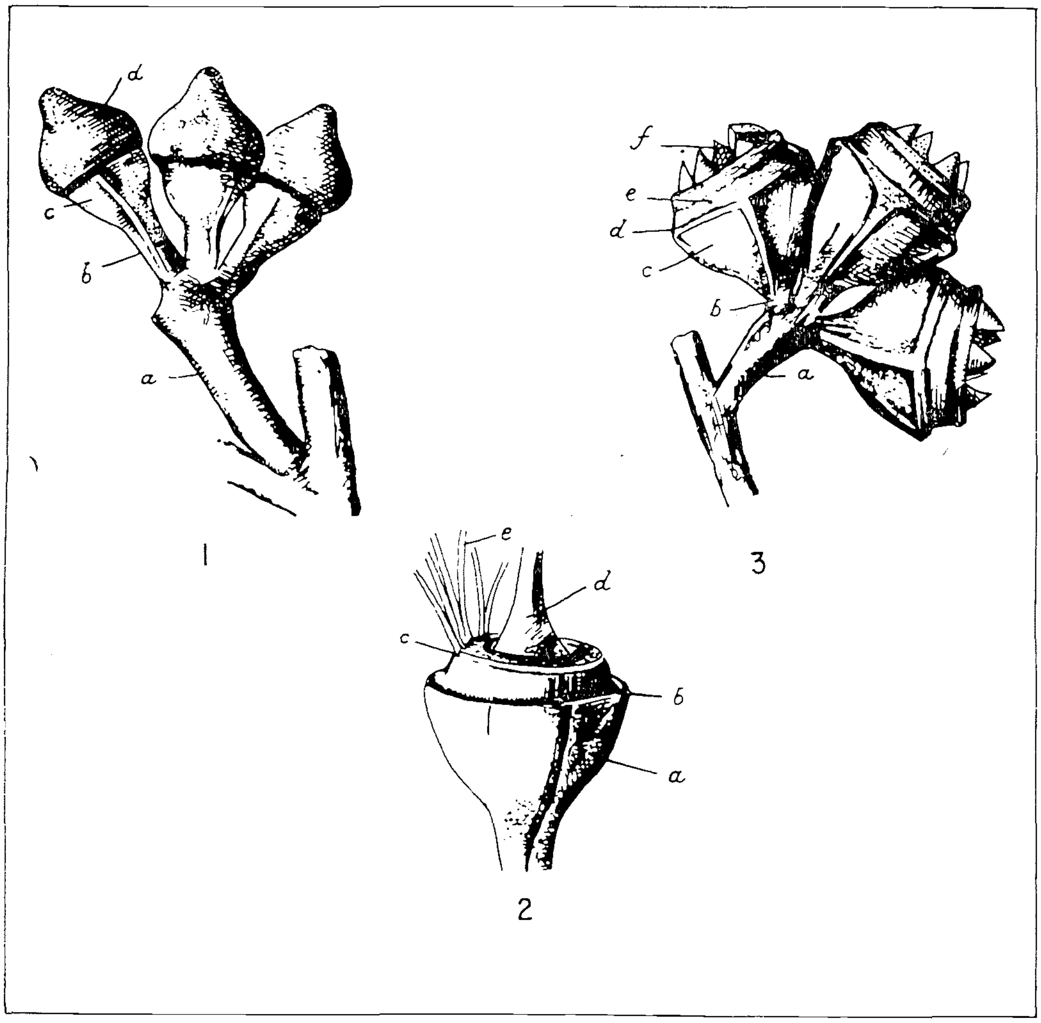
Enclosed valves. Such valves have their base well below the level of the calycine ring beyond which their summit may project slightly.

Level valves. "Level" valves are those which have their base level with or slightly below the calycine ring, the points being at the level of, or slightly above the latter.

SEED

The flowers of eucalypts are pollinated in the main by insects, particularly bees, blowflies and ants, and rarely by wind. Nectar is secreted in the cup of the flower. This nectar is very attractive to insects. When eucalypts are in full flower in plantations a veritable roar of bees can be heard.

Each eucalypt fruit contains a number of ovules. Some, but never all of these ovules, are fertilized during pollination. It is important to remember that each ovule must be fertilized by a separate pollen grain, so while each



X Buds, flower and fruit of *E. pellita*

1 - Buds in axillary umbels: *a*, flattened peduncle; *b*, ribbed buds; *c*, ribbed receptacle; *d*, operculum

2 - Flower: *a*, receptacle; *b*, calycine ring; *c*, staminal ring; *d*, ovary and base of style; *e*, stamen filaments

3 - Umbel of fruit: *a*, flattened peduncle; *b*, short angular pedicel; *c*, ribbed receptacle; *d*, calycine ring; *e*, disc; *f*, valves (deltoid and exsert)

After W.F. Blakely

seed in a fruit is from the same female parent, there may be several different male parents involved in the seed within one capsule. So if other species which can hybridize with the female parent are also flowering in the vicinity, it is possible that there may be one or more hybrid seeds in the fruit.

The fertilized ovules expand in about six months, or even less, after pollination, and the capsule swells to the size normal for the species. The seed is usually viable as the capsules are changing in colour from green to brown. Mature capsules are brown and usually remain closed for several months or even two or more years if they remain attached to their parent branches. If fruits or the branches are detached from the tree the valves which hold the seed in the capsules open in the course of hours or days and the seed is shed, together with the unfertilized ovules, which are usually smaller and lighter in weight than the fertile seed, and are known as "chaff."

Seed characteristics

Many authors have commented on features of *Eucalyptus* seed (Bentham, 1867; Mueller, 1879; Maiden, 1904-31; Grose and Zimmer, 1958; Gauba and Pryor, 1958, 1959, 1961; Carr and Carr, 1969). Only Maiden produced a large-scale seed classification. Some of his groupings are now recognized to be anomalous because they are based on superficial or too few characters only.

However, close examination of *Eucalyptus* seed usually reveals characters which place species together into groups which accord with their natural affinity as shown in a modern classification like that of Pryor and Johnson (1971). This system is based on an appraisal of all characteristics of a taxon which are believed to be strictly inherited.

Eucalyptus seeds vary greatly in size, from less than 1 mm in *E. populnea* to more than 2 cm in *E. calophylla*; in colour, from black in *E. tereticornis* to yellow in *E. camaldulensis*; in shape, from almost spherical in *E. wandoo* to cuboid in *E. tetrodonta* and subulate in *E. curtisii*; and in sculpure, from shallowly reticulate in *E. leucoxylon* to deeply pitted in *E. griffithsii.*

Many species are easily attributable to subgenera by their seed characteristics alone. The seed of many species of the woody-fruited bloodwoods (subgenus *Corymbia*) is prominently winged; that of the paper-fruited bloodwoods (subgenus *Blakella*) saucer-shaped and unwinged.

A seedlot of the large subgenus *Monocalyptus* can usually be recognized, as the seeds plus chaff are, with some exceptions, more uniform in size, shape and colour than in the other subgenera. The seeds themselves are usually brown or black, more or less smooth and shiny on the dorsal side and, on the ventral side, with ribs ascending to the hilum, which is the scar left on the seed after it has been shed from the placenta in the fruit. There is usually an absence of subulate chaff in the seedlots of species of this subgenus.

In contrast, there is a great deal of variability in seedlot characteristics between groups of species in subgenus *Symphyomyrtus*. The seed may be cuboid, pyramidal, elliptical, etc.; smooth-edged or tooth-edged; whitish, grey, yellow, red, brown or black. The seed of some species, e.g., *E. pyriformis*, may resemble that of some species in *Monocalyptus* but the high percentage of subulate chaff in *E. pyriformis* clearly distinguishes it.

A detailed treatment of seed characteristics with photographic plates is given in the *Eucalyptus seed manual* (Boland *et al.*, in press).

4. Eucalypts as plantation trees

The first edition of *Eucalypts for planting* introduced a chapter on eucalypts as exotics with the words, "As far back as the early nineteenth century, numerous eucalypt species were introduced into many arboreta throughout the world, especially in Europe," and went on to describe the enthusiasm for acclimatizing exotic species at that period and the later urge to experiment with many of them as commercial species. The area of eucalypt plantations in 1955 was estimated to be about 700 000 hectares throughout the world. From the information given to FAO during the preparation of the present edition, commercial eucalypt plantations now cover about 4 million hectares in 58 countries and areas, including Australia; another 50 have trial plantings or ornamental plantings. Several of these areas could embark on commercial plantings in the next few years.

This chapter will therefore summarize briefly what has been achieved and some of the problems that have been encountered. During the last 25 years, many plantation practices have become very similar throughout the world. Because of this, much of the valuable information on plantation practices given to FAO in the Country Reports has been included in the technical chapters and will not be repeated in this chapter.

Countries and areas are discussed in alphabetical order. A tabular statement of areas planted appears in Appendix 5. Unless otherwise stated, the area data have been taken from Country Reports. In some cases they may reflect areas planted and not established, fully stocked plantations.

Area reports

Algeria

Algeria borders the southern shore of the Mediterranean and extends southward well into the Sahara desert. Its latitudinal range is from 37°N to 19°N. The Atlas mountains rise to 2 326 m in the north and have a major effect on the forests and other rural activities of the country.

Eucalypts were introduced into Algeria between 1854 and 1860 and several species have given excellent results in the subhumid and semi-arid portions of the country, mainly below 800 m and in areas with a rainfall in excess of 450 mm. By 1965 the estimated area of plantations was 28 200 ha.

Plants are normally raised in polythene tubes. Site preparation consists of removal of woody vegetation, followed by mechanical subsoiling down to 50-80 cm. In shallow soils in dry areas the "méthode steppique," by which ridges of topsoil from the intervening strips are piled in ridges above the subsoiled lines and planting is done on the ridges, has given improved results. Average initial stocking is 1 000/ha and planting is done into pits of 50 cm^2 × 50 cm deep. Mechanical harrowing between the lines, combined with manual hoeing round the plants, is necessary for two to three years after planting. The rotation is 12-15 years and an average yield of 9 m^3/ha/yr is expected.

E. camaldulensis is the species most widely spread. Provenance trials were planted in 1968 at Bou Rouis (rainfall 630 mm, mean minimum of coldest month 5.9°C, altitude 90 m). After one year provenance 6845 Lake Albacutya was the fastest growing, as it has been on most Mediterranean sites (Lacaze, 1970). Other promising species are:

(*a*) For cool humid areas: *E. botryoides, E. cladocalyx, E. diversicolor, E. maculata, E. siderophloia.*

(*b*) For high altitudes: *E. cypellocarpa, E. melliodora, E. ovata, E. smithii, E. viminalis.*

(*c*) For calcareous soils: *E. astringens, E. gomphocephala.*

In the first edition the following additional species were listed as vigorous or fairly vigorous in the vicinity of Algiers — *E. crebra, E. moluccana* (then listed as *E. hemiphloia*), *E. leucoxylon, E. punctata, E. raveretiana, E. rudis* and *E. trabutii.* The mention of *E. raveretiana* as vigorous is interesting as it could be useful in difficult soils in low latitudes. The species is rarely mentioned in trials made outside Australia.

The attacks of the borer *Phoracantha semipunctata* which have become a serious problem in Tunisia have now spread to Algeria. Tunisia has developed a promising control measure against *Phoracantha.* This is described under Tunisia and mentioned in Chapter 9.

Angola

Angola is in the southwestern part of Africa, with its coastline on the south Atlantic Ocean. Its latitudinal range is 6°S-17°S. Rainfall varies greatly, from less than 100 mm in the arid southwest coastal area to about 1 800 mm in the northeast. The greater part of the country consists of a plateau of 1 000-1 400 m elevation, with occasional higher mountains up to 2 000 m; rainfall on the plateau varies between 800 and 1 500 mm. There is a distinct dry season which coincides with the coolest temperatures. Frosts occur sometimes at the higher altitudes. On the plateau, ferralitic soils predominate to the west and sandy soils of the Kalahari series to the east. Climatic data for Luanda (dry coastal) and Nova Lisboa (moist plateau) are shown in Table 4.1.

Eucalypts were first introduced at the end of the last century. According to information summarized by Persson (1975) the total area of eucalypt plantations in 1970 was 100 600 ha, distributed as follows:

Benguela Railway Co.	37 000 ha, distributed in about 20 blocks along the Benguela-Dilolo railway line.
Ultramar Cellulose Co.	20 500 ha in several different blocks, accessible from the Benguela-Dilolo railway line.
Government Forest Service	10 000 ha
Private ownership	33 100 ha, widely scattered.

At that time it was planned to extend the Ultramar Cellulose Co. plantations to 72 000 ha by 1974 and the Forest Service was planning to plant several thousand hectares a year in addition.

The purpose of the Benguela Railway Co. plantations was to supply fuelwood to the railway, that of the Ultramar Cellulose Co.'s plantations, to supply pulpwood to the mill at Alto Catumbela, for production of bleached sulphate pulp for local consumption and for export (Petroff, 1968). Other plantations have been used for posts, poles and to a small extent for sawlogs.

Eucalyptus grandis/saligna has accounted for easily the largest part of the eucalypt plantations, over 80 000 ha. *E. camaldulensis* was the species most used in the earlier plantings of the Benguela Railway Co. and is still the second species in terms of area, around 15 000 ha. There are smaller areas of *E. alba, E. globulus, E. tereticornis, E. botryoides, E. citriodora, E. ma-*

Table 4.1 Climatic data for Luanda and Nova Lisboa (Angola)

Zone	Station	Latitude (S)	Longitude (E)	Altitude (m)	Temperature (°C) Mean maximum (hottest month)	Temperature (°C) Mean minimum (coldest month)
Dry coastal	Luanda	8°49′	13°13′	45	31° March	18° July/August
Moist plateau	Nova Lisboa	12°48′	15°45′	1 700	29° Sept.	8° June/July

Monthly rainfall (in millimetres)

Station	J	F	M	A	M	Jn	Jl	A	S	O	N	D	Total	Number of rainy days
Luanda	26	35	97	124	19	0	0	1	2	6	34	33	377	32
Nova Lisboa	209	179	231	144	16	0	0	1	19	124	231	233	1 387	110

culata, E. maidenii, E. microcorys, E. paniculata, E. punctata, E. resinifera, E. robusta, E. smithii and *E. largiflorens* and over 50 species have been planted in arboreta (Carita Frade, 1963; Persson, 1975; MMF, 1966).

E. saligna/grandis is raised in polythene pots in 3-4 months in the nursery and is planted early in the rains (October/November), after clearing of vegetation and cultivation by 12-disc harrow. Spacing is commonly 2.25 × 2.25 m (Petroff, 1968), although a variety of spacings have been used, including 2 × 2, 2.5 × 2.5, 1.5 × 3 m. Rotation is commonly 9 years and on good sites in the higher and moister parts of the plateau a yield of 28 steres (equivalent to about 20 m^3 underbark true measure) is expected. For the second and subsequent rotations, regeneration is from coppice, with two stems per stump.

Argentina

Argentina, extending from latitudes 22°S to 55°S, is one of the important eucalypt planting countries for industrial plantations, windbreaks, shelterbelts and aesthetic plantings. Industrial plantations are established for and used by pulp and paper factories, hardboard factories, charcoal for the iron industry, logs for sawmills and an extensive use of preserved poles and posts. There is a small eucalyptus oil industry based on *E. globulus*. Eucalypts supplied 44 percent of the wood volume used by the pulp and paper industries in 1974 (Videla Pilasi, 1977).

E. globulus was first introduced in 1856 and has been widely planted in blocks and as shelterbelts and windbreaks on rural properties. A wide variety of eucalypts has been introduced by the Forest Service and private owners since 1856, particularly in the past few decades. Excellent arboreta are maintained by the Forest Service at Castelar near Buenos Aires and at the Estación Forestal L.N. Alem in Missiones.

Argentina is carrying out provenance trials and tree improvement research work through the unique collaborative organization INTA, while the Instituto Forestal Nacional (IFONA) deals mainly with silvicultural and technological problems.

The main eucalypt species grown in plantations are *E. camaldulensis, E. grandis, E. saligna, E. tereticornis, E. viminalis* and *E. globulus*. Subsidiary species used are *E. urophylla* (promising), *E. bicostata, E. nitens, E. robusta, E. botryoides, E. ovata* and *E. leucoxylon*. The effective area of farm plantations, production plantations, windbreaks and shelterbelt plantings in 1973 was estimated at 80 000 ha. Projected annual plantings are between 3 000 and 6 000 ha.

Argentina has a varied topography and soil complex. Much of the central and southern part is a plain developed from loess blown from the Andes, including a substantial element of volcanic dust. The altitude of the eastern part is not high except for the central range around the city of Cordoba. This range rises to 2 800 m. In the west the boundary between Argentina and Chile is the snow-covered range of the Andes, rising to 6 960 m at Mt Aconcagua and usually between 2 000 and 5 000 m over its length of some 6 500 km. The climate varies from subtropical to temperate and cool-temperate and alpine.

There are three main areas where eucalypts are grown:

(*a*) The pampas grasslands in the east, comprising Buenos Aires province and parts of the adjacent provinces, with black and clay soils.

(*b*) Mesopotamia, the area in the northeast between the Rivers Paraná and Uruguay, with clay, sandy and lateritic soils which support vegetation varying from grassland to subtropical forests.

(*c*) The northwest, comprising parts of the provinces of Tucumán, Salta and Jujuy, with varying depths of humic soils which support subtropical forest.

Rain falls mainly in the summer, with the heaviest precipitation and the highest temperatures occurring in the northeast, and the most distinct dry season in the northwest. Climatic data from three representative stations are shown in Table 4.2.

E. camaldulensis covers 20-25 000 ha of production plantations, mainly in the Buenos Aires and Santa Fe regions, with 8 000 ha in Jujuy for the charcoal iron industry. It is also important in the flooded delta of the Paraná river because it remains alive (and recovers) after a longer immersion than other tree species. The early introductions must have been

Table 4.2 Climatic data for three representative planting areas in Argentina

Area	Station	Latitude (S)	Longitude (W)	Altitude (m)	Temperature (°C)	
					Mean maximum (hottest month)	Mean minimum (coldest month)
La Pampa	Santa Rosa	36°37′	64°19′	183	32.7° Jan.	1.2° July
Mesopotamia	Concordia	31°23′	58°23′	37	32.9° Jan.	7.2° July
Northwest	San Salvador de Jujuy	24°11′	65°18′	1 303	28.4° Dec.	3.6° July

Monthly rainfall (in millimetres)

Station	J	F	M	A	M	Jn	Jl	A	S	O	N	D	Total
Santa Rosa	54	78	86	48	36	20	25	15	34	66	49	52	563
Concordia	108	122	164	154	95	90	43	62	100	100	97	91	1 226
San Salvador de Jujuy	211	208	167	46	25	14	11	6	18	55	93	153	1 007

from southern Australia. The form is not generally good but a selection of stems for different purposes at the time of harvesting helps in the market-place. The main use is for hardboard; it produces a high-quality finish easy to paint. This hardboard is becoming one of the most important forest products for export. It is also used for posts, poles, charcoal, pulp and sawtimber. Volume growth is from 20-25 m^3/ha/year.

It is of interest that in Argentina, southern Australian provenances of *E. camaldulensis* show the better promise in trials at the present time.

E. tereticornis is sometimes mixed with *E. camaldulensis* in plantations but replaces *E. camaldulensis* in the northern area of the La Pampa region and has possibilities in Chaco and Formosa. There are approximately 15 000 ha planted with *E. tereticornis.*

E. viminalis is very common in the southern Pampean region where it tolerates the lower temperatures. It is popular as a coppice crop but requires rich soils. If it is used for making hardboard or pulp, it causes frothing, presumably due to the presence of saponins, and this is a difficulty with the species.

E. grandis/saligna plantations are seen at their best in Mesopotamia, Entre Rios, the north of Corrientes and in Missiones. They are also showing promise in the northwest. Height growth is from 2-3.5 m per year in the early years and volume growth is high, from 25-50 m^3/ha/year. The wood is used for pulp, fruit boxes, poles and general sawntimber. The area under *E. grandis/saligna* is 40-50 000 ha.

The total effective area of *E. globulus* in Argentina is difficult to estimate because of the large number of private properties involved, but the area and its productivity are important in judging the significance of eucalypts in the country because all the products are used and add to the standard of living of the rural owners. There are about 2 000 ha of plantations of *E. globulus*, but hundreds of private plots of a varying size and many shelterbelts in the farming regions, which were largely treeless. Jacobs (1959) commented that, in travelling across the pampas, as soon as a series of farm plots disappeared under the rear horizon, an equal number appeared on the horizon in front. There were always between 15 and 25 plots in view with a minimum of 15. The total effective area must be in the region of 10 000 ha.

Plants are raised in polythene tubes or in plastic or tarred cardboard containers, 10-15 cm long and 5 cm in diameter. At planting they are 20-40 cm tall after 3-6 months in the nursery. In grassland, ploughing and harrowing are done in two directions at right angles, while on forest sites the vegetation is felled and burned. Clean weeding is practised frequently for the first 1-3 years.

Growth rates reported from Argentina are high. *E. camaldulensis* produces 20-25 m^3/ha/year, *E. grandis saligna* up to 50 m^3/ha/year, and the others somewhat less.

A number of provenance trials are in progress, especially with *E. camaldulensis* and *E. grandis/saligna.*

Australia

The main purpose of this note on Australia is to cover the 26 400 ha of eucalypt plantations planted in the Commonwealth by 1972. The greater part of these plantations are *E. grandis, E. saligna* and *E. regnans* established primarily to supply pulpwood for present and future paper factories. An interesting exception is some 8 000 ha of *E. astringens* planted between 30 and 40 years ago in Western Australia to supplement the local forest industry in this species. The bark and the wood of *E. astringens* both have a high tannin content and the wood is very strong and suitable for tool handles where resistance to shock is required. Two interesting species which are being established in small quantities are *E. youmanii* and *E. macrorhyncha,* the leaves of which contain a substantial proportion of the drug rutin which is widely used in medicine. At present, Australian suppliers of rutin obtain it from natural stands of *E. macrorhyncha,* but these stands are being severely reduced because of this exploitation. *E. youmanii* produces much more rutin than *E. macrorhyncha.*

There is a considerable amount of enrichment planting during the natural regeneration of Australian eucalypt forests managed for sawlog production. This planting has not been included in the area of plantations. In all countries which are regenerating their native forests there is some enrichment treatment and it is sometimes difficult to separate this man-made activity from what is understood as plantation forestry in this book.

The plantations of *E. astringens* in Western Australia have now grown to moderate size for drier country eucalypts and the forest has become very attractive. If the Forest Service is able to protect it, the area may be maintained as a permanent forest. The difficulty is that the species is very sensitive to fire and does not coppice (see Hillis and Brown, 1978; see also Chapters 1 and 14).

Bolivia

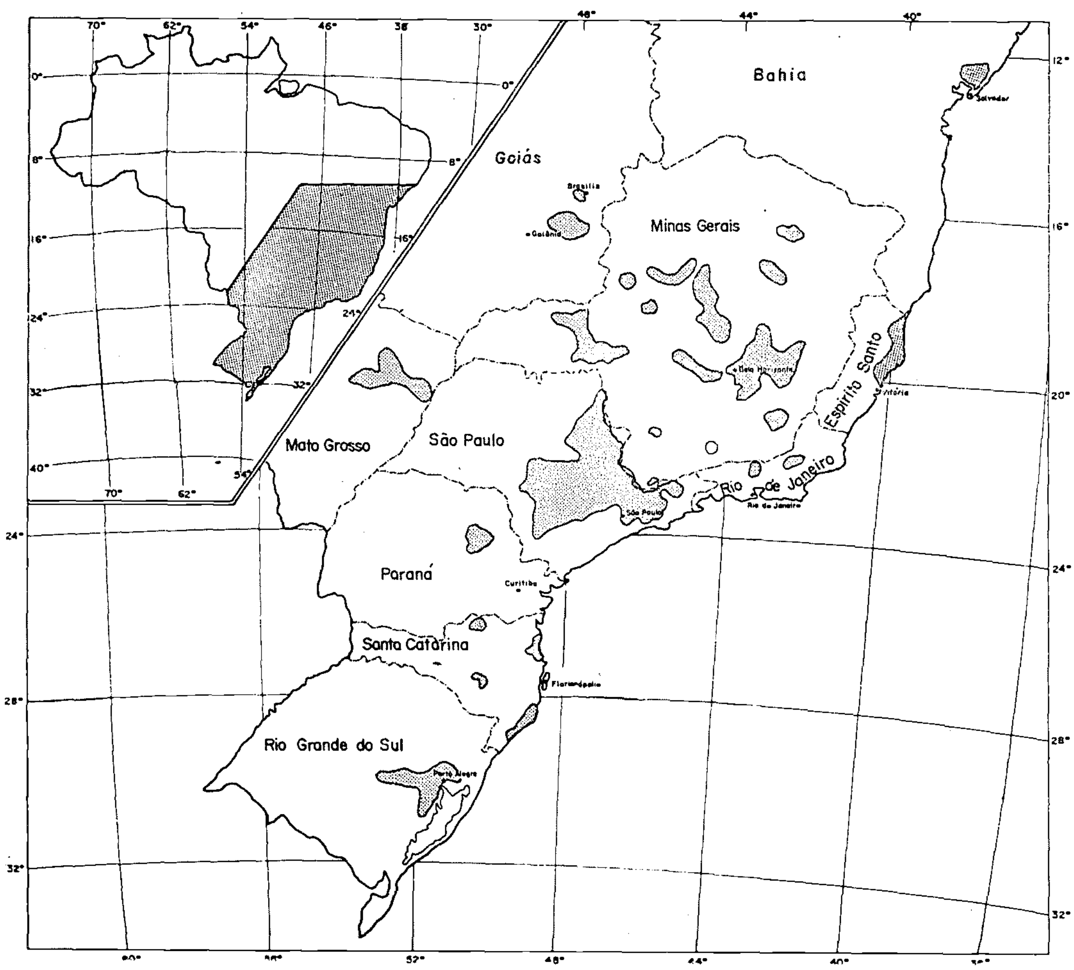
The Republic of Bolivia lies between latitudes 10°S and 23°S. Its principal feature is the large central plateau at an average altitude of 5 000 m.

Eucalypts were first introduced in 1900 (*E. globulus* seed from Argentina). *E. globulus* is still the principal species planted, and plantations are mainly in the form of small private woodlots on the high plateau. They produce mine-timber, poles, posts, some sawlogs and fuelwood and in 1973 covered some 5 000 ha.

E. globulus is first cut at 10 years and then coppiced on a seven-year cycle to about 50 years. Other species found promising are *E. cinerea, E. gunnii* and *E. viminalis.* The soils are stony and steep. Rainfall is confined to some 40 days per year in December through March. No serious pathological problems have occurred.

Brazil

Brazil is a huge country extending from latitudes 33°S to 5°N. At the time of the preparation of the first edition of *Eucalypts for planting* Brazil had by far the greatest area of eucalypt plantations — about 300 000 ha — and it is still the most important planting country, having an estimated planted area



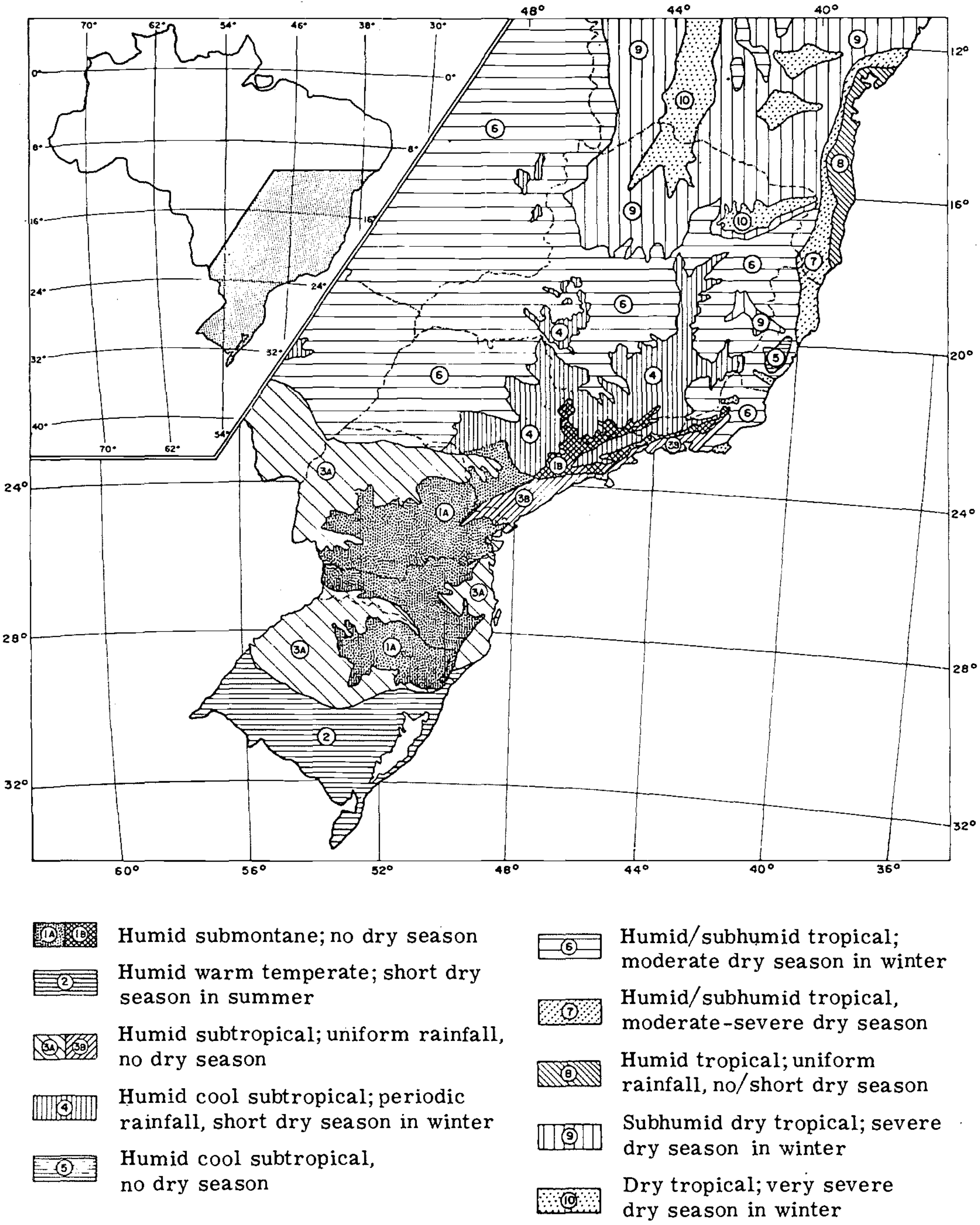
XI Principal areas of eucalypt cultivation in Brazil

in 1973 of 1 052 000 ha distributed among the states as follows:

São Paulo, 532 000 ha; Minas Gerais, 325 000 ha; Espírito Santo, 72 000 ha; Paraná, 35 000 ha; Rio Grande do Sul, 26 000 ha; Mato Grosso, 23 000 ha; Goiás, 15 000 ha; Santa Catarina, 12 000 ha; Rio de Janeiro, 7 000 ha; Bahia, 5 000 ha.

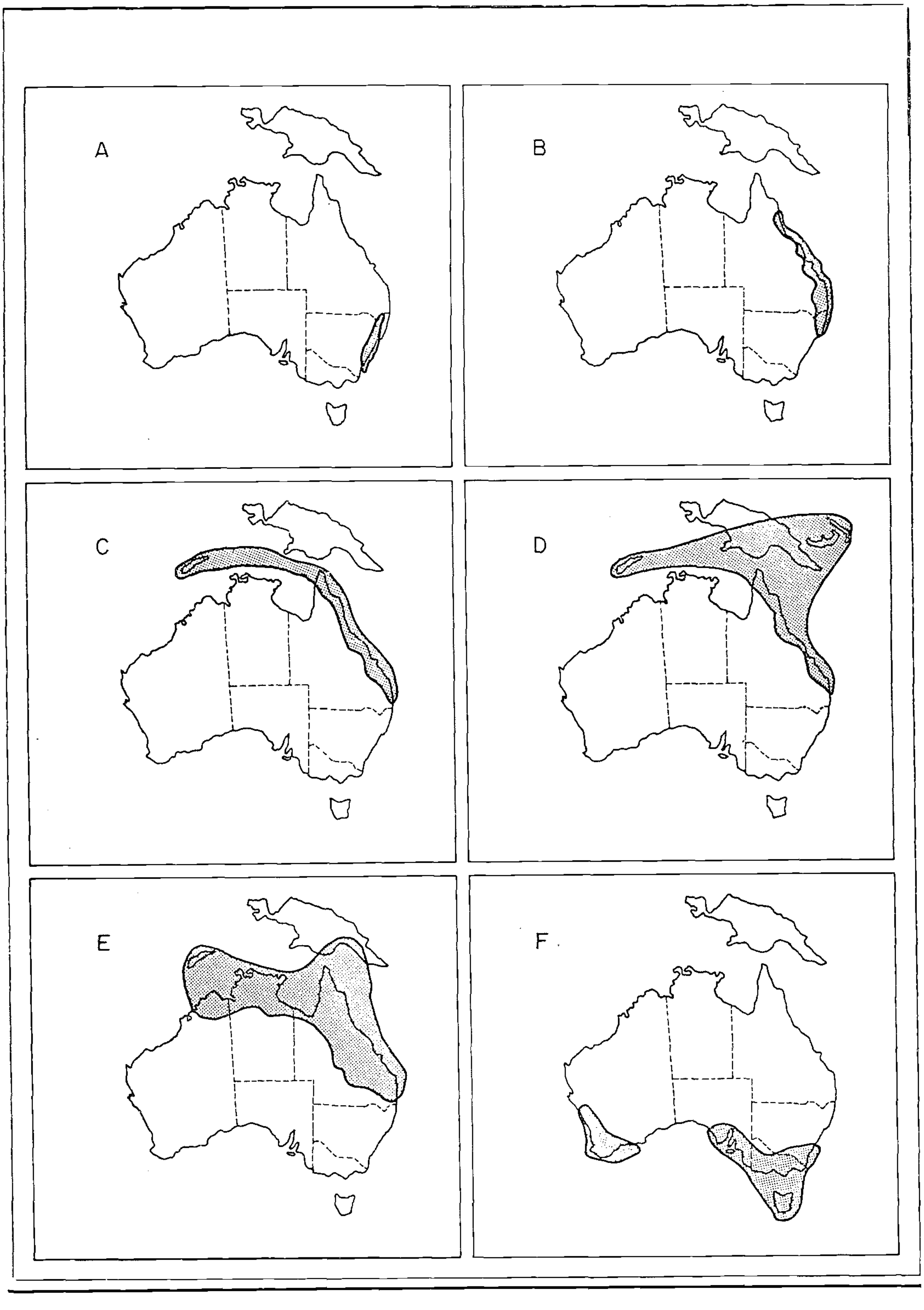
The oldest known eucalypts in Brazil are specimens of *E. robusta* and *E. tereticornis* in the Botanical Gardens of Rio de Janeiro. The plaques on these indicate that they were planted in 1825 by Emperor Pedro I of Brazil.

In the decade 1905-15 Edmundo Navarro de Andrade, the father of Brazilian plantation forestry, established a wide series of trials of 144 species of eucalypts on behalf of the Paulista Railway Company and later established the famous arboretum and forest at Rio Claro in the state of São Paulo. Other introductions were made and the names of more than 200 eucalypt taxa can be counted in Brazilian plantations. Of these, 30 are regarded as already important or worthy of further careful trials in different parts of the country. These 30 taxa are shown in Table 4.3 which also gives the characteristics of the principal planting regions where different species should be planted.



XII Climatic characteristics of principal areas of eucalypt cultivation in Brazil

The increase in area planted in Brazil during the past 20 years shows that an average of 37 600 ha of new plantings each year must have been made during that period. In fact the rate of increase of new plantings has been progressive. At the time of an FAO pulpwood survey in 1972 the annual rate of new plantings was given as 65 000 ha. Brazil has a national plan to stimulate export industries as well as to sustain internal consumption, and one of the categories of industries which will be given special attention is the manufacture and export of wood pulp, largely based on eucalypt plantations.



XIII Correlations between geographical provenance of eucalypts and Brazilian bioclimatic regions

A: areas of origin of species suitable for regions 1A, 1B and 2;[1]
B: areas of origin of species suitable for regions 3A, 3B, 4 and 5;[1]
C: areas of origin of species suitable for region 6;[1]
D: areas of origin of species suitable for regions 7 and 8;[1]
E: areas of origin of species suitable for regions 9 and 10;[1]
F: areas of origin of species which were not successful in Brazil owing to climatic unsuitability.

[1] See Figure XII

In the central and southern states of Brazil, the average annual increment of well-maintained plantations of *E. saligna* and *E. grandis* may attain 30 m^3 per ha or higher, which is very high by world standards. Overall average increments on a gross area basis are appreciably lower than this. The national average given in the 1972 FAO pulpwood survey was 18 m^3 per ha.

Most of the wood produced from Brazilian eucalypt plantations is used in the pulp and paper industry. Second in consumption is wood used in the production of charcoal for the iron and steel industry. Third in importance are the fibreboard and particle-board industries. Sawmilling and the production of posts and poles are of lesser importance than the first three industries mentioned. The production of essential oils, principally from the leaves of *E. citriodora*, is assuming significance.

The most common soil types on which eucalypts are planted in Brazil are red-yellow and dark red latosols, reddish brown laterites and red-yellow podzols. Natural vegetation on the plantation sites prior to planting includes:

(*a*) Broadleaved forests which are sometimes hygrophytic or mesophytic and deciduous;
(*b*) "Cerrados" (various types of savannas or savanna woodlands);
(*c*) "Campos" (natural grasslands).

Most of Brazil receives the greater part of its rainfall in the hotter months. Bioclimatic zones have been established, and are listed in Table 4.3. Developments in bioclimatic zonation in Brazil continue. For an updated and more detailed zonation readers should refer to Golfari, Casar and Moura (1978).

Stand treatment

The most common life cycle of eucalypt plantations in Brazil is 20-22 years, divided into 3 coppice periods of 7-10 years. It is considered likely that with improved seed in the future the life cycle may be extended to 30 years or more, with 4 or 5 successive cutting periods.

Plantation costs

The costs of preparing land, nursery costs and cultural costs up to the end of the third year are between US $300 and $600.

Pathology, pests and disorders

Because of the immense range of latitude covered in Brazil, the country is experiencing, and must experience, some trouble with plant pathogens and troublesome insect pests. The Brazilian experience provides examples of the difficulties which follow the planting of eucalypts as exotics outside their natural range of occurrence. (For further details see Chapter 9.)

British Solomon Islands

The British Solomon Islands are a Pacific Ocean island group between latitudes of about 5°S and 10°S. This island group is interested in eucalypts to supply industrial wood as saw- and veneer logs and as pulpwood for export markets. The main planting made is a 6-hectare trial of *E. deglupta*. The islands have a tropical climate with no noticeable dry season except for the northern part of Guadalcanal and this seldom exceeds three months. The mean annual rainfall is around 2 400 mm in the drier part of Guadalcanal, 3 500 mm when there is no marked dry season and 5 000 mm in the Santa Cruz group. This very high rainfall suits *E. deglupta*, and a pulpwood

Table 4.3 Bioclimatic regions in Brazil and potentially suitable species of eucalypts

Region	Type of climate and location	Altitude (m)	Mean annual temperature (°C)	Mean annual rainfall (mm)	Seasonality of rainfall	Frosts	Absolute minimum temperature (°C)	Species
1 A	Humid submontane (Southern plateau from São Paulo to Rio Grande do Sul)	500-1 300	12-18	1 250-2 500	Uniform with no dry season	Frequent	— 9	*E. viminalis* *E. dunnii* *E. stjohnii* (= *E. globulus* subsp. *E. bicostata*) *E. nova-anglica* *E. nitens* *E. dalrympleana* *E. saligna* (*) *E. grandis* (*) (*) Only in the northern area, with light frost
1 B	Humid submontane (Sierra de Mantiqueira, Cantareira, Bocaina, etc.)	800-1 800	13-18	1 300-2 000	Periodic with no dry season	Frequent above 1 100 m	— 5	*E. grandis* *E. pilularis* *E. dunnii*
2	Humid warm temperate (Southern Rio Grande do Sul)	0-500	16-19	1 200-1 650	Uniform with short dry season in summer (1-2 months)	Occasional	— 3	*E. saligna* *E. grandis* *E. tereticornis* (from south of New South Wales) *E. camaldulensis* (from south of Australia) *E. robusta* *E. botryoides*
3 A	Humid, cool subtropical (Coast of Paraná and Santa Catarina; Paraná and Uruguay river basins)	0-500	18-21	1 250-2 000	Uniform with no dry season	Rare in the coastal region, occasional in the interior	— 2	*E. grandis* *E. saligna* *E. robusta* (littoral) *E. paniculata* *E. pilularis* *E. resinifera*
3 B	Humid subtropical (Coast of São Paulo and Rio de Janeiro)	0-600	19-23	1 400-2 500	Uniform with no dry season	Absent	+ 3	*E. grandis* *E. robusta* *E. pilularis* *E. deglupta* (only in perhumid areas)

4	Humid, cool subtropical (Central region of São Paulo, valley of River Paraíba and high areas of Minas Gerais except Sierra de Mantiqueira)	500-1 200	18-21	1 300-1 700	Periodic with short dry season in winter (2-3 months)	Very rare	— 2	*E. grandis* *E. saligna* *E. pilularis* *E. microcorys* *E. maculata* *E. propinqua* *E. dunnii* *E. cloeziana* *E. citriodora*
5	Humid, cool subtropical (High area of Espírito Santo)	800-1 200	16-20	1 300-2 200	Periodic with no dry season	Absent	+ 2	*E. grandis* *E. deglupta* (only in perhumid areas) *E. cloeziana*
6	Subhumid/humid subtropical (Western São Paulo, central area of Minas Gerais, northeastern Rio de Janeiro and northwestern Espírito Santo)	0-1 000	18-23	1 100-1 500	Periodic with moderate dry season in winter (3-5 months)	Absent	+ 2	*E. grandis* (from Atherton, Qld) *E. citriodora* *E. urophylla* *E. cloeziana* *E. camaldulensis* (from northern Australia) *E. tereticornis* (from northern Queensland)
7	Subhumid/humid tropical (Northern coast of Espírito Santo and interior coastal area of Bahia)	0-400	23-25	1 100-1 500	Periodic with short to moderate dry season in autumn and winter (1-4 months)	Absent	+ 8	*E. urophylla* *E. grandis* (from Atherton, Qld) *E. cloeziana* *E. torelliana* *E. camaldulensis* (from northern Australia) *E. tereticornis* (from northern Queensland) *E. pellita* (from northern Queensland) *E. brassiana*
8	Humid tropical (Coast of Bahia)	0-300	23-25	1 600-2 300	Uniform with no or short dry season (0-2 months)	Absent	+ 11	*E. deglupta* (only in perhumid areas) *E. cloeziana* *E. urophylla* *E. pellita* (from northern Queensland) *E. torelliana* *E. tereticornis* (from northern Queensland) *E. camaldulensis* (from northern Australia)

(*continued*)

Table 4.3 Bioclimatic regions in Brazil and potentially suitable species of eucalypts *(concluded)*

Region	Type of climate and location	Altitude (m)	Mean annual tempera- ture (°C)	Mean annual rainfall (mm)	Seasonality of rainfall	Frosts	Absolute minimum tempera- ture (°C)	Species
9	Subhumid/dry tropical (Northern Minas Gerais and southern Bahia)	200-900	23-25	900-1 200	Periodic with severe dry season in winter (5-7 months)	Absent	+ 6	*E. camaldulensis* (from northern Australia) *E. tereticornis* (from northern Queensland) *E. brassiana* *E. citriodora* *E. exserta* *E. nesophila*
10	Dry tropical (São Francisco, Jequitinhonha and other river basins)	100-500	24-25	600-1 000	Periodic with very severe dry season in winter (7-10 months)	Absent	+ 6	*E. camaldulensis* (from northern Australia) *E. alba* (from Timor or Flores) *E. tessellaris* *E. exserta* *E. crebra*

programme with this species of some 32 000 hectares is planned by 1985. The original introduction of *E. deglupta* came from Keravat in New Britain. Other provenances have been obtained from the Philippines, Indonesia (Sulawesi) and Puerto Rico. Further provenances are being sought from the mainland of New Guinea.

The best soils are deep alluvial sandy loams but good growth is obtained from deep weathered clays of low nutrient status and on shallower clay soils over coral and limestone. The species is not thought to be tolerant of shallow clay soils over rock.

Nursery practice fits the outlines given in Chapter 5. Establishment requires poisoning of the remnant overwood which is done by frill girdling and poisoning with 20 percent arsenic pentoxide or 8 percent tordon 50D in water. Planting lines are cut when the trees start to die. Planting can be done over most of the year. Re-filling of failed plants should be done within 3 months of planting, preferably within one month.

Tending involves initial weeding around the planted trees starting one month after planting when fertilizing is also done. The first three tending operations should be completed within 6 months when the trees should be 1.5 m high. Thereafter, tending concentrates on cutting back regeneration between lines and keeping trees clear of climbers (particularly *Merremia* ssp.) which can be prolific and extremely vigorous.

The coreid bug *Ambleypelta cocophaga* causes tip die-back during the first 18 months. Clean weeding helps the spread of the ant *Oecophylla smaragadina* which is a predator of the bug.

A pulpwood thinning is proposed between ages 8 and 11, leaving about 100 stems per hectare. Rotation should be 8-11 years for pulpwood and 15-20 years for sawlogs or veneer logs, followed by replanting. Coppicing will not be used.

Establishment costs are summarized in Chapter 12.

Brunei

Brunei is a state on the northwest coast of the large island of Borneo at a latitude of about 5°N. A series of 27 species and provenances of eucalypts was established on a range of sites between 1967 and 1970 to ascertain if the species were suitable as plantation crops in the locality or at least as pole crops. Fuelwood from eucalypt plantations was not a requirement of the population.

The Brunei climate is low latitude tropical and humid. The annual rainfall of 2 000 mm is well spread throughout the year with occasional drought periods of up to 70 days. Soils are sandy; in some peat swamp sites they support dense swamp vegetation and in higher elevations have sparse natural vegetation.

The eucalypts were line-planted as experiments. The tests showed no promise and have been abandoned.

Burundi The Republic of Burundi is situated on the northeast side of Lake Tanganyika between latitudes 2°30′S and 4°30′S.

From Lake Tanganyika, at 780 m, and the long valley of the Ruzizi river the land rises sharply to the Congo-Nile divide, approximately 1 800 m in height, which stretches northward into Rwanda. The high peaks reach 2 600 m. Most of the remainder of the country consists of an undulating plateau lying between 1 150 and 1 800 m in height.

The climate is of the summer-rainfall type, with a cool dry season from June to August. The total rainfall and the severity of the dry season both vary with altitude, the driest areas occurring in the southwest plateau and at low elevations near the lake and the Ruzizi river. Table 4.4 gives climatic data for a representative low altitude and a high altitude station.

The earliest plantings of *Eucalyptus* spp. commenced in 1931 with seed obtained from Tanganyika, Rhodesia and South Africa. The principal species introduced were *E. camaldulensis, E. tereticornis, E. rudis* and *E. citriodora.* Later introductions have included, among others, *E. saligna, E. maidenii, E. botryoides, E. robusta* and *E. resinifera.* In replicated trials of a number of species, but excluding the most commonly planted *E. maidenii, E. botryoides* showed superior promise (Reynders, 1963).

The area planted to eucalypts by the end of 1973, excluding windbreaks and roadside plantings, amounted to 18 627 ha, of which over half has been planted to *E. maidenii.* The objects of establishment are: production of firewood and charcoal; production of poles for constructional use; and protection, particularly shelterbelts and anti-erosion works. Erosion is particularly severe in the high-rainfall, mountainous areas following deforestation.

Table 4.4 Climatic data from representative low altitude and high altitude stations in Burundi

Station	Latitude (S)	Longitude (E)	Altitude (m)	Temperature (°C)	
				Mean maximum (hottest month)	Mean minimum (coldest month)
Bujumbura	03°23′	29°21′	805	31° September	17° July
Kisozi	03°33′	29°41′	2 155	23° September	9° June/July

Monthly rainfall (in millimetres)

Station	J	F	M	A	M	Jn	Jl	A	S	O	N	D	Total	Number of rainy days
Bujumbura	94	109	121	125	57	11	5	11	37	64	100	114	848	138
Kisozi	167	160	196	228	120	12	6	16	64	115	174	189	1 447	175

Plants are raised in polythene pots 20 cm deep by 11 cm in diameter. Previously seed was sown in seed beds and pricked out into pots later, but recent trials of direct sowing into the pots have proved very successful and this method will be adopted as the standard practice in future. The age of stock at planting out is 5 months (low altitudes) and 7 months (high altitudes).

The planting site is cleared by manual labour and anti-erosion works are sited along the contours. Planting pits are 40 cm deep. At low altitudes the planting seasons are from mid-October to the end of December and from February to the end of March. At high altitudes the corresponding dates are from the beginning of October to the end of March. The espacement chosen varies according to site but is usually from 1.50 × 2 m to 2 × 2 m. A rate of survival of 75 to 95 percent at the end of the first year can be expected. Weeding is done at the rainy season in the year of planting.

Fire protection is ensured by the annual maintenance of perimeter firebreaks. The small areas of annual planting do not warrant the construction of internal fire lines.

Thinnings are not carried out, the plantations being worked on a coppice system. The rotation varies between 7 and 10 years according to the site conditions. Little information is available on financial data but the cost of establishment per hectare was estimated at FBu 30 000 in 1975.

Cameroon

Cameroon lies on the Gulf of Guinea between latitudes 2°N and 13°N. The climate varies from equatorial in the south to dry tropical in the north, with most of the rainfall falling in the warm season. The area of eucalypt plantations in 1970 was about 2 000 ha (Persson, 1975), mainly in the savanna areas. The main species in use were *E. saligna, E. grandis* and *E. camaldulensis* (Amougou, undated).

Chad

The Republic of Chad lies in north-central Africa between latitudes 7°N and 23°N. It is a dry, hot country with a long dry season and with rain falling in the hot months. Many eucalypts have been tried as windbreaks, to control erosion and to provide transmission poles. The leaves are used to make tea and a sauce. *E. camaldulensis* has proved successful on the plains, particularly the provenance from Katherine in the Northern Territory of Australia. Comparative failures have been *E. occidentalis, E. tereticornis, E. saligna* and *E. robusta.* Damage is reported by termites, sheep and drought.

The area planted by 1973 was 223 ha.

Chile

The Republic of Chile in South America lies between the top of the watershed dividing east- and west-flowing rivers in the Andes and the Pacific Ocean, between latitudes 17°S and 56°S. Covering such a wide range of latitude and altitudes, varying from sea-level up to about 7 000 m, it has a wide variety of climates. Soils vary from recent volcanics to rocky soils and desert sands. Rainfall varies from less than 100 mm in the northern coastal desert to 1 500 mm in the west country. In the dry north, the rain falls mainly in the hot months but the better land has a winter rainfall. The main plantation areas are north of latitude 40°S and the climate of the main eucalypt planting regions is indicated in Table 4.5.

Chile has tried a considerable number of eucalypts and well-acclimatized specimens can be seen in different parts of the country. The total area of eucalyptus plantations in 1966 is given as 31 052 ha, which is substantially less than the total area of 44 561 ha recorded by Métro (1955). The main production species has been *E. globulus* grown over a wide range of latitude and altitude. The species is grown on coppice rotations of 10-15 years to provide fuelwood, pulpwood and poles or to ages of 30 years or more in higher areas to provide sawtimber.

Eucalypts planted on a reduced scale are: *E. "amygdalina"*, possibly a provenance of *E. radiata*, used for essential oils; *E. bicostata*, good growth, similar to *E. globulus* but more tolerant of cold and dry conditions; *E. viminalis*, a rapid grower that tolerates low temperatures; and *E. delegatensis*, growing well in higher closed-forest country.

The following potentially useful species are represented by healthy individuals: *E. bridgesiana, E. citriodora, E. cornuta, E. cinerea, E. diversicolor,*

Table 4.5 Climatic data for the main eucalypt planting areas in Chile

Zone	District	Latitude (S)	Altitude (m)	Annual rainfall (mm)	Mean temperature (°C)			Number of dry months
					Jan.	July	Annual	
Desert	Copiapó	27°21′	380	28	20.9	11.9	16.3	12
Steppes	La Serena	29°55′	32	110	18.3	11.7	14.8	11
	Ovalle	30°36′	220	129	19.8	11.1	15.3	10
	Los Andes	32°50′		304	22.2	9.1	15.5	9
Chaparral	Santiago	33°27′	520	360	20.6	18.0	14.2	8
	San Antonio	33°34′		438				
	San Fernando	34°35′		780	20.0	7.5	13.5	6
	Constitución	35°20′		990	18.2	10.1	13.3	5
Woodland	Concepción	36°50′		1 338	17.8	9.1	13.0	3
	Arauco	37°15′		1 493				3
	Angol	37°48′	72	1 140	19.2	7.8	13.0	4
Closed forest	Temuco	38°45′	111	1 345	17.0	7.8	12.0	2
	Osorno	40°35′	1	1 330	17.6	7.1	11.2	2

E. camaldulensis, E. gomphocephala, E. longifolia, E. maculata, E. obliqua, E. paniculata, E. pilularis, E. ovata, E. resinifera, E. sideroxylon, E. regnans, E. tereticornis, E. robusta, E. smithii and *E. viminalis.*

Chile has a wide range of successful trials on which to base future development work. The remarkable success of *E. globulus* over such a wide range of climates may be due to the fact that the Andes trap the prevailing westerly winds and improve humidity (Pryor, 1965).

China

China occupies the eastern part of continental Asia, with a latitudinal range from about 53° to about 18°N.

In 1977 an FAO study tour on forestry support for agriculture studied plantation forestry in several provinces of China. The only province where eucalypt plantations were examined was Kwantong province, of which the peninsula of Leichow and the island of Hainan are part. It has a range of latitude from 18°-25°N. About 52 000 ha of eucalypts had been planted there. More than 60 species were tried, but only three are used in large-scale plantations: *E. exserta, E. citriodora* and a local land-race called "Leichow No. 1." Other species such as *E. tereticornis, E. grandis* and *E. saligna* grow well in diameter but are not as straight as the three main planting species. The plantations are managed under a 25-year rotation with thinnings at 5, 7 and 10 or 12 years. The overall MAI is given as up to 15.75 m^3/ha/year. The leaves are first distilled for eucalyptus oil, then for tannins; the residue is buried in trenches to improve soil organic matter. *E. exserta* gives 0.7 percent oil, and *E. citriodora* 1.2 to 1.7 percent. The tannin content is generally eight times higher than the oil content.

Several eucalypts have been successfully established in Taiwan province (latitude 22°-25°N) including *E. deglupta, E. citriodora, E. robusta, E. tereticornis, E. microcorys* and *E. camaldulensis* (Pryor, 1967).

North of the Tropic of Cancer, some of the more frost-resistant eucalypts would be suitable for planting in coastal areas up to about 30°N. North of that, periodic severe freezes limit eucalypt planting.

Colombia

The Republic of Colombia lies in the extreme northwest of South America, having a coastline on both the Atlantic and Pacific oceans. It has a latitudinal range of 4°13'S to 12°30'N, and the range of elevation is from sea-level to about 5 700 m.

Colombia has experimented with several species of eucalypts, the main ones being *E. camaldulensis, E. tereticornis, E. citriodora* and *E. globulus.*

The plantations are established for roundwood, pulpwood, posts, mine-timbers, firewood and essential oils (from *E. globulus*). Plantation practice varies with the very wide range of climates experienced, varying from equatorial coastal climates with a rainfall as low as 260 mm to higher zones with high rainfalls exceeding 2 000 mm. There is a very wide range of soils. Practice has been carefully worked out to suit each climatic zone.

The total area planted to the end of 1973 was about 13 800 ha, largely *E. globulus* and *E. camaldulensis*. The rate of new planting then planned was 2 500 ha a year. With such a great range of altitude, Colombia has been divided into five planting zones (see Table 4.6).

In former times zones A, C, D and E were covered by forest which was cut for conversion to pasture. Zone B is the natural savanna.

Nursery practices for large-scale reforestation

Seeding

In the warm climate seed is broadcast-sown in germination frames 2.4 m long, 1.0 m wide and 0.3 m deep. Seed is sown from January to July; transplanting to bags is about 30 days later. In the cold climate seed is sown in germination beds 1.0 m wide of variable length. Seed is sown in January, February, June and July, with transplanting 45 days later. In both climates when the seedlings are 5.0 cm tall they are transplanted to

Table 4.6 Planting zones of Colombia

Zone [1]	Climate	Annual rainfall (mm)	No. of rainy days	Maximum temperature (°C)	Minimum temperature (°C)	Terrain and soils
A	Cold tropical	1 049	—	21.5	2.4	Plains and broken sloping terrain with deep fertile loamy soils of acid reaction. Some hardpan occurs.
B	Hot humid tropical	2 180	164	36.7	20.5	Plain soils of clay loam. Acid reaction and low fertility. Depth limited by hardpan.
C	Very dry tropical	260	45	37.7	28.1	Red gravelly soils of silty clay to 50 cm in depth. Low fertility and slopes of 50 percent.
D	Humid tropical	2 217	154	32.0	8.0	Reddish brown soils to 50 cm depth from weathered granite. Low fertility.
E	Dry tropical	900	—	37.0	16.0	Reddish yellow deep silty clay soils of marine or estuary origin. pH 7.5.

[1] Representative stations: A. **Vitelma**. Latitude 4°34'N. Altitude 2 700 m. — B. **Ayapel**. Latitude 8°20'N. Altitude 50 m. — C. **San Pedro Alezandrino**. Latitude 11°13'N. Altitude 100 m. — D. **Pueblo Bello**. Latitude 10°25'N. Altitude 1 100 m. — E. **El Limón**. Latitude 10°24'N. Altitude 150 m.

polythene bags of 9 × 15-cm dimension. Sifted organic fertilizer is generally used; or a complete (NPK) mineral fertilizer.

Shade

In the warm climate, agave (*Foucrea cabuya*) fibre nets are used for protection against rain; the nets are strong, with zinc frames. These are used both for germination and transplant areas. Shade is not used in the cold climate.

Irrigation

In the warm climate, infiltration irrigation is used during germination; watering is with a backpack sprayer. Plants transplanted to plastic bags are watered with special equipment for this purpose. In the cold climate, germination beds are watered using watering cans; for the remaining period the plants are in the nursery, both watering cans and sprinklers with hoses are used.

Disinfection and insect control

Germination areas are customarily disinfected with methyl bromide or a compound based on formaldehyde. Control of insects in nurseries is achieved with chlorate and phosphate products; fungal diseases with copper and manganese products. Weeding is done by hand.

Planting out

In the warm climate, planting out is done when plants are 0.25 to 0.35 m tall and of an age of 90-120 days. In the cold climate, planting out is done when the plants are 0.20 to 0.30 m tall and of an age of 90-120 days.

PROMISING SPECIES AND PROVENANCES

E. viminalis does not grow as well as *E. globulus* in Zone A.

E. tereticornis, Australian provenance, grows well in Zone E; at age 6 the height is 16 m and diameter 18 cm.

E. camaldulensis of provenance No. 9 from Spain gave a survival of 100% in Zone E at age 6, a good form and a height of 12.4 m and a diameter of 11 cm.

E. camaldulensis of provenance 8218-1 from Australia gave 100% survival in Zone E at age 6 but the form, although good, was inferior to the Spanish provenance. The height was 11 m and the diameter 10 cm.

E. citriodora in Zone B showed severe gummosis problems.

Comoro Islands

Comoro Islands lie between Madagascar and mainland Africa at a latitude of about 12°S. The climate is tropical and moist with rain falling in the warm months. The soils are derived from volcanic rocks.

Eucalypts have been planted mainly on degraded savanna or on laterites. A total of 638 ha of eucalypt plantations had been established by 1973, mainly *E. robusta, E. citriodora* and *E. camaldulensis*, at altitudes of between 300 and 700 m. The eucalypts are growing vigorously.

Congo The People's Republic of the Congo has a latitudinal range of 0° to 13°S. It is an equatorial country with an annual rainfall of 1 200-1 600 mm, falling on 100-120 days in the main localities where eucalypts are planted, namely Loudima, Pointe-Noire and PK 45 (Brazzaville). The altitude of these districts is 80-700 m, and their latitude between 4° and 5°S. The mean maximum temperature of the hottest month (March or April) is 26-27°C and the mean minimum of the coldest month (July) 21-22°C. The soils at Loudima are rather poor clays with a pH of 4.7-5; at Pointe-Noire the soils are poor sands; at PK 45 also poor sands but rich in organic matter.

The Congo had planted 5 500 ha of various eucalypts by the end of 1973, mainly at Loudima to provide the townships of Pointe-Noire and Brazzaville with household fuel. Of the total area, 3 500 ha were planted with provenance 12ABL of *E. tereticornis* from Madagascar. Provenances of this species from Queensland and New Guinea promise a superior performance.

Plantation practice is normally one seedling crop followed by two coppice crops, all of 5-7 years. At age 6 the poorer soils of Pointe-Noire give a yield of 12 m^3/ha/year and the clays of Loudima about 22 m^3/ha/year.

Regeneration from the coppice stumps is excellent (99%) and of good vigour. The main defect of provenance 12ABL is that it does not shade the soil well. It makes a good fuel with a mean calorific value of 19 700 kilojoules (4 700 kcal) per kg of dry wood. It makes a good charcoal, but is too high in phosphorus content for metallurgical purposes.

The Congo has a hybrid introduced from Java which was called *E. platyphylla*, locally called *Eucalyptus PFI*. Believed to be a hybrid between *E. urophylla* and *E. alba*, it grows best on the good soils of Loudima. It produces 17-20 m^3/ha/year at Pointe-Noire and 32-35 m^3/ha/year at Loudima. The form is excellent and the cover better than 12ABL.

E. deglupta grows well on the good soils of Loudima but at present using this species in industrial plantations is not envisaged.

Research in the Congo aims at the genetical improvement of eucalypts. Fundamental studies have been made on the vegetative reproduction of eucalypts to determine the optimum conditions for the rooting of cuttings to enable the reproduction on a large scale of "plus" trees (Chaperon, 1977).

Costa Rica The Republic of Costa Rica extends across southern Central America between 8°17′ and 11°10′N. The coastal areas have a near equatorial climate but the interior plateau with an altitude of around 1 500 m is temperate. Seed of *E. deglupta* was first imported in 1965 from Garoka, Papua New Guinea, together with *E. grandis, E. saligna* and *E. alba*. Trials commenced in 1968, near Turrialba, on deep clay loam soils of volcanic origin. Annual rainfall is 2 700 mm. Mean annual temperature is 22°C and relative humidity 88 percent. *E. deglupta* is the most successful species with a mean annual increment ranging from 19-32 m^3/ha/year. Thinning is required between 9 months and 2 years after planting. Transmission poles are produced after six years and sawlogs between 12 and 15 years. *E. camaldulensis* and *E. citriodora* show promise in areas with a well-pronounced dry season between 1 200 and 1 600 m; *E. globulus* seems to be the best species at higher elevations. In areas with higher rainfall and no dry spells, *E. grandis, E. saligna, E. maculata* and *E. robusta* are well adapted, especially at altitudes above 1 000 m.

There is a considerable demand by farmers for eucalypt seedlings, and small woodlots are scattered throughout the country.

Cuba

The Republic of Cuba, the largest of the islands of the Caribbean Sea, lies between latitudes 20°N and 23°N.

Cuba is planting eucalypts for farm purposes, fuelwood, posts, preserved poles and possibly other purposes. A plantation area of 50 000 ha is planned of which 36 000 ha were established by 1973.

Nursery work and plantation establishment are within the range described in Chapter 5. The rotation aimed at is 12 years.

More than 90 species of eucalypts have been tried out since 1972. The main species being used in substantial planting are *E. saligna, E. alba* (*E. urophylla* hybrid), *E. citriodora, E. tereticornis, E. maculata, E. grandis* and *E. deglupta.*

Cyprus

Cyprus is an island in the Mediterranean Sea lying at latitude 35°N. It has an extreme Mediterranean climate with a hot, dry summer and a variable warm winter. There is an extensive igneous massif rising to 2 000 m in the west of the island and a narrow limestone range of mountains with an altitude of up to 600 m in the north.

Cyprus has been interested in planting eucalypts for swamp drainage, fuelwood, posts and poles, parquet flooring, windbreaks and essential oils from the leaves of certain species.

The soils of Cyprus are rendzinas and terra rossas from limestones, red, red-brown, grey, and grey-brown soils from igneous rocks and sands, lithosols and salines from windblown or sea-borne deposits. Most eucalypt plantings are on poor soils and mechanical methods are used to rip and prepare sites.

The principal species used are *E. camaldulensis* and *E. gomphocephala.* A total area of 2 000 ha had been planted by 1973. The rotations used are 10-15 years for the first seedling crop and 7-8 years for succeeding coppice rotations. The main pest is *Phoracantha semipunctata* on *E. gomphocephala.*

Dominican Republic

The Dominican Republic occupies the eastern two thirds of Hispaniola Island in the West Indies, at latitude 18°-20°N. The climate is tropical in the lowlands and semi-tropical to temperate in the higher altitudes. The Republic does not have formal plantations of eucalypts. There are many specimens of *E. globulus* and *E. robusta* and further trials are being made.

Ecuador Ecuador is an equatorial country on the western coast of South America extending from latitude 1°38′N to 4°50′S. The country rises from sea-level to a fertile elevated plateau and then on to some of the high peaks of the Andes, the highest in Ecuador being the volcano, Chimborazo, at 6 272 m.

The main eucalypt species planted is *E. globulus*, first introduced in 1865 and widely planted on the central plateau between altitudes of 1 800 and 3 300 m. Best growth occurs in localities between 2 000 and 2 900 m where the annual rainfall is 1 000-2 000 mm, corresponding to Holdridge's designation, "Lower montane wet forest" zone (Holdridge, 1967). Other eucalypt plantings are done in the "Lower montane dry forest" zone with a rainfall of 500-1 000 mm. The principal eucalypts grown other than *E. globulus* are *E. saligna, E. camaldulensis* and a little *E. robusta*, but trials are also being made with the following species (Ecuador, 1973):

E. botryoides, E. paniculata, E. citriodora, E. propinqua, E. grandis, E. resinifera, E. maculata, E. tereticornis, E. microcorys and *E. umbra.*

A total of 17 716 ha of eucalypts had been planted to 1975. About half of these were established by the national forest service; the remainder are private plantations. The wood is used for fuel, posts, poles, mine-timbers and sawnwood. The main concentration of plantations is between Quito and Lacatunga, but the plantations are spread over the provinces of Azuay, Bolivar, Cañar, Carchi, Cotopaxi, Chimborazo, Imbabura, Loja, Pichincha and Tungurahua. The soils are of volcanic origin and are fertile.

In 1976 the Government of Ecuador produced the *Inventario de áreas forestadas en el Ecuador* (Narvaez, 1976). This inventory covered all plantation species, eucalypts, pines and others. The inventory gives the plantation areas by number of plantations, species and plantation ages for each parish, canton and province. Tables 4.7 and 4.8 summarize some of the data.

Tables 4.7 and 4.8 show how an important eucalypt asset can be built up by very small, small, medium and larger-sized plantations. The wide spread of the plantations over the country means that the distances over which timber products must be transported are not great.

Egypt Egypt lies between latitudes 22°N and 32°N. Much of it is desert and the main plantings of eucalypts are in towns and along irrigation channels from the Nile. The climate is hot and dry. The principal species grown are *E. camaldulensis* and *E. microtheca.* These species are used for shade, fuelwood or construction timbers and poles. There are many hundreds of kilometres of line plantings but an area and yield have not been placed on them.

El Salvador The Republic of El Salvador extends along the Pacific coast of Central America between latitudes 13°N and 14°N. The country is very moun-

Table 4.7 Areas of plantation of different eucalypt species in Ecuador

Species	Area planted (ha)	Percent of total
E. globulus (seedling crops)	12 899	73
E. globulus (coppice crops)	4 506	25
E. saligna	156	1
E. camaldulensis	132	1
E. robusta	5	—
Other eucalypts	18	—
Total	17 716	100

tainous, with many extinct volcanoes. The climate is moist tropical on the coast but more temperate inland.

Eucalypts were first introduced in 1953 and several species have been planted. Growth is vigorous in the fertile soils. *E. deglupta, E. alba, E. citriodora* and *E. longifolia* are the species most planted.

Ethiopia

Ethiopia lies between 3.5° and 18°N in East Africa. It is mountainous; the northern coastal area and the lower slopes toward Somalia are very dry, but the elevated interior is much more moist. The highest mountain rises to about 4 600 m and in this area there is occasional snow.

Table 4.8 Size, number, area and age of eucalypt plantations in Ecuador

E. globulus coppice crops		Other plantations (additional to **E. globulus** coppice)		**E. globulus** seedling crops		**E. globulus** coppice	
Size (ha)	Number	Size (ha)	Number	Age	Area (ha)	Age	Area (ha)
Under 5	280	Under 5	883	Under 5	4 362	Under 3	1 342
6-20	115	6-20	399	6-10	5 266	4-6	1 621
21-50	30	21-50	95	11-15	290	7-9	1 159
51-100	9	51-100	33	16-20	666	10-12	363
Over 100	5	Over 100	5	20+	96	12+	21
	439		1 415		10 680		4 506

Eucalypts are important in Ethiopia, where they are used for fuelwood, building poles, transmission poles, fenceposts, sawnwood for boxes and crates, fibreboard and particle board. They are also used for shelterbelts and soil conservation.

The total area planted up to the end of 1973 was 42 300 ha of which 40 000 ha were private woodlots and 2 300 ha government plantations. Planned extensions of government plantations were at the rate of 1 770 hectares annually. Private plantings are erratic. Regions where eucalypts are planted may be divided into four climatic zones, shown in Table 4.9.

Main soil types are:

(*a*) Reddish brown clay and clay-loam ferrisols derived from volcanic rocks; drainage fair.

(*b*) Black or dark brown clays and clay-loams derived from volcanic rocks; drainage poor.

(*c*) Soils of light to medium texture derived from basement complex rocks such as schist, granite and diorite; drainage fair to good.

Planting has also taken place to a very limited extent on localized calcareous soils derived from limestone. The natural vegetation on planting sites is usually degraded forest regrowth or montane grassland; occasionally evergreen thicket formations; rarely wooded grassland.

The usage of available land, private or government-owned, to make eucalypt plantations to improve the situation of the local population in Ethiopia is an excellent example of good land use. The highlands are cold, and natural fuelwood very scarce. The use of eucalypts was suggested to the Emperor Menelik II in 1895 by a French railway engineer, M. Mondon-Vidaillet, who was studying Ethiopian languages as a hobby. He suggested an interesting and sensible list for trial (Breitenbach, 1961). It was very soon apparent that *E. globulus* did best, no doubt because hungry cattle and sheep will not eat the glaucous juvenile leaves. This then became the main species used and approximately 30 000 hectares of it have been planted, mainly in the moister regions. *E. camaldulensis* grows well over a wide range of soils in a rainfall varying from 550 to 2 200 mm. *E. clado-*

Table 4.9 Planting zones of Ethiopia

Zone	Elevation (m)	Mean annual rainfall (mm)
Moist montane	1 750-3 000	1 000-2 000 +
Dry montane	1 750-3 000	450-1 000
Moist highland	1 000-1 750	1 000-1 800
Dry highland	1 000-1 750	600-1 000

calyx makes an interesting tree over plantings of cactus spp. near Asmara. Plots of *E. grandis* and *E. saligna* were planted near Addis Ababa about 1959 and grew better than *E. globulus* when fenced and protected from cattle and sheep.

Fiji

Fiji consists of a group of 322 islands in the southwest Pacific Ocean, over a wide range of latitude: 15°51′S to 21°10′S. The climate is tropical and moist and the soils largely volcanic and good.

No major plantings of eucalypts have been made in Fiji because of uncertainty about their timber potential, but a wide series of trials is now proceeding and *E. deglupta* is one of the species favoured as a replacement for mahogany (*Swietenia macrophylla*) in forest service plantations.

France

France has played an important part in developing knowledge about eucalypts, in their culture as plantation and ornamental trees and in their spread around the globe. The French botanist L'Héritier gave the genus its name the year before the French Revolution. Two French botanists, De Candolle, father and son, were active in the study of the growth habits of the genus and in the naming of certain species early in the nineteenth century. Countries in which French foresters were active have become important planting countries. A French forester, M. André Métro, prepared the draft of the first edition of this book.

Most of France experiences occasional cold periods which kill eucalypts but the nation has many fine specimens in its warmer parts and still supervises many international trials with provenances of promising species. At the second World *Eucalyptus* Conference, France was credited with 1 130 ha of plantations. The greatest area of French eucalypt plantations is in Corsica, where *E. globulus* and *E. viminalis* have given the best results (Degos, 1962).

The establishment of commercial plantations on the mainland of France is limited by the severe frosts of the order of —15°C every 4 or 5 years and the prevalence of calcareous soils which do not suit most eucalypts. Experiments on various species to determine the types of soil and the lowest temperatures they can tolerate have been carried out (see Table 4.10).

France is experimenting with provenances of *E. dalrympleana* and with the selection of individuals, to establish a seed orchard aiming at providing seed which will give good tolerance to severe cold and less spiral grain (see Chapter 13).

Ghana

Ghana is situated on the Gulf of Guinea in Africa between latitudes 4°45′N and 11°11′N. Eucalypts are being introduced to Ghana's afforestation programme to provide transmission poles, pulpwood and fuelwood. The total area planted to the end of 1973 was approximately 900 ha, 75 percent in the drier savanna zone in the north and 25 percent in the forest zone in the south. The southern portion has a high rainfall up to 2 000 mm and supports a luxuriant moist tropical forest. The savanna section has a rainfall down to 750 mm. The soils of the forest zone are red to yellow-brown, relatively

Table 4.10 Resistance of eucalypt species to cold and to adverse soil conditions (France)

Species	Soil tolerated	Minimum temperature tolerated	Growth in height	Comments
E. dalrympleana	Not calcareous	—15°C	15 years - 16 m	Very straight boles; good self-pruning; frequent spiral grain; poor soil cover
E. rubida	Not calcareous	—15°C	15 years - 16 m	"
E. macarthurii	Not calcareous	—17°C	15 years - 10 m	Self-pruning; moderate large crowns; good control of ground vegetation
E. gunnii	Tolerates calcareous soils well	—17°C	15 years - 8 m	These species are resistant to severe cold but give a product of low value
E. stellulata	Does not tolerate calcareous soils	—17°C	15 years - 8 m	
E. pauciflora	"	—17°C	15 years - 8 m	

well-drained and overlain by a layer of decomposing leaf litter. The soils are described as forest ochrosols. The plantations in the savanna belt are on tropical black earths and dark grey clays which are heavy and plastic when wet and hard and cracked when dry, and likely to be deficient in nitrogen.

Nursery practice comes within the ranges described in Chapter 5.

E. tereticornis has been planted in both savanna and moist forest. Its initial growth is better in the moist zone and poor on the heavy black savanna soils. Termites are a problem. The growth of *E. alba* has been slower than that of *E. tereticornis*. A hybrid "*E.* hybrid *cadambae*" is growing better than *E. tereticornis* in the savanna zone. Of other species tried *E. deglupta* shows promise for poles in the moist zone. *E. camaldulensis, E. maculata* and *E. grandis* also show promise as poles. Failures are *E. robusta* and *E. polycarpa*, the latter growing well but being attacked by termites which eat into it and make it liable to windthrow. This is interesting because *E. polycarpa* is also attacked by termites in Australia.

Greece

Greece is a Mediterranean country in latitudes 34° to 42°N. The climate is rather extreme Mediterranean, with hot summers and variable winters. The mainland is rugged, with mountains rising to 2 917 m.

Greece has experimented with eucalypts for use as windbreaks, shelter trees and ornamentals. The main species found successful are *E. camaldulensis*, *E. dalrympleana, E. viminalis* and *E. gunnii.* Good form has been shown by *E. saligna, E. cladocalyx, E. botryoides* and *E. gomphocephala. E. torquata* has been used as an ornamental.

The area of government plantations is 100 ha, but numerous plantations have also been established on private land.

Guyana

Guyana is situated on the northeast coast of South America between latitudes 1°N and 9°N. There are two dry seasons, one from the middle of February to the end of April, and the second from the middle of August to the end of November. The yearly rainfall is subject to wide variation, from 2 300 mm on the coast to 1 500 mm in the savanna.

Eucalypt plantings are very much in the trial stage but it is hoped they may prove suitable for large-scale reforestation in areas cleared for wood pulp. Soils are deep sands with good drainage but low fertility.

Species being experimented with are *E. saligna, E. camaldulensis, E. tereticornis, E. citriodora* and *E. deglupta.* Total plantings in 1973 were only 2 hectares.

Honduras

The Republic of Honduras lies between latitudes 13°N and 16°30′N in Central America. About 300 ha of eucalypt plantations were planted between 1964 and 1972 in central Honduras (Troensegaard, Stolz and Lainez Calderón, 1973), where there is a seasonal rainfall pattern, the wet season being from May to October and the dry season from November to April.

Of the species tried the most promising have been *E. robusta* and *E. grandis,* of Brazilian seed origin, and *E. grandis,* of Australian seed origin; the first two are thought to contain some genes from other species. Yields from 7 to 45 m^3/ha/yr at ages 7.5 to 8.5 have been obtained in the trials, and an average mean annual increment (MAI) of 16 m^3 or more could be expected if large-scale planting were to be done.

Hong Kong

Hong Kong consists of a number of islands and a portion of the mainland on the southeastern coast of China at the mouth of the Pearl river between latitudes 22°9′N and 22°37′N.

The administration in Hong Kong have made a number of trials with eucalypts, essentially for environmental purposes including the revegetation of denuded water catchments. Species such as *E. pilularis, E. grandis, E. tereticornis* and *E. robusta* grow well.

India

India occupies the south central peninsula or subcontinent of the Asian continent. The latitudinal range is from 8°N to 36°N, the Tropic of Cancer crossing the country about midway. Longitudinal range is from 68°E to 98°E. There are three main physical divisions: the high peaks and steep slopes of the Himalaya mountains in the north; the fertile alluvium of the great plains of northern India; and the southern plateau of peninsular India, 300-900 m in altitude and flanked by narrow coastal strips.

Because of the huge size of the country and the great variations in topography, India presents a wide range of climatic conditions, both in rainfall

Table 4.11 Climatic data for some representative planting areas in India

Station	Latitude (N)	Longitude (E)	Altitude (m)	Temperature (°C)			
				Hottest		Coldest	
				Month	Mean temperature	Month	Mean temperature
Bangalore	12°58′	77°35′	920	April	27.2	December	20.6
Jagdalpur	19°05′	82°02′	553	May	31.4	December	19.3
Jodhpur	26°18′	73°01′	224	June	39.2	January	17.0
Midnapore	22°25′	87°19′	45	May	32.2	January	20.0
Ootacamund	1°24′	76°44′	2 250	May	16.5	January	12.5

Monthly rainfall (in millimetres)

	J	F	M	A	M	Jn	Jl	A	S	O	N	D	Total
Bangalore	7	9	11	45	107	71	111	137	164	153	61	13	889
Jagdalpur	5	15	17	51	66	212	398	381	246	116	24	4	1 535
Jodhpur	7	5	2	2	6	31	122	146	47	7	3	2	380
Midnapore	14	30	34	44	109	232	322	336	262	132	36	3	1 554
Ootacamund	35	13	33	86	159	156	201	147	139	202	158	49	1 378

and in temperature. The annual cycle of seasons is dominated by the monsoons, but the amount of rainfall in a given area is largely governed by the land relief, especially by the Himalayas. Table 4.11 gives climatic data representative of some of the areas where eucalypts have been planted on a large scale or are under trial.

The first introduction of eucalypts was in 1790, when a number of species were planted in the palace garden at Nandi Hills near Mysore. Regular trials were started in 1843 when Captain Cotton of the Madras Engineers successfully introduced *Eucalyptus globulus* at Wellington in the Nilgiri hills. The oldest surviving stand of this species was planted in 1863 and is maintained as a preservation plot. The tallest tree in the plot measured 76 m at age 90 and the thickest tree was 1.8 m in diameter.

Among all the species so far tried in India, the Nandi provenance of *Eucalyptus tereticornis*, popularly known as Mysore hybrid or Mysore gum, has been the most widely used species for raising plantations in the denuded and barren areas and also for replacing low-value natural crops. The species was first raised on a plantation scale in Karnataka state in 1952. Extensive plantations followed to meet the needs of fuelwood, small timber and pulpwood. In Punjab and Haryana, where the area under forests is negligible, *E. tereticornis* has been planted in strips 3-6 rows deep along important highways, canals and railways. It is estimated that up to 1974 this species had been planted over an area of about 415 000 ha, as detailed below:

	Region	State	Hectares
1.	Northeastern	Arunachal Pradesh	41
2.	Northeastern	Nagaland	1 800 (up to 1969)
3.	Northeastern	Tripura	178
4.	Northeastern	West Bengal	21 900 (up to 1972)
5.	Northern	Bihar	15 782
6.	Northern	Uttar Pradesh	70 853
7.	Northern	Haryana	5 026 (up to 1971)
8.	Northern	Punjab	10 684
9.	Northern	Himachal Pradesh	14 000 (up to 1969)
10.	Central	Madhya Pradesh	43 855
11.	Western	Gujarat	30 524
12.	Western	Maharashtra	19 231 (up to 1971)
13.	Southeastern	Orissa	14 800 (up to 1969)
14.	Southern	Andhra Pradesh	6 782
15.	Southern	Karnataka (Mysore)	129 034
16.	Southern	Goa	4 815
17.	Southern	Tamil Nadu	18 300 (up to 1972)
18.	Southern	Kerala	7 233
			414 838 Total

In addition to *E. tereticornis*, other eucalypts which are of particular importance in India are *E. globulus, E. grandis* and *E. camaldulensis*. Regular plantations of *E. globulus* were planted in the Nilgiris and the Palni hills of Tamil Nadu (altitude 2 000-2 500 m) and about 9 000 ha had been planted up to 1972. This species is a very rapid grower and is considered to be the fastest growing tree in India. It has excellent coppicing power and can regenerate itself by coppice for 4 rotations of 15 years each, after which this power dwindles considerably.

E. grandis was first introduced in Kerala state in 1948. Initially raised mainly for firewood, it was grown at altitudes varying from 800 to 1 800 m. Subsequently it was also found useful for pulp and was planted in several states. Up to 1971 about 24 100 ha in Kerala and 1 800 ha in Tamil Nadu had been planted with this species. In Karnataka also some plantations were raised in the hills of Coorg.

E. camaldulensis has proved useful for afforesting semi-arid tracts and many of its provenances are currently under trial. *E. tessellaris, E. terminalis* (syn. *E. polycarpa*) and *E. melanophloia* have been tried in the Rajasthan desert area and have shown satisfactory performance.

Both container plants and naked-root plants are used for planting. In both cases seed is sown into drills in raised seed beds 10 m × 1 m × 10 cm. Date of sowing depends on the size of plant which will be required for planting in the field in June-July. If tall plants are required (e.g., for planting roadside strips) sowing is done in September-October, after the monsoon rains have ceased (9 months in nursery). If tall plants are not required, sowing is done at the end of the winter season in February-March (4 months in nursery). About 200 g of seed are sown per bed and yield 12 000 to 15 000 seedlings. Pricking out is done 4 to 6 weeks after germination, when the seedlings are 5-10 cm tall. For container plants, polythene bags of 150 gauge are used, the usual size being 20-25 cm × 10-15 cm. For raising naked-root plants, seedlings are pricked out into transplant beds at 10 × 10 cm spacing.

Plants are normally 50-60 cm tall at the time of planting in the field. Spacing varies. In taungya plantations it is usually 4 × 2 m, to allow easy cultivation of the interspace for agricultural crops during the first three years. Elsewhere spacing is normally 2 × 2 m. In dry areas planting is done alongside or in contour trenches dug to conserve moisture.

Vegetative propagation by rooting lignotuberous tissue, branch cuttings from young trees and epicormic shoots from older trees has been carried out successfully in *E. tereticornis* and *E. camaldulensis*. Two promising hybrids between the same two species, FRI 4 and FRI 5, have been produced. At age 4 they have produced nearly three times the volume of *E. tereticornis*. Hybrids between *E. grandis* and *E. tereticornis* have also been developed. More details of the work in vegetative propagation and hybridization may be found in Chapter 7.

E. globulus on suitable sites is the highest yielding species in India. The overbark MAI at 15 years is 30.3 m^3 solid (48.5 stacked) for Quality 1 sites, 22.4 m^3 solid (35.9 stacked) for Quality 2, and 14.6 m^3 solid (23.3 stacked) for Quality 3. Areas planted with *E. globulus* are allowed to regenerate by coppice for 4 rotations of 15 years each, after which the area is replanted with fresh seedlings. This is due to the fact that, at successive fellings, the yield of fuel decreases progressively. This may be due partly to the death of some stumps and partly to the loss of vigour in the stools due to repeated cutting. The fall in yield is estimated to be roughly 9 percent in the third coppice rotation and 20 percent in the fourth and final rotation.

Volume yields for the most widely planted species, *E. tereticornis*, reveal very big differences even within a single state, due to the wide variations in site quality and stocking. For example, in Tamil Nadu the best stands have an overbark MAI of 40 m^3 at age 8, the poorest a little over 2 m^3. In Kerala, overbark MAI for *E. grandis* varies from 47 m^3 in the best stands to less than 4 m^3 in the poorest. Volume tables have been published for both *E. tereticornis* (Chaturvedi, 1973) and *E. grandis* (Chaturvedi and Pande, 1973; Pande and Jain, 1976).

Preliminary studies carried out over a period of 10 months at the Forest Research Institute on evapotranspiration of different forest species in the juvenile stage have shown that *E. citriodora, Dalbergia latifolia, Pinus roxburghii* and *Populus* 'Casale' seedlings between ages of 6-16, 12-22 and 5-17 months used respectively 5 526, 1 143, 936 and 2 704 mm of water. Though the consumption of water by *E. citriodora* was higher, water consumed per unit gram of total dry matter produced was least for *E. citriodora*, i.e., 1.41 mm per gram of dry matter as against 2.59 mm for *Dalbergia latifolia*, 3.04 mm for *Populus* 'Casale' and 8.87 mm for *Pinus roxburghii*.

Investigations on interception of rainfall by eight-year-old *E. tereticornis* standing at 1 660 stems/ha showed that 11.5 percent of rainfall was intercepted, compared with 88.5 percent which reached the soil by throughfall (80.8 percent) or stemflow (7.7 percent). Interception by three indigenous species (*Shorea robusta, Alstonia scholaris* and *Pinus roxburghii*) varied from 22 to 26 percent.

The most serious pathogen is the fungus *Corticium salmonicolor* which girdles the branches and stems of young *E. tereticornis, E. grandis, E. globulus* and *E. citriodora* in conditions of high rainfall and high temperature in Kerala, Goa and Karnataka. *E. torelliana* exhibits some degree of resistance.

The fungi *Cylindrocladium scoparium* and *C. quinqueseptatum* cause seedling blight, leading to mortality, in nursery stock and young outplantings during the wet season. Root rot caused by *Ganoderma lucidum* has caused casualties in a number of species. Chlorosis has occurred in *E. tereticornis* plantations in Uttar Pradesh, planted on highly calcareous soils with a pH of 8.6.

Main uses for eucalypts in India

Fuelwood and charcoal. Mainly *E. tereticornis, E. camaldulensis, E. globulus, E. grandis, E. saligna.* An eight-year coppice rotation is suitable.

Pulpwood. The aim of most eucalypt plantations in India is pulpwood production. In addition to the species listed under fuelwood, *E. torelliana, E. deglupta, E. viminalis* and *E. citriodora* are considered suitable. Rotation 8-10 years. The new Kerala Newsprint Mill will use cold soda pulp from *E. grandis* and *E. tereticornis* mixed with chemical pulp from *Ochlanda* reeds.

Essential oils. The most important species is *E. globulus*, the oil of which contains 62 percent cineole. For details see species monographs (Chapter 14). Oil is also distilled on a small scale from *E. citriodora* and contains 65-80 percent citronellal. Research is in progress to study the possibilities of extracting oil from the more widely planted *E. tereticornis* and *E. camaldulensis* and of propagating two cineole-rich specimens of these species or their hybrids discovered at Bangalore.

Oxalic acid. A process for the extraction of oxalic acid from the bark of Mysore gum has been developed in the Forest Research Laboratory, Bangalore. Oxidation is carried out by nitric acid in the presence of Vanadium pentoxide which acts as a catalyst. A 42 to 45 percent yield of oxalic acid has been obtained.

As host plant

Eucalypts have been used as a host plant for sandalwood (*Santalum album*). There is some evidence that eucalypts reduce the incidence of spike disease on sandalwood, in comparison with other host species, by reducing the amount of ground vegetation in which breed the leaf-hopper insects transmitting the spike disease.

In addition to those mentioned above, numerous other species have been tested. Those which have given promising results include, for higher altitudes: *E. amygdalina, E. dalrympleana, "E. elaeophora",*[1] *E. eugenioides, E. fastigata, E. gunnii, E. leucoxylon, E. paniculata, E. pilularis, E. regnans.* For lower or medium altitudes the following have proved useful: *E. crebra, E. drepanophylla, E. gomphocephala, "E. hemiphloia",*[2] *E. intermedia, "E. kirtoniana",*[3] *E. maculata, E. marginata, E. melliodora, E. microcorys, E. microtheca, E. obliqua, E. paniculata, E. polyanthemos, E. propinqua, E. resinifera, E. robusta, E. rudis, E. sideroxylon, E. tessellaris.*

Indonesia The Republic of Indonesia covers a very large archipelago. The complex of islands covers a wide area of ocean and the land area is nearly 2 000 000 km^2 in extent, entirely within the tropics and extending from latitude 6°N to 11°S. The rainfall is adequate to very high, the soils frequently volcanic and rich, but sometimes poor. Much of the uncultivated parts is clothed with rain forest, mainly dipterocarps.

Indonesia is the home of at least three species of eucalypts. *E. deglupta* follows the chain of volcanoes from New Britain in Papua New Guinea, along Indonesia to Sulawesi and then north to Mindanao in the Philippines. It is the only equatorial eucalypt and flourishes in low latitudes when the rainfall is very high (preferably 2 000 mm) and the dry months are few. *E. urophylla,* a most promising eucalypt for low latitudes, occurs naturally only in Timor and islands close to it. *E. alba* is not as good a species as the other two but grows to quite a useful tree on the southern coast of Timor and covers the landscape in many drier places in eastern Indonesia and New Guinea.

Indonesia is preparing projects to see if *E. deglupta* might make an acceptable quick-growing replacement for some of the rain-forest species it is

---

[1] Regarded as a synonym for *E. goniocalyx* by Pryor and Johnson 1971. — [2] Regarded as a synonym for *E. moluccana* by Pryor and Johnson 1971. — [3] Regarded as of hybrid origin by Pryor and Johnson 1971.

felling in concessions. Between 1937 and 1940 trials were made of 48 species of eucalypts. From these and other tests, *E. alba, E. paniculata, E. grandis, E. saligna, E. citriodora* and *E. tereticornis* are recommended for larger-scale planting. These eucalypts thrive in the drier parts of the islands. *E. deglupta* thrives in higher-rainfall country.

Iran

Iran is situated on the northeastern side of the Persian Gulf, between the Gulf and the Caspian Sea. The range of latitude is 25°-40°N. The country has a varied topography and climate, the central and eastern part being dry to arid, the northern part hilly to mountainous, with much forest and some arid steppes. Near the Caspian Sea, which is below mean sea-level, the soil is rich and the rainfall is 2 000 mm. The Caspian area would grow many eucalypts but poplars are likely to be the principal plantation trees.

In the south of the country, where eucalypts could be very valuable in providing fuel and other forest products, the rainfall varies from 200 mm to more than 1 300 mm. Part of this area is too cold for the genus, but there are many places where certain species grow healthily. Species which show promise include *E. microtheca, E. sideroxylon, E. intertexta, E. rudis, E. striaticalyx, E. le soueffii, E. occidentalis,* and a western Australian (Wiluna) provenance of *E. camaldulensis* (Webb, 1974; Iran, 1973). *E. camaldulensis* is frequently poor and does not flower in Iran.

Iraq

Eucalypts grow well in several parts of Iraq and present an opportunity to provide a large volume of timber and fuelwood in a country where forests have been over-exploited for many centuries.

Iraq is situated northwest of the Persian Gulf between latitudes 29°N and 37°30′N. The southern section of the country is too dry to support eucalypt plantations without irrigation, but it has the two large rivers, the Tigris and the Euphrates, which give opportunities for irrigated plantations on a considerable scale. There is a belt about 100 km wide in the northeast where a wide range of eucalypts will grow with the normal rainfall; then in the extreme northeast sector the climate is too cold for eucalypts as the altitude climbs to 2 000 m and higher.

The main species grown in the lower country are *E. camaldulensis* and *E. microtheca.* Other species growing well are *E. largiflorens, E. sideroxylon, E. melliodora, E. tereticornis* and *E. occidentalis.* It is estimated that the area planted to *Eucalyptus* to the end of 1973 was 3 000 ha.

Ireland

The Republic of Ireland lies between latitudes 51° and 55°N. The climate tends to be windy and moist. Typical rainfall figures (latitude 52°N, altitude 82 m) are 950 mm annual precipitation spread over 200 rainy days. Due to the ameliorative effects of the Gulf Stream, the climate is generally mild. However, in the east frost is recorded on an average of 120 days per annum and snowfall (ephemeral) to 5 cm per annum. An absolute minimum screen temperature of −5.9°C has been recorded.

Planting sites for eucalypts range from acid brown earths to peaty podzols. The typical ground cover is *Rubus, Vaccinium* and *Luzula.*

Eucalyptus species were introduced in 1908. Over 40 species and many varieties and hybrids have subsequently been tried, but the total area planted to 1973 was not more than 20 ha, composed of widespread small plots and group plantings. Only 5 percent of the total is in the form of line plantations.

The plots have been established for experimental purposes, in particular for growth assessment, spacing trials and to determine frost hardiness and suitability for introduction as windbreak species.

Normal practice is to prick out seedlings into 10- to 15-cm plastic containers 2-3 months after sowing. Stock is ready for planting 12-15 months from sowing, when plants are 20-40 cm tall.

Site preparation consists of vegetation clearance and pit-digging, using a post-hole borer at espacements of 2 to 4 metres. Survival rates are variable, losses being mainly caused by frost and exposure to cold winds.

As the present plantings are small in area, no specific thinning regime has been adopted. Plots are allowed to grow on to high forest condition.

In the older plantings the species most consistently frost-resistant and of good form are *E. urnigera, E. johnstonii,* and *E. muellerana.* Examples of growth rates in plots in Glenealy Forest are:

Species	Age *(yrs)*	Mean dbh *(cm)*	Mean height *(m)*
E. johnstonii	40	28.4	27.2
E. muellerana	40	26.6	26.0
E. urnigera	40	25.4	20.3

Other species which have done well on mild coastal sites, or which show promise in younger trials, include *E. dalrympleana, E. delegatensis, E. globulus, E. gunnii, E. ovata, E. pauciflora* and *E. viminalis* (mountain variety).

Israel Israel lies at the eastern extremity of the Mediterranean Sea between latitudes 29°30′N and 33°15′N. The climate is of the east Mediterranean type, with large semi-arid and arid zones. Rainfall occurs mainly during the winter from December to March, while practically none is recorded during June, July or August. Four main climatic zones and a number of soil types are recognized. Table 4.12 gives climatic data from selected meteorological stations and indicates the main soil types in each climatic zone where eucalypts are grown on a large scale.

Eucalypts were first introduced into the area late in the nineteenth century, primarily to drain malaria-infested swamps along the coastal plain. The first planting of *E. camaldulensis,* the most important species, was at Mikve in 1884 from seed of a source unknown, but thought to have originated from the lower reaches of the Murray river. All *E. camaldulensis* trees in the country, except for recent provenance trials, are descendants from this early introduction.

Table 4.12 Climatic and soil data from selected stations (Israel)

Zone	Station	Latitude (N)	Longitude (E)	Altitude (m)	Mean annual rainfall (mm)	Number of rainy days (⩾ 1 mm)	Temperature (°C) Mean maximum temperature (hottest month)	Temperature (°C) Mean minimum temperature (coldest month)	Temperature (°C) Absolute minimum	Main soil types
A	Dafne	33°13′	35°38′	150	569	59.7	34.6	7.1	—5.2	Dark brown grumusols of alluvial origin. Hydromorphic soils and gley-peat.
B	Hadera	32°26′	34°55′	35	542	49.2	30.4	9.0	—1.9	Mediterranean red soils. In some places a hardpan limits tree growth.
C	Pelugot	31°38′	34°45′	100	379	35.6	32.5	6.7	—	Brown lithosols and grumusolic dark brown soils. Calcareous sandstone ridges representing fossil dunes occur.
D	Beersheba	31°14′	34°47′	270	200	27.8	33.7	6.2	—5.6	Loessial brown soils, loessial sierozems and sandy soils in the north.

The total area planted to eucalypts to the end of 1973 is given as 10 022 hectares, of which 7 percent are windbreaks and roadside plantings. Block plantations are established as soil conservation measures and for the production of stakes, posts, fuelwood, charcoal, sawnwood and industrial products (mainly chipboard and fibreboard). Demand for timber is much greater than might be indicated by the 1974/75 annual cut of 22 000 m^3, most of which was converted to industrial products, but the prospects for establishing additional commercial plantations are limited by the scarcity of suitable land in areas receiving sufficient rainfall and the competition for these sites from agriculture and grazing.

Commercial planting is done on deep soils in valleys and plains, where use of subsoilers, rippers or rooters and other mechanical methods is standard practice. Deep ploughing to a depth of 40-50 cm is also used. Outplanting is at spacings of 3 × 2 m and 3 × 3 m in the north and 4 × 4 m and 4 × 5 m in the drier south using stock 30-50 cm high and 8-10 months old. Both polythene bags and naked-rooted transplants raised in tin containers are used. Mechanical cultivation is practised during the first three years following planting. Rotations vary from 7 to 12 years depending on site quality, but 15-20 years have been suggested for sawtimber. Table 4.13 summarizes information on yields and site preferences of the principal species.

Preliminary results from *E. camaldulensis* provenance trials have given some indication of the adaptability to climatic zones and soils, and are shown in Table 4.14. Information on promising minor species is summarized in Table 4.15.

Table 4.13 Yields and site preferences of principal eucalypt species (Israel)

Species	Area planted	Remarks
	ha	
E. camaldulensis	7 200	Planted in all climatic zones, but best growth of 20 30 m^3/ha/yr is attained on deep soils in climatic zones A and B where rainfall is above 400 mm. Drought limits its use in zone D, and iron-induced chlorosis is a problem on calcareous sites.
E. gomphocephala	1 500	Planted in the past in zones B, C and D but not much used any more. Best growth of 10 m^3/ha/yr reached in zone B. Almost a complete failure in zone D. Prefers deep, well-drained soils, but tolerates shallow calcareous soils. Drought limits its growth and increases susceptibiilty to *Phoracantha semipunctata*.
E. occidentalis	500	Planted in zones C and D where growth is 2 and 1 m^3/ha/yr, respectively. Is drought resistant and tolerates high temperatures, salinity and lime. Prefers deep clay soils and can also be planted on sites subject to prolonged waterlogging.

Table 4.14 Adaptability of provenances of *E. camaldulensis* to climatic zones and varying soil conditions in Israel

Provenance	Climatic zone + soils
Angaston, SA	Zones A + B
Darlington Point, NSW	Zones A + B
Lake Albacutya, Vict.	All zones
Mundiwindi, WA	Calcareous soils in zones C + D
Silverton, NSW	Calcareous soils in zones C + D

E. cinerea and *E. stuartiana* are intensively cultivated and their decorative branches are pollarded annually for export and sale to flower shops.

Table 4.15 Promising secondary eucalypt species for different climatic zones in Israel

Climatic zone	Promising species	Remarks
A + B	*E. cladocalyx*	Vigorous and straight form
	E. hemiphloia	Tolerates lime
	E. maculata	Vigorous and straight form
	E. tereticornis	Vigorous and straight form
C + D	*E. astringens*	
	E. brockwayi	
	E. clelandii	
	E. dundasii	
	E. intertexta	Mallee
	E. kondininensis	
	E. loxophleba	
	E. oleosa	Mallee
	E. populnea	Mallee
	E. stricklandii	
	E. torquata	

Italy

Italy, which covers a latitudinal range of about 37° to 47°N, has many fine specimens of eucalypts in different parts of the country and has played an important part in the development of knowledge of the genus. The famous botanical gardens, Hortus Camaldulensis, from which *E. camaldulensis* was given its name, were situated near Naples. The director of the gardens, Dehnhardt, named several Australian plants.

The regions of southern Italy where eucalypts have been mainly planted (Sicily and Calabria) have a typical Mediterranean climate near the coast, with a hot dry summer and a mild winter. As a rule rainfall increases and temperature decreases with increasing altitude and distance from the sea. Data from two representative climatic stations are given in Table 4.16.

In Sicily the soils planted are derived from Upper Pliocene sands, overlying clays and marls intermixed with calcareous rocks. In Calabria the soils are saline clays, containing soluble salts of NaCl and Na_2SO_4. Limiting factors are high salinity and alkalinity, especially in the dry season.

Eucalypts were recorded planted as specimen trees near Naples by 1803 and the first introduction was probably a few years earlier. The first eucalypt plantations were those planted by the Trappist Fathers at the Abbey of Tre Fontane near Rome in 1870. Extensive planting of shelterbelts in Sardinia and the Pontine Marshes started in 1923, while the main afforestation programme in Sicily and southern Italy started in 1950. The total area planted by 1975 was about 38 000 ha, of which 3 percent consists of shelter-

Table 4.16 Climatic data for two representative eucalypt planting areas in Italy

Station	Latitude (N)	Longitude (E)	Altitude (m)	Temperature (°C): Hottest month: Mean maximum	Temperature (°C): Coldest month: Mean minimum	Temperature (°C): Coldest month: Absolute minimum	Number of days with frost
Crotone (Calabria)	39°05′	17°09′	6	31.9° Aug.	6.5° Jan.	—6°	0
Piazza Armerina (Sicily)	37°23′	14°23′	721	32.6° Aug.	3.0° Jan.	—8°	11

Monthly rainfall (in millimetres)

Station	J	F	M	A	M	Jn	Jl	A	S	O	N	D	Total	Number of rainy days
Crotone	90	56	69	27	22	12	3	12	44	107	128	109	679	61
Piazza Armerina	104	79	83	50	35	23	8	14	53	67	98	120	734	74

belts or roadside planting. The main species are *E. camaldulensis* (18 000 ha), *E. × trabutii* (8 000 ha), *E. globulus* (5 000 ha) and *E. occidentalis* (5 000 ha). Annual planting rate is about 1 000 ha a year.

The main use of the wood is for pulp production. Some is used for charcoal and for crates. The plantations also play an important role in soil conservation in hilly areas, while the roadside and shelterbelt plantings serve a valuable amenity and protective purpose.

Plants are sown in seed beds and transplanted into plastic containers 12 × 10 × 10 cm, holding a soil volume of about 850 cm^3. Transplants are 5-10 months old and 15-35 cm tall when planted in the field. On gentle slopes soil preparation is by complete ploughing. On hill slopes up to 30 percent, *gradoni* (terraces) are made and plants are planted in pits 30 × 30 × 30 cm. Spacing is 3 × 3 m (about 1 100 trees/ha). Hoeing twice a year is done for the first three years. Plantations are normally neither fertilized nor irrigated.

Plantations are managed as coppice, with no thinning. The initial seedling rotation is 10-12 years and subsequent coppice rotations 8-10 years. Representative data on growth and yield for the four main species are given in Table 4.17.

Of the four main species, *E. camaldulensis* and *E. occidentalis* are frequently forked and crooked; *E. globulus* and *E. × trabutii* are of better form. *E. globulus* is the fastest growing on good sites but needs a deep, fertile, light soil with good moisture relations. *E. camaldulensis* is adaptable to a variety of the lighter soils, but does not do well on heavy clays of high salinity, while *E. occidentalis* tolerates a high clay content. All species coppice vigorously after felling. All are susceptible to fire damage, but sprout readily again later. *E. occidentalis* and *E. × trabutii* are very susceptible to frost damage, *E. globulus* and *E. camaldulensis* less so.

Species which are not yet extensively planted but have shown considerable promise in experimental plantings are *E. botryoides, E. gomphocephala* and *E. gunnii.* Species which have failed or given poor results under trial are:

Table 4.17 Representative data on growth and yield for the main eucalypt species grown in Italy

Species	Age	Number of stems/ha	Mean DBH (cm)	Mean ht (m)	Basal area (m^2)	Volume (m^3/ha)	MAI (m^3/ha/yr)
E. camaldulensis	12	1 040	14.0	10.5	15.5	77	6.5
E. × trabutii	10	867	13.2	11.8	11.9	62	6.2
E. globulus	11	774	15.5	17.0	14.6	85	7.8
E. occidentalis	6.5	1 022	9.6	8.3	7.3	38	5.8

E. brockwayi, E. citriodora, E. cornuta, E. diversicolor, E. goniocalyx, E. linearis, E. nigra, E. obliqua, E. paniculata, E. paulistana, E. racemosa, E. saligna and *E. salmonophloia.*

Ivory Coast The Republic of the Ivory Coast is situated on the Gulf of Guinea between latitudes 5°N and 10°N. The southern half is tropical rain forest and the northern half savanna.

The Ivory Coast is experimenting with the planting of eucalypts for two main purposes. In the dry northern part the aim is to produce posts, poles and fuelwood; in the moister southwest the aim is to produce wood pulp from several thousands of hectares of planting each year.

The total experimental plantings made to 1973 amounted to 150 ha. The species tried are *E. camaldulensis* and *E. tereticornis* in the drier zone and *E. deglupta* in the moist zone. All trials are very promising. Dangers are termites and fire in the dry zone. The extensive programmed plantings of *E. deglupta* will require a great deal of seed but the species is seeding in three years in the trials. The rainfall in the drier zone is 1 300 mm and in the moist zone 1 900 mm, mostly falling in the hotter months.

Japan Extensive trials of eucalypts were made in the decade following the Second World War but on most sites these were unsuccessful because of excessive cold in winter and damage from typhoons.

Jordan Jordan is in the latitudinal range of 29°N to 32°N. The western part is fertile and the eastern part semi-desert or desert. The climate is of the Mediterranean type with a prolonged dry hot summer. The soils in the closely populated parts are fertile red and yellow Mediterranean soils of a calcareous nature. *E. camaldulensis* plantations planted on a calcareous substratum may start well but later suffer and die from chlorosis.

Jordan uses eucalypts as windbreaks or for local timber production on a small scale because they are fast-growing trees and easy to handle. By 1973 the Forestry Department had two plantations in the Jordan valley which did not exceed 10 ha. Private owners plant them along watercourses and irrigation channels throughout the country. *E. camaldulensis* is the main species used and is very successful in all localities. Other successful species are *E. gomphocephala* and *E. occidentalis.* Studies show that the plantings produce 18-20 m^3/ha/yr. Watercourse plantings probably boost the increment.

Kenya Kenya is bisected by the equator and has a latitudinal range from 4°N to 4°S. The country ranges from sea-level to highlands between 1 000 m and 2 500 m in altitude. The highland soils are very fertile, usually derived from volcanic rocks and the highland rainfalls favourable for all agricultural pursuits.

Kenya has an extensive experience with eucalypts. In earlier years plantations were established to provide firewood for the railway line to Nairobi and Uganda. Between 1903 and 1906 some 19 species were tried out and *E. saligna* and *E. globulus* were selected as the best-yielding trees. The treatment of fuelwood plantations was to coppice them every 10 years until the stools began to deteriorate at about age 30. With the decline in the use of fuelwood for the railway in 1948 the plantations were proposed to produce power poles and telecommunication poles. There were also attempts to use them for sawnwood, but conversion difficulties made this venture impracticable. The completion of a fibreboard factory at Elburgon will require production from 200 ha annually around the mill.

Eucalypts have also been used in rural areas for fuel and pole production and for windbreaks. The total area planted in plantation form to 1973 was 11 296 hectares, excluding windbreaks and avenues. The principal planting areas are in the highlands between 1 800 m and 2 700 m in altitude and with a rainfall of 750 to 1 800 mm. Within this region is the well-known Muguga Forest Reserve where 83 species and varieties of eucalypts have been planted in plots of 0.04 ha in extent since 1951. These and other experiments in Kenya gave the following results in eucalyptus culture in good equatorial forest soils at high altitudes:

(*a*) *E. saligna* has produced the highest volume. It should be planted at spacings of about 2.74 × 2.74 m. The Kenya strain produces nearly 24 m^3/ha/yr of fuelwood overbark. In fuelwood an overbark volume is acceptable. The Kenya strain of *E. saligna* is believed either to be hybridized with *E. grandis* or to be *E. grandis*. Later tests have shown that *E. grandis* from Queensland produced 15 percent more fuelwood than *E. saligna* from Kenya.

(*b*) *E. globulus, E. camaldulensis, E. viminalis* and *E. bicostata* were defoliated by the eucalyptus weevil, *Gonipterus scutellatus*, and yielded less than 10 m^3/ha/yr of fuelwood at Muguga.

(*c*) *E. fastigata* and other stringybarked eucalypts grow well at Muguga but it is noted that they are less suitable for fuel production because they do not coppice. This comment may be compared with Australian experience, where small stems of *E. fastigata* coppice well after a fire. *E. fastigata* is also classed as a good coppice tree in the coppicing table in the South African *Handbook on eucalypt growing*, but is queried in other South African reports. In Australia it is usual for forests with "stringybarked eucalypts" to have been burned at intervals. This burning may keep the bark thin and thus less of an impediment to the development of dormant buds.

(*d*) Experiments in Kenya showed that neither the height of stumps nor the use of axe or saw felling had any effect on the survival and coppicing of the stumps or on the size of the subsequent crop. Nevertheless it is admitted that low cuts with a saw produced slightly better coppicing and prevented the development of over-bulky stumps in succeeding rotations. This would fit in with the recommendations in Chapter 5 on the management of coppice crops to produce higher grade stems.

(*e*) Muguga experiments on fuel production over 20 years from 32 sets of data, 16 from the seedling rotation and 16 from the first coppice rotation, have shown that the mean annual increment of stacked billets per hectare varied from 17.3 m^3 to 39.6 m^3 for the seedling rotation and from 16.5 m^3 to 55.8 m^3 for the first coppice rotation (conversion factor from stacked to solid volume = 0.65).

Kuwait Kuwait is on the Persian Gulf between latitudes 28°30'N and 30°N. It has an arid climate. In irrigated trials *E. microtheca* and *E. camaldulensis* showed the most promise. Amenity planting and shelterbelts are the main purpose (Firmin, 1971).

Lebanon Lebanon is on the Mediterranean coast between latitudes 33°N and 34.5°N. The climate is Mediterranean but not severe. Eucalypts are used mainly for environmental purposes, but there is an important place for them in providing farm timbers and fuelwood. Species which have done well include *E. camaldulensis, E. citriodora, E. sideroxylon, E. botryoides, E. globulus, E. gomphocephala, E. leucoxylon, E. occidentalis* and *E. astringens* (Pryor, undated).

Lesotho Lesotho is a high and cold country lying entirely within South Africa between latitudes 28°30'S and 30°41'S. It forms the roof of the southern African subcontinent with elevations ranging from just under 1 520 m to 3 170 m (highest peak, 3 483 m).

The summers are pleasantly warm but the winters are cold. Snowfalls are experienced every winter and Sehlabathebe (2 250 m) has an average of 276 days of frost per year and probably a more protracted and severe winter than any other continuously inhabited part of Africa. Rainfall occurs principally in the summer between October and April and consists mostly of thunderstorms.

Uncoordinated planting of eucalypts as windbreaks and as ornamental trees in towns has been going on in Lesotho for more than 50 years. No less than 25 species were recorded by Pryor (1973b). In 1973/74 the "Lesotho Woodlot Project" was started to establish small woodlots near villages for the production of firewood and building poles. It is estimated that to the end of 1973 about 360 ha of eucalypts had been planted.

Nursery sowings are made earlier than in other parts of southern Africa because of the coldness of the climate. The main species, *E. camaldulensis*, is sown in August to plant in the following February or March. *E. viminalis, E. rubida* and *E. bridgesiana* are sown in February to be ready after 12 months. Planting-out and fertilizing procedures are similar to those used in South Africa.

The recommended species for the lowlands are the following: for main plantings — *E. camaldulensis, E. bridgesiana, E. rubida*; others — *E. tereticornis, E. sideroxylon, E. polyanthemos, E. melliodora, E. cinerea, E. dives*; for trials, *E. viminalis* and *E. dalrympleana* were used. For highland trials *E. macarthurii, E. nova-anglica* and *E. pauciflora* were used.

Libya Libya faces north into the Mediterranean Sea between the longitudes of Sicily and western Greece; its latitudinal range is 20°-33°N. The rainfall is low, reaching 700 mm in a restricted area in Cyrenaica. Most of the eucalypts which are used for production plantations in Tunisia, Algeria and Morocco are found in appropriate localities in Libya. Eucalypts from the drier winter rainfall regions in Australia, particularly those which tolerate calcareous soils, are likely to grow in Libya. Pryor (1964a) states that the main species planted grow better in Libya than they do in a similar rainfall regime in Australia and attributes this to the effect of the maritime situation of the main plantings.

E. gomphocephala is the main species planted, as well as *E. camaldulensis* and a hybrid swarm believed to be *E. camaldulensis* × *E. rudis*. *E. camaldulensis* suffers from chlorosis after perhaps 20 years on calcareous sands, whereas the hybrid *E. camaldulensis* × *E. rudis* is healthy and of better growth. *E. gomphocephala* has rather a poor form with forked stems, and Pryor recommended selection of the better stems and the establishment of seed-producing plantations.

About half the area planted in Libya has been established for the purpose of the stabilization of sand dunes (Agricultural Extension, Tripoli, 1973). In this, *E. gomphocephala* and *E. camaldulensis* are frequently planted in mixture with *Acacia cyanophylla*. Spacing is 4 × 4 m or 4 × 5 m and a first rotation of 15-25 years according to site is expected. The advantage of the mixture of *Acacia cyanophylla* is that this shrubby tree reproduces itself vigorously by seeds and suckers and enriches and protects the soil. Other well-grown eucalypts seen in Libya by Pryor in 1964 were *E. bosistoana, E. amplifolia, E. leucoxylon, E. melliodora, E. occidentalis, E. sideroxylon, E. platypus, E. tereticornis* and *E. torquata.*

The area of eucalypt plantations in Libya in 1965 was 26 000 ha, out of a total plantation area of 56 000 ha (FAO, 1967a). A more up-to-date figure for eucalypts is not available, but the total area of state plantations had increased to about 75 000 ha by 1972 (Persson, 1975). On the assumption that eucalypts maintained the same proportion of total planting after 1965 as they had before, the eucalypt plantation area would have amounted to about 35 000 ha by 1972.

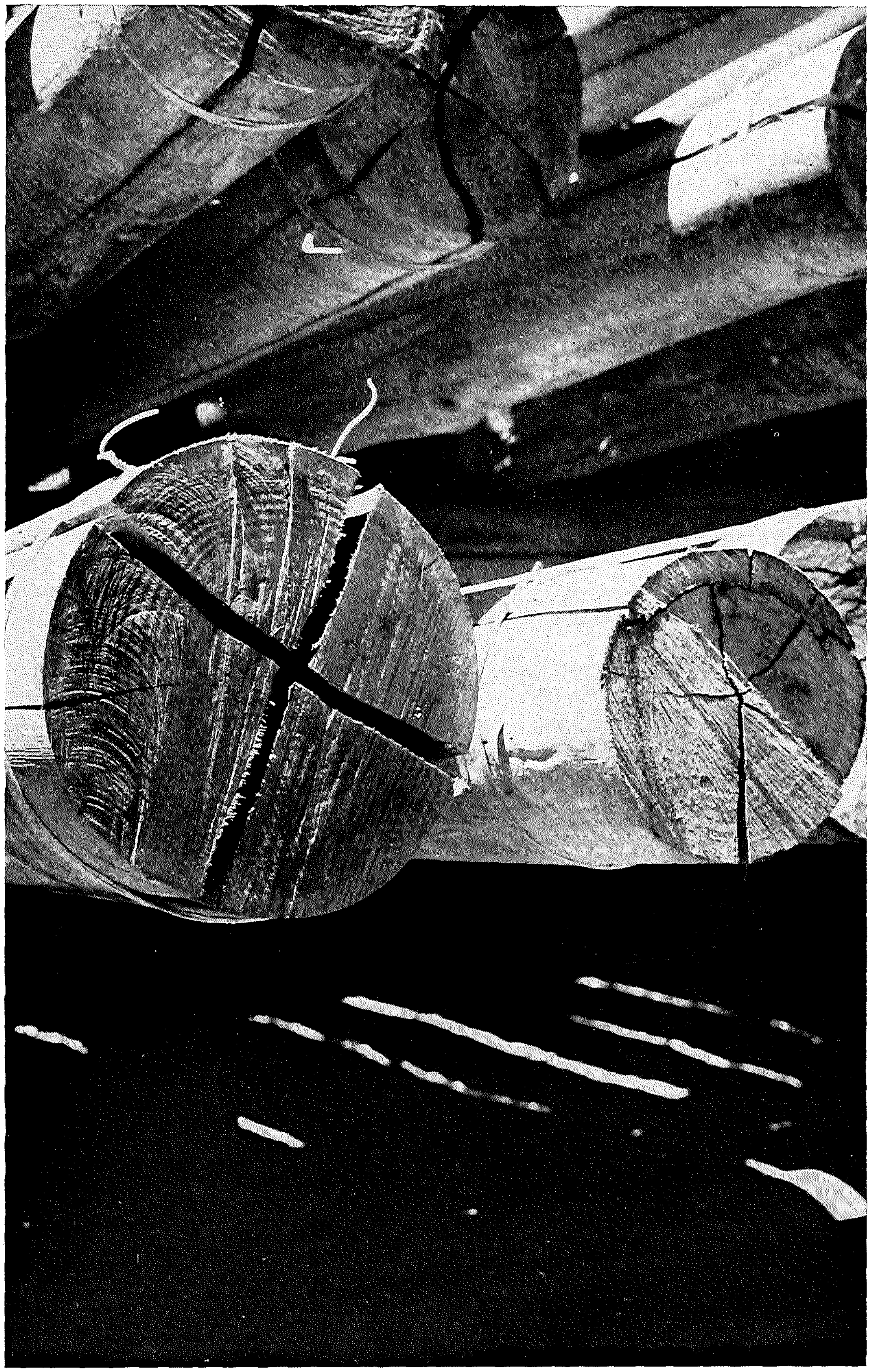
Madagascar

Madagascar, the fifth largest island in the world, lies about 400 km off the east coast of Africa between latitudes 12°S and 25°S.

The island has a wide range of climatic conditions, but a common feature is minimum rainfall during the cool season. The dry season is progressively more sharply defined from the wet east coast (e.g., Tamatave) to the mountainous interior and the high tablelands (e.g., Tananarive), and still more so on the southwestern coast of Tulear.

The three main climatic zones recognized, with their characteristic soil types, are shown in Table 4.18.

Most planting of eucalypts has been done in the moister areas, that is, in over 1 000 mm rainfall in the tropical dry zone and over 1 400 mm in the high altitude areas, as well as in the tropical moist zone. Limiting soil factors in certain areas include soil depth, laterization and occurrence of a plinthite layer, infertile sands and presence of excessive calcium or salinity. Climatic data for three stations — Tulear (extreme dry, southwest coast); Tamatave (extreme wet, east coast); and Tananarive (representative of central highlands) — indicate the wide range in climate.



17. Transmission poles of eucalypt wood being dried in Madagascar. Note use of banding iron to reduce end-splitting
FAO photo

Table 4.18 Climatic and soil data for main planting zones in Madagascar

Zone	Rainfall (mm)	Occurrence	Soil types planted with eucalypts
Tropical dry	< 1 500	Western plains. The driest areas (down to 300 mm) are in the southwest	Ferralitic red soils over volcanic rocks, mainly basalt; ferruginous tropical soils; lithosols and sandy soils; calcareous and saline soils
Tropical moist (low altitude)	> 1 500	Eastern coast and northwest corner	Ferralitic yellow soils with concretions and indurated plinthite layer
Tropical moist (high altitude)	1 000-2 600	Central highlands and plateau	Brown eutrophic soils over volcanic rocks, mainly basalt; sandy dune soils, poorly developed

Plantations were first made at the end of the last century by missionaries, settlers and the forestry administration. The country now has an extensive eucalypt programme, with 180 000 ha planted to the end of 1973 for fuelwood, charcoal, fenceposts, transmission poles, construction timber, windbreaks and erosion control. *E. robusta* is also used for bridging timber and

Table 4.19 Climatic data from some meteorological stations in Madagascar

Zone	Station	Latitude (S)	Longitude (E)	Altitude (m)	Temperature (°C)	
					Mean maximum (hottest month)	Mean minimum (coldest month)
Tropical dry	Tulear	20°23′	43°44′	9	32° Feb.	14° Jul.
Tropical moist (low altitude)	Tamatave	18°07′	49°24′	5	30° Jan.	17° Aug.
Tropical moist (high altitude)	Tananarive	18°54′	47°32′	1 310	26° Nov./Feb.	10° July

Monthly rainfall (in millimetres)

Station	J	F	M	A	M	Jn	Jl	A	S	O	N	D	Total	Number of rainy days
Tulear	71	71	42	6	18	11	4	3	10	14	34	57	341	34
Tamatave	420	441	528	404	302	300	257	208	134	87	184	259	3 524	240
Tananarive	255	187	263	42	8	9	17	13	16	47	170	366	1 393	133

flooring. A great part of the plantations is in private or communal ownership, in numerous separate blocks of small individual extent, but there are some larger blocks under the control of the Central Government, notably in the Moramanga area.

The two species most widely planted are *E. robusta* and *E. camaldulensis*. The first is found over the whole of the eastern escarpment from sea-level to the high tablelands at 1 200 m, on a variety of soils, but does not grow well on too dry or sandy soils. It accounts for nearly three quarters of the total area planted. *E. camaldulensis*, which has great morphological diversity, is plentiful on the high tablelands on soils degraded by burning but is also adaptable to other climates and seems indifferent to soil physical properties. Third in importance is *E. citriodora*, which is planted from sea-level up to 600 m elevation.

Normal nursery practice is to raise plants in soil blocks 5 × 10 cm or in polythene pots 8 × 15 cm. Bare-root planting has also been used. Plants are 4-5 months old and 20-25 cm high when out-planted. Woody vegetation is removed from the site and a subsoiling operation done before planting is carried out in the rainy season (December-March). On grassland, planting is done in pits without subsoiling. The first weeding is done six months after planting, over a circle of 1 m radius, and a 10-m firebreak round the plantation is kept free of vegetation. The coppice rotation is 5 years, and for sawlog production the rotation is 25-30 years. For costs of establishment see Chapter 12.

For *E. robusta*, yields vary between 10 and 35 m^3/ha/yr at 11 years. *E. camaldulensis* and *E. citriodora* are lower yielding.

Table 4.20 Promising eucalypt species and provenances (Madagascar)

Species	Provenance	Remarks
E. cloeziana	S. Africa, Mauritius	Tested on east coast and central plateau, 30-37 m high at 12-16 years, straight
E. eugenioides	France, Australia	18-20 m at 12-16 years, straight
E. fastigata	Australia	14-20 m at 11-13 years, not always straight
E. maculata	S. Africa, Australia, Mauritius	20-30 m at 10-15 years, straight, good self-pruning
E. paniculata	S. Africa	20-30 m at 16 years, straight, good self-pruning
E. pilularis	Australia	30-40 m at 10-15 years, straight
E. torelliana	Australia	18 m at 9-10 years, straight, good self-pruning

Table 4.21 Species unsuitable for large-scale planting in Madagascar

Species	Climatic zone	Remarks
E. gummifera	Tropical moist (low altitude)	Slow growth
E. diversicolor	Tropical moist	Poor survival
E. globulus	Tropical moist	Slow growth, high mortality
E. maidenii	Tropical moist	Twisted or forked
E. resinifera	Tropical moist	Slow growth, stem not always straight
E. sideroxylon	Tropical dry	Slow growth, twisted stems
E. viminalis	Tropical moist (low altitude)	Slow growth

Species listed in Table 4.20 have not yet been planted on a large scale, but have given promising results on suitable sites, mainly in the central plateau area. Species that have been tried but which are considered unsuitable for large-scale planting are listed in Table 4.21.

Mention should be made of the eucalypt known as 12ABL which was named after Ambila, where it was first planted. Seed from this stand, which is thought to be a form of *E. tereticornis*, was used in the Congo with what were initially very promising results but second-generation stands there indicated severe in-breeding depression which showed itself in high mortality and incidence of dwarfing (see Chapter 7).

Malawi

Malawi includes Lake Malawi and its western shore, with the high tableland separating it from the basin of the Luangwa river, the watershed forming the western frontier with Zambia. The latitudinal range is 9°-17°S.

No details are available for privately owned plantations but the figure is of the order of 6 000 hectares of which nearly all (over 95 percent) is *E. grandis*. The areas of state-owned plantations and the breakdown into age-classes are given in Table 4.22.

The altitudinal and latitudinal ranges and the presence of Lake Malawi produce a wide variation of climate. The rainfall pattern shows a distinct summer rainfall and winter drought throughout the country but there is a large diversity of rainfall and in the length of the wet season. In the south there is a single rainy season. In the far north there are two peaks within the rainy season, with February usually being rather dry.

The country has been provisionally divided into 11 climatic zones on the basis of rainfall and temperature, as shown in Table 4.23. The figure under dry season denotes the average number of months with under 60 mm of

Table 4.22 Areas of state-owned plantations in Malawi

Species [1] \ Climatic zone [2]	A	D	E	G	J	K	L	M	Total (ha)
E. *microcorys*				47.9	18.2	55.5		38.9	160.5
E. grandis			137.4	185.6	1 649.3	339.5	178.1	152.5	2 637.4
E. saligna				32.1		38.7			70.8
E. maidenii			3.3	66.7	3.1	44.5		60.2	177.8
E. cloeziana				1.7	54.8	92.1		1.9	150.5
E. tereticornis	54.7	5.0	4.8		4.4	1.9			70.8
Other species	7.7	5.3		42.9	20.9	86.1	41.5	48.1	252.5
Research areas									112.5
Total									3 632.8

[1] Age-class breakdown: 90 percent of area < 10 years old; 5 percent of area 10-20 years old; 5 percent of area 20 years plus. — [2] See Table 4.23.

rainfall; a-d denotes the severity of the dry season subjectively, d being the most severe. The monthly average rainfall figures give an under-estimate of the dry season because rainy-period dates vary each year.

Table 4.23 Climatic zones of Malawi

Zone	Altitude (m)	Mean annual rainfall (mm)	Mean annual temperature (°C)	Dry season (average number of months with rainfall < 60 mm) [1]
A	200	710-840	25 +	7-8 a
B	200-700 1 000-1 200	710-840	21-25	7-8 a
C	500-1 000	840-960	21-23	7-8 a
D	1 000-1 500	840-960	19-21	7-8 a
E	1 000-1 600	960-1 050	19-21	7 b
G	900-1 500	1 050-1 200	19-21	7 c
H	475-1 000	(1 050) 1 200-1 600	23 +	7 b
J	1 000-1 500	(1 050) 1 200-1 600	19-21	6 d
K	600-1 100	(1 050) 1 200-1 600	21-23	6 c
L	475-1 000	1 600 +	23 +	5 c
M	1 500	1 050-1 600	19	6 c

[1] a-d denotes the severity of the dry season (d = most severe).

For nutrient values used in soil classification, see Table 4.24.

Ferralitic

Generally sandy profiles with low nutrient status and low mineral reserves; some profiles display a sandy clay horizon at depth, but most clay is of the kaolinitic group. The pH range is 5.0-6.0, nitrogen is invariably low but phosphorus and potassium vary widely. There are quite extensive areas of laterization under ferralitic soils, which limit rooting depth.

Ferruginous

Generally heavier profiles with red subsoil; usually having an adequate reserve of weatherable minerals. Nitrogen levels are normally medium while phosphorus is low and potassium adequate. The clay minerals include illite and montmorillonite as well as kaolinite. The pH range is 5.0-6.0.

Ferrisolic

Intermediate between the previous two groups in terms of weathering, kaolinitic clays predominating. The texture is usually sandy clay to clay and the colour red to dark red. The profile is free draining. Phosphorus level is usually higher than in ferruginous soils, the nitrogen levels low to medium and potassium medium. They are always strongly acid, pH usually 4.5 to 5.0.

Regosolic

These soils are derived from sands, coarse sand being the principal constituent. They occur in the lakeshore area. Nitrogen is invariably low, although phosphorus levels are usually medium to high and potassium varies widely.

Calcimorphic

Usually alluvial in origin, these are grey-brown soils with impeded drainage. Nitrogen is usually low although phosphorus and potassium levels are high. While of small extent these are potentially very fertile soils.

Table 4.24 Nutrient values used in soil classifications in Malawi

	Nitrogen	Phosphorus	Potassium
	Percent	*ppm*	*Percent*
Low	0.04-0.1	0-20	0.03-0.2 me
Medium	0.1-0.2	20-50	0.2-0.4 me
High	0.2-0.4	50-100	0.4-0.8 me

Table 4.25 Main species planted on various soil types in several climatic zones of Malawi

Species	Soils					
	Ferralitic	Ferruginous	Ferrisolic	Regosolic	Calcimorphic	Hydromorphic [1]
E. grandis	G, K, M, E, D	D, G	J, L	L		(D)
E. maidenii	D					
E. cloeziana		G	J			
E. tereticornis		D				
E. camaldulensis	D, G, C	D, G			A	(G)
E. microcorys	G, M					

[1] Bracketed letters indicate failures.

Hydromorphic

These soils occur in valley floor sites and are predominantly montmorillonitic clay. They are regularly flooded and some are almost permanently waterlogged. Nutrient levels would be adequate in most cases after drainage and planting of suitable species.

Establishment techniques

Nursery practice

This is standard and in conformity with methods described in Chapter 5. One gram of NPK fertilizer per plant is usually applied in two doses after the seedlings have recovered from pricking out, and is added to each pot individually away from the plant. Aldrin is applied to all nursery stock except in Zone M to give protection from termites. Three applications are made at 10-day intervals. The rate of application is 28 litres 0.1 percent aldrin suspension per 1 000 plants each time. Plants are normally 3-4 months old when planted and the usual size is 15-20 cm.

Plantation establishment.

Preparation of the site. Most areas are prepared entirely by hand; some mechanical preparation has been done in Zones M, J, D and L.

- Land clearing: Felled by hand, cut, stacked and burned. Where mechanical preparation is to be done, stumping is done, usually by tractor and winch.

- Mechanical preparation: Complete ploughing by disc plough to a depth of 20-25 cm. Harrowed twice to break up clods. Mechanical preparation is not done on slopes in excess of 15°.

- Hand preparation: Pits of 30 cm^3 are dug during the dry season, preferably in June to August but usually in October or November. The soil is put back with the topsoil at the bottom of the pit after the first rains and the surrounding area cultivated so that it is weed free.

Date of planting. After 50-100 mm of rain have fallen and the wet season is well established. This is usually mid- to late December. The planting date gets later with decreasing latitude and in the far north of the country can be as late as mid-January.

Espacement. The usual espacement is 2.75 × 2.75 m. Where a market exists for small poles, and the moisture regime permits, closer espacements have been used, down to 2.1 × 2.1 m. Where mechanical cultivation is employed a rectangular spacing is used, e.g., 2.75 × 2.1 m rather than 2.4 × 2.4 m. In the drier Zones A, B, C and D a spacing of 3 × 3 m is occasionally used, particularly where there is little demand for small thinnings.

Survival. Usually in excess of 90 percent, beating up can be done in March if required but beating up the following season is usually unsatisfactory because of the disparity of size, unless large groups have failed.

Tending. The aim is clean cultivation until the canopy has closed. Where mechanical cultivation is employed, this requires 5-8 harrowings. For manual tending, 3-6 cultivations are required during the first year, depending on rainfall. In most areas canopy closure takes place during the second year and only limited cultivation is required. In Zone L more frequent cultivation is required in the wet season, weed growth sometimes continuing for 10-11 months.

Fertilization. All eucalypts receive 50-75 g NPK compound 321(25) 3-4 weeks after planting. The higher rate is used in Zones A, B, C, D and parts of H and L. Fertilizer borate 46 percent is applied where rainfall is limiting or where there is a known boron deficiency. Plants in Zones A, B, C, D, H and L receive 50 grams and those in E, G and K, 25 grams. The borate is applied just before the end of the rains when there is a slight dry spell.

Protection. Aldrin is usually applied for termite control in all zones except M and parts of J. The rate of application is 1 litre 0.1 percent suspension per tree in February to April. In parts of Zones B, C and D where virgin land is being planted, aldrin application is not always essential.

To control *Phoracantha semipunctata*, all felled eucalypts are debarked within 7 days. Substantial areas of unthrifty plantations are felled and utilized to reduce breeding areas.

Fire protection. Plantations are split into blocks and divided and surrounded by firebreaks. Active fire precautions by means of fire lookouts and stand-by parties are maintained in most areas. Controlled burning under established plantations of *E. grandis* which have closed canopy has been successful in reducing fire risk in some areas.

Malaysia Malaysia, including peninsular Malaysia, Sabah and Sarawak, covers latitudes 1°N to 7°N.

Eucalypts are being experimented with in secondary forest in peninsular Malaysia because of their fast growth. At present there is no developed plan to change the tests into industrial plantations. The total area planted is about 40 ha.

Early plantings of *E. robusta* were established with seedlings grown from seed from Queensland in 1883. In the highlands of peninsular Malaysia its volume increment is around 35 m^3/ha/yr. Natural pruning is very effective and long straight poles are obtained at an early age. *E. grandis* also grows well in these highlands; the average girth of a plot 12 years old was 111 cm and the height 35.4 m.

E. deglupta does best on the lowlands from 150-450 m, but the form is poor with forking common. In the nursery it is susceptible to damping off and young saplings are attacked by the Cossid moth, *Zeuzera coffeae*, which is followed by black ants and termites.

Mali Mali is an inland country of northwest Africa between latitudes 10°N and 24°N. It is fairly arid and eucalypt plantations could be important in providing wood products for the population. Trials are being conducted with *E. camaldulensis, E. gomphocephala* and *E. microtheca.*

Malta Malta is an island in the Mediterranean situated at latitude 36°N. Eucalypts are planted as street trees and in valleys and swampy places to improve drainage. The soils are alkaline and the main species used are *E. gomphocephala* and *E. camaldulensis.* An experiment is under way to test a range of species for tolerance to sea spray and shoreline conditions.

Mauritius The island group of Mauritius lies in the Indian Ocean between latitudes 11°S and 20°33′S. The main island has a maritime subtropical climate with an adequate rainfall to keep the island green. It is frequently struck by hurricanes.

Mauritius has a number of eucalypts growing on the island and has played an interesting part in the development of knowledge of the genus because of historical factors. The island was an important revictualling port for early explorers and settlers going to Australia. Flinders, with most of his plant collections, was imprisoned there for some years during the Napoleonic wars owing to a misunderstanding by the French Governor. Eucalypts went to South Africa from Mauritius early in the nineteenth century. The area of eucalypt plantations in Mauritius in 1970 was estimated to be about 3 000 ha (Persson, 1975).

Mexico Mexico lies in the latitudes 14.5°N to 32.5°N, and has a wide variety of climates, topography and soils. Eucalypts were introduced early in the century but controlled trials only started at Chapingo arboretum in 1948 (SNA, 1970). Plantations of eucalypts, mainly *E. camaldulensis*, commenced in 1956 at El Rancho Casas Blancas, and by 1967 extended to 2 000 ha (Reynders, 1970a).

In 1967 seed of several provenances of *E. camaldulensis, E. citriodora, E. tereticornis, E. botryoides, E. saligna, E. grandis* and *E. deanei* was obtained from Australia, together with seed of 17 other eucalypt species. Controlled provenance trials were laid out at Chapingo, El Rancho Casas Blancas and El Tormento in southern Mexico.

E. camaldulensis and *E. tereticornis* provenances from northern Queensland and Western Australia are the most promising and show rapid increment. *E. citriodora* and *E. botryoides* are also promising for special uses (Reynders, 1970b).

Morocco

Morocco is situated in the northwest corner of Africa, between latitudes 27°40'N and 36°N.

The climate is Mediterranean, with most rainfall occurring in the winter, and a distinct dry season coinciding with the highest temperatures. Bioclimatic zones have been mapped. The main zones of interest are listed in Table 4.26.

The balance is made up by the Saharan zone in the southeast (less than 100 mm rainfall) and the high mountain zone over 3 000 m (accounting for only 1 percent). In general the rainfall decreases from north to south, but the Atlas mountains running from northeast to southwest divide the country into two sectors and modify the rainfall pattern. The plains on the west side adjacent to the Atlantic are moister and have smaller fluctuations in temperature than those on the east next to the Sahara, while the mountains themselves fall mainly into the subhumid and humid zones.

Climatic data for some representative stations are found in Table 4.27.

Eucalypts were introduced into Morocco early in the twentieth century, *E. camaldulensis* in 1918, *E. gomphocephala* in 1920. The total area of

Table 4.26 Bioclimatic zones of Morocco

Zone	Annual rainfall (mm)	Percentage of area (approximate)
Arid	100-350	30
Semi-arid	350-600	30
Subhumid	600-900	20
Humid	900-1 200	3

Table 4.27. Climatic data for some representative planting areas in Morocco

Zone	Station	Latitude (N)	Longitude (W)	Altitude (m)	Temperature (°C) Mean maximum (hottest month)	Temperature (°C) Mean minimum (coldest month)
Arid	Marrakech	31°36′	8°01′	460	36° Aug.	7° Jan.
Semi-arid	Rabat	34°03′	6°40′	75	27° Aug.	9° Jan.
Subhumid	Tetuan	35°35′	5°20′	5	30° Aug.	9° Jan.
Humid	Ifrane	33°31′	5°07′	1 640	31° Jul.	—5° Jan.

Monthly rainfall (in millimetres)

Station	J	F	M	A	M	Jn	Jl	A	S	O	N	D	Total	Number of rainy days
Marrakech	28	29	32	31	17	7	2	3	10	21	28	33	241	51
Rabat	66	64	66	43	28	8	<1	1	1	49	84	86	496	70
Tetuan	121	126	115	44	22	8	0	4	14	43	65	120	682	?
Ifrane	112	127	125	117	82	38	8	11	40	137	152	163	1 112	78

eucalypts planted in Morocco by the end of 1974 was 117 743 ha, the largest area in any one country in North Africa. The species breakdown in 1974 was as shown in Table 4.28; the figures include areas planted on communal and private lands, as well as state forest plantations. It is apparent that two species, *E. camaldulensis* and *E. gomphocephala*, are the most important in terms of area planted.

Eucalypts play an important part in afforestation for production, protection and amenity. The most extensive plantations are in the Rharb/Mamora area northeast of Rabat, where the object of management is supply of pulpwood (*E. camaldulensis*) to the pulp and paper mill at Sidi-Yahia. Drought-resistant species have been introduced in the arid regions of eastern and southern Morocco for afforestation and soil restoration of bare ground.

E. camaldulensis, planted at a spacing of 3 × 3 or 3.5 × 3.5 m, on ploughed land in the plains, or on terraces on hill slopes, with nursery-grown pot-plants, gives yields which vary considerably according to site and treatment. Yield tables compiled for the Mamora include five productivity classes with mean annual increments at 16 years ranging from 3 to 11 m^3/ha/yr. In the case of management as coppice, clear-felling is recommended at ages 12, 19 and 29 years (rotations of 12, 7 and 10 years).

Table 4.28 Eucalypt plantations in Morocco (1974)

Species	Area planted	Remarks
	ha	
E. camaldulensis	87 096	Suitable for deep sandy soils in semi-arid and subhumid zones. Minimum temperature —5°C, minimum rainfall 400 mm. Unsuitable for calcareous or saline soils. Lake Albacutya provenance consistently best in trials.
E. gomphocephala	65 789	Suitable for planting on deep soils in semi-arid and subhumid zones. Minimum temperature —4°C, minimum rainfall 300 mm (200 mm at Agadir on coast). Unlike *E. camaldulensis*, it tolerates calcareous, as well as non-calcareous soils, but is less resistant to temporary waterlogging.
E. sideroxylon	5 245	Suitable for semi-arid zone and moister parts of arid zone. Minimum temperature —6°C, minimum rainfall 300 mm. Tolerates infertile soils over schists and quartzites. The best species grown locally for posts and poles.
E. cladocalyx	4 272	Suitable for similar conditions as *E. camaldulensis*. Lower yielding, but somewhat more tolerant of aridity and infertile soils over schists and quartzites. Minimum temperature —2 to —4°C, minimum rainfall 300 mm.
E. occidentalis	2 743	Suitable for heavy clay and marl soils in the semi-arid zone. Tolerates some soil salinity. Coppices well.
E. grandis/saligna	2 620	Suitable for deep, non-calcareous soils in the humid and subhumid zones. Exceptional for rapid growth and good form, provided sites are carefully selected.
Other species	9 978	
Total	177 743	

E. gomphocephala is quoted as producing similar yields (6-10 m^3/ha/yr) on average sites. In plots on exceptionally fertile soils at La Déroua, irrigated for the first five years, yields varied between 21 and 44 m^3/ha/yr. On good sites, *E. gomphocephala* will produce sawlogs.

There are nearly 10 000 ha of secondary eucalypt species in Morocco; some of them are listed in Table 4.29.

Two well-known species which have given poor results in Morocco are *E. citriodora* and *E. robusta.*

Mozambique

Mozambique extends south from the Tanzanian border from latitude 11-12°S to latitude 27°S at Maputo. Its altitude varies from sea-level to 1 800 m.

Table 4.29 Secondary eucalypt species grown in Morocco

Species	Remarks
E. globulus	Suitable for deep, non-calcareous soils in the humid zone (over 900 mm). For sawlogs or peeling.
E. bicostata *E. maidenii*	Similar site requirements as *E. globulus*, but less extensively planted.
E. astringens	Suitable for heavy clay and marl soils in the semi-arid zone, where *E. camaldulensis* gives poor results. Has also performed well on sandy soils in the moister parts of the arid zone. A poor coppicer in Morocco.
E. sargentii	Similar site requirements as *E. astringens*. In addition, it is the most tolerant of high soil salinity of any species tried in Morocco.
E. brockwayi *E. loxophleba* *E. salmonophloia*	Suitable for soil conservation, shelterbelts and production of firewood in the arid zone down to 200 mm rainfall.
E. salubris *E. stricklandii* *E. torquata*	Suitable for soil conservation, shelterbelts and as ornamentals in the arid zone down to 200 mm rainfall. Too small to be suitable for firewood.
E. transcontinentalis	Considered the most drought resistant of any species for protective planting in the arid zone, but is a bush rather than a tree.

The climate is tropical with not a great variation in temperature but with a considerable variation of rainfall with altitude. Representative stations are listed in Table 4.30.

The area of eucalypts planted in the various provinces are: Mozambique, 5 ha; Zambezia, 970; Tété, 22; Vila Pery, 2 500; Inhambane, 280; Gaza, 2 470; Maputo, 1 750; total, 7 997.

The total planted area includes state-owned and private plantings. It is intended to plant 30 000 ha in the Province of Vila Pery to service a paper pulp factory.

The main species planted are *E. saligna, E. paniculata, E. maculata, E. citriodora, E. camaldulensis, E. tereticornis, E. botryoides, E. rudis* and *E. robusta.* The first three are planted in the zones with a rainfall of 1 000 mm or more and the remainder in the drier regions. *E. saligna* is used for posts preserved by using creosote by the vacuum and pressure method. All species are used for fuel and charcoal. *E. saligna* is used for wood pulp, made by the sulphate process. A secondary use for eucalypt plantations is the production of honey.

Nepal Nepal lies between latitudes 27°N and 30°N on the southern slopes of the Himalayas and includes Mt Everest, with an altitude of 8 847 m.

Table 4.30 Climatic data from some representative meteorological stations in Mozambique

Station	Latitude (S)	Altitude (m)	Rainfall (mm)	Humidity (%)	Type of climate
Salamanga	26°28′	25	800	75	Warm: 6- to 7-month rainy season; winter drier than summer.
Namaacha	12°23′	599	800	70	Temperate humid: 7- to 8-month rainy season; without a dry season.
Matola	12°35′	25	700	70	Warm and dry with a dry season in winter.
Marracuene	25°02′	26	900	70	Warm and humid, with a marked dry season.
Sussundenga	19°33′	1 200	1 200	70	Temperate humid with a dry season
Messambuzzi	18°12′	1 050	1 200	70	Temperate humid with a dry season.
Penhalonga	18°56′	1 800	1 100	70	Temperate humid with a dry winter.
Tété	16°09′	130	600	60	Warm and dry with a dry season in winter.
Nieuadala	17°36 ′	30	1 400	75	Warm and humid with a marked dry season
Alto Molocué	15°30′	583	1 400	70	Warm and humid with a dry season.

Eucalypts were first introduced into Nepal in the late nineteenth century as ornamentals and many fine specimen trees still exist in Kathmandu city. In the 1950s an attempt was made to establish a small plantation near Kathmandu but this was not successful probably due to poor nursery stock and inadequate site preparation. The oil crisis of the early 1970s, coupled with local fuelwood shortages, rekindled interest in growing eucalypts for fuelwood and poles, and trials commenced in 1973.

Land available for forestry in the midland valleys is usually steep and highly erodible, but at lower elevations there are deep soils with a high water table — "terai soils," and others with a low water table — "bhabar plains." All three sites are being tested.

Nursery and planting practices are standard, but at high elevations special care must be taken in the nursery against frost.

E. camaldulensis and *E. maidenii* are the most promising species in the midland valleys or hill country, growing best on deep brown, slightly acidic soils. On the "terai" and "bhabar" soils, *E. grandis* and *E. tereticornis* have grown well.

Introductory trials continue and fifteen species are being tested (Mather, 1974; Fernside, 1975).

New Zealand New Zealand consists of two main islands and several subsidiary islands in the south Pacific Ocean, about 2 000 km southeast of Australia, extending from latitudes 47°S to 32°S.

The north island contains a considerable proportion of recent or fairly recent volcanic deposits. The south island includes on its eastern side flatter and more rolling country and also the southern alps which rise to an altitude of over 3 600 m and which are not a volcanic range. Most of the north island of New Zealand and the southern part of the south island were covered with a rain forest of both primitive conifers and hardwoods before European settlement. Since European settlement much of the rain forest has been exploited and replaced by farming land and plantations of a wide variety of exotics, e.g., pines, Douglas fir and eucalypts. The plantations are very vigorous, particularly on the pumice soils in the volcanic areas of the north island. In 1973 New Zealand had about 12 659 ha of eucalypt plantations, mainly *E. regnans, E. delegatensis, E. nitens* and *E. fastigata.* They are being extended by plantings of approximately 1 000 ha per year. A considerable proportion of the eucalypt plantations have been established using bare-root seedlings. In earlier years New Zealand planted a considerable amount of *E. globulus* but this species was attacked by *Gonipterus scutellatus* and also by an Australian eucalypt scale insect and the beetle *Phoracantha semipunctata.* Predators of these pests have been introduced, and New Zealand is now looking again at the possibility of planting more *E. globulus.* The eucalypt planting work is referred to in Chapters 5 and 6.

Niger Niger is a landlocked country in northwest Africa with a latitudinal range of 12°N to 24°N. Vegetation is mainly dry savanna woodland. Eucalypts are expected to be important to provide firewood, house-poles, farm timbers, shelterbelts and shade trees. Many trials have been made, including a trial of 29 provenances of *E. camaldulensis*; by the end of 1973, a total of 40 ha of eucalypts had been planted in Niger.

Nigeria Nigeria is a major African nation carrying out a well-organized experimental programme and substantial plantings to get the best use from the genus *Eucalyptus* for the savanna regions of the country, and possibly for other regions. It is a tropical country covering latitudes of approximately 4°N to 14°N. After a coastal belt of mangroves some 6-50 km wide, there is a zone of tropical rain forest 40-60 km wide changing toward the north to open woodland and savanna. Temperatures are high, the mean monthly maximum of the hottest month varying from 30°C along the coast to more than 38°C in the savanna. The rainfall varies from under 600 mm in the northern savanna to more than 5 000 mm in the eastern rain forest.

The eucalypt plantings totalled 4 000 ha at the end of 1973 and it was planned to extend them at the rate of 800 ha per year. Over fifty species of eucalypt have been tried, and a number of these have been selected for further trials. Several of the species chosen have a wide range of natural occurrence in Australia, and particular provenances of them will be sought.

A major forestry problem in Nigeria is to provide forest products for the large population living in the northern savanna regions. Species chosen for the main savanna vegetation zones, listed in order of decreasing dryness, are indicated below:

Sudan Zone

Climatic conditions in this zone are dominated by the severely dry harmattan wind from the northeast. Total rainfall varies between 500 mm and 1 000 mm, but for seven consecutive months the rainfall is either nil or less than 25 mm. It is common to have 275 consecutive days without rain. On deep dry sands both *E. camaldulensis* and *E. microtheca* are promising. *E. microtheca* suffers little termite damage.

Northern Guinea Zone

Mean annual rainfall in this zone varies from 1 016 mm to 1 270 mm, with only three months without rain. Soils are commonly reddish brown sandy loams and the natural vegetation is affected by farming and fierce grass fires over a long period.

Promising eucalypts are *E. camaldulensis, E. citriodora, E. cloeziana, E. propinqua, E. grandis/saligna* and *E. tereticornis.*

Southern Guinea Zone

This zone receives about the same amount of rain as the Northern Guinea Zone but the wet season is more prolonged and the dry season less severe. Similar eucalypts are promising, with *E. camaldulensis* being generally the most suitable but others producing good poles more quickly on the best sites. These are *E. cloeziana, E. propinqua, E. punctata, E. robusta* and *E. saligna.*

E. camaldulensis was introduced to Nigeria in 1916 (Jackson and Ojo, 1973) and was then planted bare-rooted in the northern parts without protection against termites. Results of recent provenance trials are summarized under *E. camaldulensis* in Chapter 14.

In the rain forest zone *E. deglupta* is growing well in trial plantations.

The *E. citriodora* × *E. torelliana* hybrid is of considerable interest. *E. citriodora* comes from a moderately low latitude (17°S-26°S), while *E. torelliana* is one of the low-latitude eucalypts in Australia (16°S-19°S). *E. torelliana* has a very heavy crown, whereas *E. citriodora* has a light crown but a straight bole. The branches of *E. torelliana* tend to droop and sweep the ground in plantings outside Australia. A stabilized hybrid swarm could prove a valuable eucalypt. Alternate lines of *E. torelliana* and *E. citriodora* may give a continuing supply of F_1 hybrids which could be very useful (see Chapter 7).

Pakistan

The latitudinal range of Pakistan, situated in the northwestern part of the Indian subcontinent, is 23°N to 37°N.

Eucalypts are useful plantation species in Pakistan, which has planted a number of species since 1867. Many species have been tried in irrigated plantations, riverain forests and foothills. At first the trees were used for fuelwood, but later also for posts, poles, chipboard and other purposes. By the end of 1973, 1 000 ha of eucalypt plantations had been established in Pakistan.

Much of Pakistan, including areas where plantations to provide wood products are most needed, has a severe climate. Data from three representative stations, Hyderabad, Lahore and Abbotabad, are shown in Table 4.31.

Zones of eucalypt growth

Eucalypts are grown in four zones:

Arid marine tropical coastal land

This zone is characterized by a steady sea breeze throughout the summer. The mean annual rainfall is more than 150 mm and the mean annual temperature is above 33°C. There are no major changes in seasonal and diurnal temperatures and the relative humidity is high.

Table 4.31 Climatic data from some representative meteorological stations in Pakistan

	Monthly rainfall (in millimetres)													
	J	F	M	A	M	Jn	Jl	A	S	O	N	D	Number of months with rainfall < 51 mm	Number of rainy days
Hyderabad (Lat. 25°23′N Alt. 30 m)	5	5	5	3	5	10	76	51	15	0	3	3	10	9
Lahore (Lat. 31°N Alt. 221 m)	25	25	20	15	15	41	140	136	56	5	3	13	9	28
Abbotabad (Lat. 34°15′N Alt. 1 266 m)	86	164	114	89	50	79	229	249	71	30	18	20	3	78

Arid subtropical continental lowlands

The plains in this zone are characterized by great annual and daily variations in temperature. The maximum temperature in June is 41°C, and the mean minimum in January is 5-8°C with a few frosts. The relative humidity is generally low and the mean annual rainfall 70-200 mm.

Semi-arid subtropical continental lowlands

In this zone the temperatures correspond to the previous zone but the rainfall is 200-500 mm.

Subhumid subtropical continental lowlands

This includes the northeastern strip of the Indus Plain and the Potwar Uplands with a mean annual rainfall of 500-1 200 mm, sharply increasing toward the hills. The winter is colder and the summer cooler than in the previous region.

The main species planted are *E. camaldulensis, E. microtheca, E. tereticornis, E. citriodora* and *E. melanophloia.* The trees grow well with irrigation but are not usually satisfactory without irrigation.

In recent provenance trials of *E. camaldulensis* the following provenances have given the best performance: Provenance No. 3, Newcastle Waters Creek (Australian origin: Northern Territory); No. 4, Katherine (Northern Territory); No. 5, Fortescue River (Western Australia); No. 1, Alice Springs (Northern Territory); No. 16, Quilpie (Queensland); No. 19, Bullock ex/ Porcupine Ck. (Queensland).

Irrigated plantations have given a mean annual increment at age 9 of 7.1 m^3/ha/yr.

E. torelliana has proved a very good tree at Hyderabad and Peshawar for windbreaks and shelterbelts because of its heavy crown.

Panama

Panama, a tropical country in Central America, has a latitudinal range between 7°12'N and 9°38'N. There is an experimental planting programme on *Eucalyptus* totalling 5 ha in area, mainly for aesthetic purposes. Many low-latitude eucalypts suit the conditions in Panama.

Papua New Guinea

Papua New Guinea consists of the eastern part of the large island of New Guinea (of which the western part forms West Irian, part of Indonesia), together with the Bismarck archipelago, of which New Britain is the largest island. Latitudinal extent is approximately from 2° to 12°S.

The mainland of Papua New Guinea is a mountainous country. Most of the island receives a high rainfall, but there is drier country in the south-eastern section around Port Moresby, where several indigenous eucalypts are found, including *E. alba* and *E. tereticornis.* On the northern side of the main island and also in New Britain there occurs the most easterly extension of the only important native equatorial eucalypt, *E. deglupta*. This species colonizes sandbanks left by floods and the inside and outside slopes of recently active or still semi-active volcanoes. In the western district of Papua *E. brassiana*, one of the promising low-latitude eucalypts, occurs.

Planting of eucalypts has been done in both the wet lowlands and the wet highlands. Although there is a relative diminution in rainfall between May and September, no month even in that period receives less than 100 mm. Climatic data from two representative stations are found in Table 4.32.

In the lowlands eucalypt plantations are established on cleared rain forest sites with deep alluvial soils of moderate to high fertility, where the main limiting factor is poor drainage. Earlier lowland plantations in New Britain are on alluvial flats and soils derived from pumice. In the highlands, planting is done on drained swamplands dominated by *Phragmites*, and on *Imperata cylindrica* grasslands.

The first eucalypt plantations were made in 1948 with *E. deglupta* from seed collected at Keravat (New Britain). By the end of 1973 the total plantation area planted by the Government amounted to 736 ha of *E. deglupta* in the lowlands, and 483 ha of *E. robusta* plus 129 ha of *E. grandis* in the highlands. Planting rate in 1973 was 800 ha a year in the lowlands (expected to rise to several thousand hectares a year) and 100 ha a year in the higlands. In

Table 4.32 Climatic data from two representative meteorological stations in Papua New Guinea

Zone	Station	Latitude (S)	Longitude (E)	Altitude (m)	Temperature (°C)	
					Mean maximum (hottest month)	Mean minimum (coldest month)
Lowlands (0-200 m)	Madang	5°14′	145°47′	8	30.1° Feb.	22.8° Jun./Jul.
Highlands	Mt Hagen	5°51′	144°09′	1 700	24.4° May	12.4° Jun.

Monthly rainfall (in millimetres)

Station	J	F	M	A	M	Jn	Jl	A	S	O	N	D	Total	Number of rainy days
Madang	361	335	375	452	377	209	166	128	138	255	403	394	3 593	198
Mt Hagen	267	274	287	269	178	127	133	178	236	206	215	229	2 599	250

addition to the above areas, there are small areas of trials and village extension planting in lowland grassland areas. The primary purpose of planting *E. deglupta* is for pulpwood, although some plantations for sawlogs have also been established. In the highlands, *E. robusta* and *E. grandis* are planted for poles, posts and firewood, including firewood for drying purposes in tea factories; some sawlogs may also be produced.

Normal practice is to raise plants in black polythene tubes, 20.5 cm by 7.5 cm, with several 4-mm perforations to improve drainage and aeration. As planting expands, it is intended to raise plants and to plant out continuously throughout the year in the lowland areas, as is already done in the highlands. Plants are 2 months old and 25-30 cm in height when planted. Earlier plantations of *E. deglupta* were planted after clearing and burning natural forest, but the present technique of line planting in heavily logged-over forest without clearing or burning appears to give even better results.

For *E. deglupta* grown for pulpwood, a rotation of 7-10 years is proposed. There will be no thinning. Initial stocking is expected to be between 625 and 1 100 stems/ha; the final choice will depend on results from current spacing trials. For sawlog plantations in both the highlands and lowlands it is expected that the rotation will be 25 years with thinnings at 4-5 years (for posts and fuelwood) and 8-12 years (for poles). Whereas *E. robusta* coppices well, a disadvantage of *E. deglupta* for short rotation crops is its poor coppicing ability.

Provenance trials of *E. deglupta* have been established at three lowland sites and assessments after two years show there are significant provenance × site interactions. In general, the New Britain, Mindanao and Sulawesi provenances have produced superior growth to provenances from mainland Papua New Guinea.

Two additional species under trial show promise. *E. tereticornis* is promising in lowland grassland areas but, because of its very sparse crown, it is less successful on rain forest sites which regenerate vigorously. Provenance trials of both Australian and Papua New Guinea provenances have been established recently. Several provenances of *E. urophylla* have been planted in grasslands at Bulolo (altitude about 800 m). A provenance from 580 m on Timor showed the best early growth and survival. Best trees were 11 m high and 22 cm DBH at age 4.

Paraguay

Paraguay is a landlocked country in the centre of the South American continent between latitudes 19°S and 27°S. About 60 percent of the country is savanna (*chaco*) and most of the remainder is subtropical humid forest with some swamp areas. In 1972 it was estimated that 2 900 ha had been planted to eucalypts.

Peru

Peru lies on the western side of the South American continent between the equator and latitude 18°21′S. It is a very long country, its western border being the Pacific Ocean and its eastern border the Amazon basin. The highlands of the country are covered by the Andes mountains, with several peaks approaching or exceeding 6 000 m in altitude. Located entirely within the tropics, the lowlands of Peru are hot and in the southern part of the country arid. Nevertheless, there is a very substantial area of arable or plantable highlands where eucalypts thrive.

During the past 15 years, Peru has embarked on a vigorous programme of eucalypt planting. The total area planted by 1975 was 92 882 ha. The purpose of the plantations is to produce industrial timber, wood for the many mines in Peru, for rural construction purposes, fuelwood, posts, etc. The main species planted is *E. globulus* in the highlands. This species was introduced into Peru in 1860 and has been most successful. Soils used for forest crops are those most suited for this purpose in national planning. They tend to be rocky and slightly acid, deficient in nitrogen and organic matter, with a low content of available phosphorus but a high content of potassium. Rainfall tends to be more frequent in the summer months, the total varying from less than 500 mm to 1 500 mm.

Apart from *E. globulus* the following species have shown promise: *E. botryoides, E. camaldulensis, E. citriodora, E. grandis, E. longifolia, E. tereticornis, E. viminalis.*

Philippines

Philippines is an archipelago of many islands extending from 4°30′N to 21°20′N. It is one of the homelands of the important equatorial eucalypt, *E. deglupta*, which occurs on one of the large southern islands of the group, Mindanao. There are several occurrences of *E. deglupta* in Mindanao, some of which have been exploited along with the rich rain forests of the island. *E. deglupta* is being regenerated naturally in the Philippines, and also planted together with other eucalypt species. In 1975 there were 7 070 ha of eucalypt plantations in the Philippines, mainly *E. deglupta.* Because of the danger of losing one of the natural occurrences of *E. deglupta*, much of the remaining forest has been included in a National Park.

Portugal

Portugal occupies the western part of the Iberian Peninsula between latitudes 36°58′N and 42°9′N. From the south, where the climate is typically Mediterranean, with a hot dry summer, there is a gradual increase in the Atlantic influence (higher total rainfall, less severe summer drought) as one goes northward along the coastal plain. In the interior toward the Spanish border the climate is more continental, with a hot summer and a cold winter and the increasing altitude depresses still further the winter temperatures. Detailed ecological mapping has been done (De Pina Manique and Albuquerque, 1954) and forms the basis for delineation of zones by their suitability for eucalypt planting (Goes, 1962). Soils are varied, deriving mainly from schists, granites and sandstones. Climatic data for representative coastal stations are shown in Table 4.33.

The first eucalypts to be planted in Portugal are thought to be those planted in 1829 at Vila Nova de Gaia near Oporto, but reliable records are not available before 1852. Large blocks were first planted in 1875. By the end of 1973 the total area of eucalypts planted was 250 000 ha and the average planting rate for the previous five years was 15 000 ha/yr.

Portugal is a most important eucalypt-planting country because of the early work it accomplished in making paper from *E. globulus.* Ninety-five

Table 4.33 Climatic data from some representative coastal stations in Portugal

Climatic zone	Station	Latitude (N)	Longitude (W)	Altitude (m)	Temperature (°C) Mean maximum (hottest month)	Mean minimum (coldest month)
A × MA[1] (Predominantly Atlantic with slight Mediterranean influence)	Oporto	41°08′N	8°36′W	95	25.0° Aug.	4.8° Jan.
AM[1] (Mediterranean with considerable Atlantic influence)	Lisbon	38°43′N	9°09′W	77	27.7° Aug.	7.8° Jan.
M[1] (Typical Mediterranean)	Praia da Rocha	37°07′N	8°32′W	19	27.8° Aug.	8.0° Jan.

[1] Nomenclature of De Pina Manique and Albuquerque, 1954.

Station	Monthly rainfall (in millimetres) J	F	M	A	M	Jn	Jl	A	S	O	N	D	Total	Number of rainy days
Oporto	159	112	147	86	87	41	20	26	51	105	148	168	1 150	156
Lisbon	111	76	109	54	44	16	3	4	33	62	93	103	708	113
Praia da Rocha	59	38	69	31	24	7	2	1	18	44	58	66	417	74

percent of *Eucalyptus* plantations in Portugal are made up of *E. globulus*, because the ecological conditions are highly suitable for this species and because of the quality of its timber which is used not only for pulpwood but also for building, furniture, etc. Eighty-five percent of the wood produced in the plantations is used by the cellulose industry and the remaining timber for sawmills or fuel. Roadside plantings and windbreaks, again mostly *E. globulus*, are significant in Portugal but only account for 5 percent of the total area. Essential oils are made from the leaves in about 10 percent of the area planted.

The main areas for planting *E. globulus* have been a 60- to 70-km-wide strip along the Atlantic coast, both north and south of the Tagus river, and in the tertiary basin of the Tagus and Sado rivers. Growth is best in the moister conditions north of the Tagus. South of the Tagus, nursery plants are raised in plastic bags 10 cm in diameter by 15 cm high; in the moister conditions north of the Tagus naked-rooted plants may be used. At the time of planting, plants are 4-7 months old and 20-40 cm high. On flat ground ploughing is normally done to 50 cm depth followed by ripping to 70-80 cm. On steep slopes over 30 percent, 4-m-wide terraces are made by angledozer and 180-hp crawler tractor. Planting is best done in October/November or February/April, but may be extended throughout the period October/April in the case of potted plants planted on schistose soils. Spacing is normally 3 × 3 m on flat ground, 2 m between trees and 4 m between terraces on steep slopes.

Almost all *E. globulus* stands in Portugal are exploited on a short rotation coppice system with a rotation of 8-12 years. The mean annual increments obtained vary from between 4 and 40 m^3 per ha depending on the ecological conditions. In the better ecological zones, north of the Tagus river, the average annual growth is between 15 and 30 m^3.

The stools of *E. globulus* have an excellent capacity for regeneration, thus allowing 4 or 5 cuttings of the crop from the same stumps and obtaining a good economic return from the enterprise. Apart from *E. globulus* the following species are planted on a minor scale: *E. camaldulensis*, about 3 500 ha (S.W. Alentejo, semi-arid zone, continental climate); *E. maidenii*, about 7 500 ha (southern Portugal, e.g., Serra de Monchique); *E. sideroxylon* and *E. tereticornis*, for drier inland areas with continental climate.

Well over 100 other species have been introduced into various parks and arboreta. *E. maidenii* was an important addition because it could be planted in poorer soils than *E. globulus* and endured frost and drought better than *E. globulus*. Moreover, it is related to *E. globulus* and is suited to the paper industry. The most serious pest attacking *E. globulus* in Portugal is an insect of the psyllid family, *Ctenarytaina eucalypti* Marsh (*Rhinocola eucalypti*).

To protect the important plantations against fire there is a network of fire lines and roads, fire-towers and radio communication between the fire-towers and the administrative officers. Cost figures are given in Chapter 12.

Puerto Rico

Puerto Rico is an island belonging to the Greater Antilles group in the West Indies, situated between latitudes 17°N and 18°N.

Eucalypts are planted in Puerto Rico mainly for erosion control and general rehabilitation of deforested areas, and produce posts, poles and sawtimber. By the end of 1973, some 800 ha of eucalypts had been planted on public land; in addition, around 40 ha had been established in small (⩽ 1-ha) plots on private land. The planned annual planting rate was 8-10 ha.

The main plantation areas at Toro Negro and Carita State Forests are situated at an altitude of about 800-1 000 m, in the Subtropical Wet Forest life zone according to the Holdridge Classification. The mean annual rainfall is 2 000-2 800 mm with no distinct dry period; the mean annual temperature of the hottest month is 22.5°C and of the coldest month, 18.5°C.

The soils are primarily poorly to well-drained degraded clays, covered before planting by tall brush and ferns.

The first introductions of eucalypts into Puerto Rico date back to 1929 (*E. robusta*). Since then, numerous species and provenance trials have been established at varying altitudes and on a range of soils.

At present the most widely used species is *Eucalyptus robusta*, which has been planted on a variety of sites from sea-level to 1 100 m elevation. The species grows well on heavy wet clays above 450 m. At elevations ranging from 600 to 1 000 m, 13-year-old trees of this species have a DBH of 20-40 cm and a height of 19 m. *E. resinifera* has been found to be one of the best-adapted species for high elevation areas. Other species which seem well adapted to mountain sites include *E. maculata* and *E.* × *kirtoniana*. Species adapted to low elevations include *E. tereticornis* and *E. alba* (Caribbean Forester, 1973). Provenance trials of *E. deglupta* and *E. urophylla* are also under way (Whitmore, 1973; Whitmore and Macía, 1975). Other species tried with varying success include *E. botryoides, E. citriodora, E. gummifera, E. globulus, E. pilularis, E. propinqua* and *E. sideroxylon* (Caribbean Forester, 1973).

Nursery practice follows the outlines in Chapter 5. Planting is done 6-8 months after sowing when plants are 30-38 cm high. Spacing is either 1.8 × 1.8 or 2.4 × 2.4 m. Three or four hand weedings are required per year for the first two years. The first thinning is at age 4-5, the second thinning (for poles) is done at age 20, and a possible third thinning is done at about age 30. The planned rotation is 30-40 years.

E. robusta has recently suffered a severe black gummosis disorder and trunk rots caused by *Polyporus schweinitzii* and *Fomes* spp. Another fungus, *Botryosphaeria ribis*, causes cankers on the trunk.

Zimbabwe (ex-Rhodesia)

Zimbabwe lies in southern Africa between latitudes 22°30′S and 15°45′S. Topographically, the country can be divided into three distinct regions, the mountainous Eastern Highlands with peaks rising to above 2 500 m above sea-level, the extensive central plateau, or highveld, averaging somewhat above 1 000 m above sea-level, and the lowveld, mostly below 1 000 m above sea-level which comprises the Valley of the Zambesi in the north and those of the Sabi, Nuanetzi and Limpopo in the southeast and south.

The country has been divided into five provisional silvicultural zones (Barrett and Mullin, 1968) according to rainfall and altitude which, together with incidence of frost, limit the choice of exotic species for afforestation (see Table 4.34). Some details of these zones are given in Table 4.35. Zimbabwe enjoys summer rainfall (October/November to March/April) with comparatively little rainfall in the remainder of the year. It can be seen from the data given below that the wettest and best silvicultural zones (I to III) account for only some 13 percent of the total land area. This highlights the importance of harsh-area-tolerant exotic species for planting as fuelwood in Zones IV and V in which the majority of the population is to be found and where fuelwood demand is increasing with the rise in population. It has been shown, however, that high yields from eucalypts can be obtained even in Zone V under irrigation (Barrett, Carter and Seward, 1975).

The introduction of *Eucalyptus* spp. dates back to the early 1890s. They have been planted particularly in Zones II, III and IV covering a total area in 1965 of about 25 000 ha.

Table 4.34 Silvicultural zones of Zimbabwe

Zone	Total area	Annual rainfall	Altitude	Remarks
	Percent-age	*mm*	*m*	
I	1.5	> 1 000	610-2 130	Commercial afforestation with *Eucalyptus* sp. (but mainly pines)
II	1.7	900-1 000	1 220-1 675	Commercial afforestation with *Eucalyptus* sp.
III	9.6	700-900	1 065-1 525	Small-scale commercial afforestation with *Eucalyptus* sp.
IV	22.2	600-700	> 1 065	Marginal for exotics afforestation
V	65.0	< 600		Not suitable for *Eucalyptus* sp. except under irrigation

Table 4.35 Climatic data from meteorological stations representative of silvicultural Zones III and V

Zone	Station	Location			Temperature (°C)	
		Latitude (S)	Longitude (E)	Altitude (m)	Mean maximum (hottest month)	Mean minimum (coldest month)
III	Salisbury	17°50′	31°01′	1 470	29° October	7° June/July
V	Bulawayo	20°09′	28°37′	1 344	30° October	7° June/July

Monthly rainfall (in millimetres)

Station	J	F	M	A	M	Jn	Jl	A	S	O	N	D	Total	Number of rainy days
Salisbury	213	173	101	39	11	5	1	3	5	30	100	186	867	73
Bulawayo	134	112	65	21	9	3	0	1	5	25	89	124	589	50

Afforestation has largely been confined to very fertile, slightly acid, reddish brown clays derived from igneous rock; to deep fine sands, comprised in part of Kalahari sands, well supplied with a low-lying water table suited to deep-rooted species (central plateau); and, on the eastern border, where rainfall is high, to deep free-draining moderate to strongly acid, fine and medium-grained, loamy sands.

The most outstanding and widely planted species on the more favourable sites is *E. grandis*. *E. camaldulensis* is also widely planted on the drier sites. Other species commonly planted are *E. botryoides*, *E. maculata*, *E. paniculata*, *E. punctata*, *E. resinifera*, *E. robusta*, *E. sideroxylon* and *E. tereticornis*. As a result of trials of numerous species (summarized by Barrett and Mullin, 1968), *E. nitens* and *E. regnans* are recommended for high altitudes to provide shelter and possibly sawlogs, and *E. cloeziana* in the frost-free areas as the best species for high-quality poles.

The majority of planting has been carried out by private estates in the form of farm woodlots, shelterbelts, firebreaks and small-scale commercial forestry. The major state-planted area is concentrated in the central plateau in Zone IV at Mtao. The greatest demand for produce has been in the form of a wide range of pole sizes. Some utilization as sawntimber has been carried out but is on a comparatively small although increasing scale.

Seed is sown into covered drills or direct into polythene tubes (125 mm flat × 150 mm deep). Pricking out is done in September/October in the former case. Planting commences as early as possible in the rainy season; a plant height of 250 mm appears to be average. An espacement of 2.75 × 2.75 m is to be aimed at, on land preferably completely ploughed and harrowed (where topography allows; otherwise patch-hoed), and subsequently clean weeded. Blanking is essential and is completed as early as possible during the current planting season.

No thinnings are carried out; the crops growing on to pole size (25 cm u.b.butt diameter) are felled in 12-15 years. After clear-felling, the coppice regrowth is reduced to two stems after two years and to one stem after four to six years. At each stage the thinnings are saleable. Indications are that coppice rotation will decrease by one year over each preceding rotation. The yield of *E. grandis*, the main species, varies greatly according to site quality, from a MAI of about 7 m^3 to well over 40 m^3/ha/yr. A eucalypt tree-breeding programme is now out of its infancy and shows much promise for considerable benefits to be secured in a comparatively short time. A notable feature of all Zimbabwe-grown eucalypts of importance is their apparent immunity to destructive pathogens and their comparative freedom from devastating insect pests.

Rwanda

The Republic of Rwanda is a landlocked country in central Africa, lying between 2°S and 4°S latitudes. The country has a substantial area of eucalypt plantations totalling about 23 000 ha (1970). The most successful species have been those originating from the coastal and subcoastal areas of New South Wales. *E. botryoides*, *E. citriodora*, *E. globulus*, *E. longifolia*, *E. maculata*, *E. maidenii*, *E. microcorys*, *E. paniculata*, *E. punctata*, *E. ro-*

busta, E. saligna and *E. tereticornis* have given good results in Rwanda but mediocre results have been obtained with *E. camaldulensis, E. obliqua* and *E. viminalis.*

The objectives of establishing these plantations have been to supply the local population with fuelwood, house-poles and other forest products and to supply industrial fuelwood for mining industries.

Senegal

Senegal is situated on the west coast of Africa between latitudes 12.5°N and 16.5°N. The climate is difficult but some provenances of *E. camaldulensis* and *E. microtheca* could provide shelter, poles and fuelwood. The total area of eucalypt plantations was 50 ha in 1965.

Sierra Leone

Sierra Leone is situated on the west coast of Africa between the latitudes of 7°N and 10°N. The country is interested in eucalypts for the provision of fuelwood, poles and pulpwood. Species being experimented with are *E. camaldulensis, E. tereticornis, E. saligna, E. grandis, E. microcorys, E. paniculata, E. maculata, E. citriodora* and *E. alba.* The average rainfall is 2 000 mm or more. The soils are mostly lateritic derived from granite and acid gneiss. Nursery and plantation practices correspond to those outlined in Chapter 5. There is a long dry season of 6-7 months.

South Africa, Republic of

The Republic of South Africa, extending in latitude from about 22°S to Cape Agulhas at 34°50′S, has a wide variety of climates and has been divided into a number of silvicultural zones. The zones are based on a combination of the following factors:

Seasonal rainfall distribution. W, predominantly winter rainfall; U, uniform rainfall; S, predominantly summer rainfall.

Humidity. Based on the Thornthwaite method which takes into account rainfall, potential evapotranspiration and the occurrence of seasonal dry periods, the zones are classed as (A) humid; (B) subhumid; (C) semi-arid; and (D) arid.

Temperature. This is expressed as the probable severity of frost, 1 being frost severe; 2, frost moderately severe; 3, frost light; and 4, frost virtually absent.

Both hailstorms and windstorms sometimes cause severe local damage to plantations, but in most cases eucalypts recover well from the damage. Hailstorms are most frequent in the summer rainfall zone.

Soils are extremely variable. Generally speaking, the best rates of growth are obtained on rich clay-loam soils of doleritic origin, but certain eucalypts grow better on lighter soils derived from granite and sandstone. Some soils, such as those derived from the Table Mountain Sandstones in the winter and uniform rainfall zones, are often extremely leached, acid and infertile and are unsuitable for eucalypts.

Eucalypts were first introduced into South Africa in 1807 from Mauritius in containers. By the last quarter of the nineteenth century there was a growing demand for fuelwood and mine-timbers, and eucalypts were being grown as coppice crops to provide fuelwood, house-poles, mine-timbers, transmission poles and later pulpwood for the growing industrial complex in South Africa. The Government played a leading part in demonstrating to landowners which species should be used in different parts of the country but within a few decades industrial eucalypt plantations had become an important part of the private investment sector of the economy.

By March 1973 eucalypts occupied 347 464 ha, almost exactly one third of the total area of commercial timber plantations in the country (Department of Forestry Report on commercial timber plantations, 1972/73). This figure excludes arboreta and research plantings. Approximately 12 percent of the area was in public, the remainder in private, ownership. An area of 10 426 ha had been planted in the year 1972/73. *E. grandis/saligna* accounted for 274 898 ha or 79 percent. Techniques in establishment, management and utilization are well developed.

Overwhelmingly the greatest part of the eucalypt plantations are in the summer-rainfall zone; winter- and uniform rainfall zones combined account for only 2.2 percent. Within the summer-rainfall area the majority of the commercial plantations are in the humid zone with frost light (zone As3), i.e., at elevations over 600 m and with annual rainfall over 800 mm; the plantations near the Zululand coast are an exception. Climatic data for some representative stations are found in Table 4.36.

Eucalypt wood is used for a variety of industrial purposes, in addition to its use as fuelwood, charcoal, untreated fenceposts, etc. 1970/71 consumption figures are shown in Table 4.37. The total constituted about two fifths of the grand total of industrial consumption of all species in the Republic of South Africa (Rep. S.A., 1972).

Normal practice is to raise eucalypts in polythene tubes 9-10 cm layflat by 10 cm long, or in trays, or in transplant beds. In all cases plants are planted out with balls of soil attached, and not bare-rooted. Optimum size is considered to be 10-15 cm tall, which is attained about four months after sowing. Best results are obtained by intensive site preparation which may include complete ploughing, fallowing, discing twice at right angles and subsoiling to a depth of 30-45 cm along the planting lines. Initial spacing varies between 2 × 2 and 3 × 3 or 2 × 3.5 m; 2.4 × 2.4 and 2.7 × 2.7 m are common. Hoeing or disc-harrowing is necessary until the trees have reached a height of 1-1.5 m tall (usually in 6-8 months) after which inter-row slashing is done to prevent the trees being overtopped, until the crop closes canopy.

For production of pulpwood or mine-timber, a 6- to 10-year coppice rotation with no thinning is normal. In the case of *E. cloeziana* grown for transmission poles, a single 50 percent thinning is recommended at age 4, followed by clear-felling at age 12. For *E. grandis* grown for sawlogs a rotation of 30 years, with thinnings at ages 7, 11 and 15, which reduce the final crop to 250 stems/ha, is recommended. A mean annual increment of 25-35 m^3/

Table 4.36 Climatic data from some representative meteorological stations in South Africa

Zone	Station	Latitude (S)	Longitude (E)	Altitude (m)	Temperature (°C) Mean maximum (hottest month)	Temperature (°C) Mean minimum (coldest month)
B w 4	Cape Town	33°54′	18°32′	17	26° Jan./Feb.	7° July
A u 3	George	33°58′	22°25′	221	24° Feb.	7° July
A s 4	Empangeni	28°46′	31°55′	64	30° Feb.	10° July
A s 3	Piet Retief	27°00′	30°48′	1 260	27° Jan.	4° July
B s 2	Germiston	26°15′	28°09′	1 665	26° Jan.	4° Jun./July

Monthly rainfall (in millimetres)

Station	J	F	M	A	M	Jn	Jl	A	S	O	N	D	Total	Number of rainy days
Cape Town	12	8	17	47	84	82	85	71	43	29	17	11	506	68
George	81	59	78	63	61	38	47	59	71	86	73	60	776	91
Empangeni	113	124	159	74	68	59	46	42	60	74	117	120	1 056	101
Piet Retief	153	122	107	50	22	11	13	15	43	95	131	157	919	106
Germiston	117	101	78	46	25	9	8	6	25	63	110	120	708	71

ha/yr can be expected from *E. grandis* on the best sites; other species produce lower yields.

Comprehensive information on the characteristics of the eucalypts most widely grown in South Africa has been published recently (Poynton, 1979). Species of most interest, apart from the dominant *E. grandis/saligna*, are identified in the following list.

Table 4.37 Consumption figures for eucalypt wood in South Africa, 1970/71 (m^3)

Species	Sawlogs	Pulpwood	Mine-timber	Poles, etc.	Total
E. grandis/saligna	214 648	643 159	1 511 106	179 060	2 547 973
Other eucalypts	51 380	94 185	225 130	37 380	408 075
Total	266 028	737 344	1 736 236	216 440	2 956 048

CHARACTERISTICS OF EUCALYPT SPECIES WIDELY GROWN IN SOUTH AFRICA

Relatively hardy to drought, suitable for planting in semi-arid zones:

E. camaldulensis

E. citriodora

E. cladocalyx (relatively tolerant of infertile soils in the winter and uniform rainfall zones)

E. crebra

E. melliodora

E. polyanthemos

E. sideroxylon

Relatively hardy to frost, suitable for planting in zones 1 and 2:

E. bridgesiana (for shelterbelts)

E. cinerea (for ornament and shelterbelts)

E. dalrympleana

E. dives (grown on short rotation for distillation of essential oil)

E. elata

E. fastigata

E. macarthurii

E. melliodora

E. nitens

E. rubida

E. viminalis

Others:

E. cloeziana (excellent for production of large poles, particularly in the warmer humid summer rainfall zones As3 and As4).

E. diversicolor (the best species for timber production in the warmer humid uniform rainfall zones Au3 and Au4. It is climatically adapted also to the moist winter rainfall zones, but most areas in this zone are unsuitable because of soil infertility).

E. maculata (for timber production, especially in zones As3 and As4).

E. microcorys (same as *E. maculata*).

E. paniculata (excellent for production of large poles; slightly slower in growth, but more drought-resistant than *E. cloeziana*).

E. globulus, E. maidenii and some related species are severely attacked in South Africa by the snout beetle *Gonipterus scutellatus*. This places a serious limitation to their use. In addition older plantations of *E. globulus* have suffered from die-back and unthriftiness on a number of sites.

The private sector in South Africa is well supported by the Forestry Department of the Republic and also by the Wattle Research Institute attached to the University at Pietermaritzburg, Natal, which does much of the research work on eucalypts in South Africa. The Wattle Research Institute is the producer of the *Handbook on eucalypt growing* which is frequently referred to in the present manual. Growers can also obtain advice from a number of publications of the Department of Forestry (Poynton, 1960, 1971; Garnett, 1973; Keet *et al.*, 1974).

An important part of the contribution made by South African growers and research officers is in demonstrating the way that careful treatment of the coppice shoots coming from the stools enables material of higher quality and value to be obtained from a coppice crop (see Chapter 5).

Spain

Spain, lying roughly between latitudes 36°N and 43°45′N, ranks third after Brazil and India in total area planted to *Eucalyptus* species. To the end of 1973, some 390 277 ha had been planted to this genus, not counting line plantings. Two regions are important — the southwest with 269 029 ha planted, and the northwest along the Cantabrian and Atlantic coasts with 120 998 ha. Large-scale planting in the northwest is solely with *E. globulus*, whereas in the southwest both *E. globulus* and *E. camaldulensis* are important. Figure XIV gives the location of the main eucalypt-growing provinces.

In the southwest, the climate is decidedly Mediterranean, with light to moderate winter rainfall, a sharp 3- to 4-month summer dry season and a mean annual precipitation of 450-700 mm. The northwest is typified by a mild Atlantic climate. Most rainfall in this region also occurs during the cool season, but there is a spring peak and considerable summer rainfall as well, raising the mean annual precipitation to 1 000-1 500 mm and providing near optimum climate conditions for the growth of *E. globulus*. Climatic data from representative stations in the two regions are given in Table 4.38.

In the southwest, soils are slightly acid sandy clays, often shallow and stoney with lithosol inclusions, on shale parent material of Cambrian and Silurian origin. They are designated red Mediterranean soils on the Soil Map of Europe (FAO, 1965). The terrain is undulating, with elevations ranging from see-level to 660 m; alluvial soils occur along valley bottoms. The northwest is more mountainous with elevations reaching 1 000 m a.s.l. but most eucalypt planting is in the coastal region below 350 m. Acid brown forest soils of sandy to medium texture are found along the coasts of Pontevedra, La Coruña and Oviedo while deep, sandy-clay brown forest soils and rendzinas are prevalent in Santander.

The major use of *Eucalyptus* wood in Spain is for pulp. Other important industrial uses are sawnwood, particle board, parquet, mine-timbers and essential oils. Protection and amenity benefits are also important.

The first eucalypt introduced to Spain was *E. globulus*, around 1880. Comparative trials of Australian and South American seed of this species were made shortly thereafter.

Table 4.38 Climatic data from some representative meteorological stations in Spain

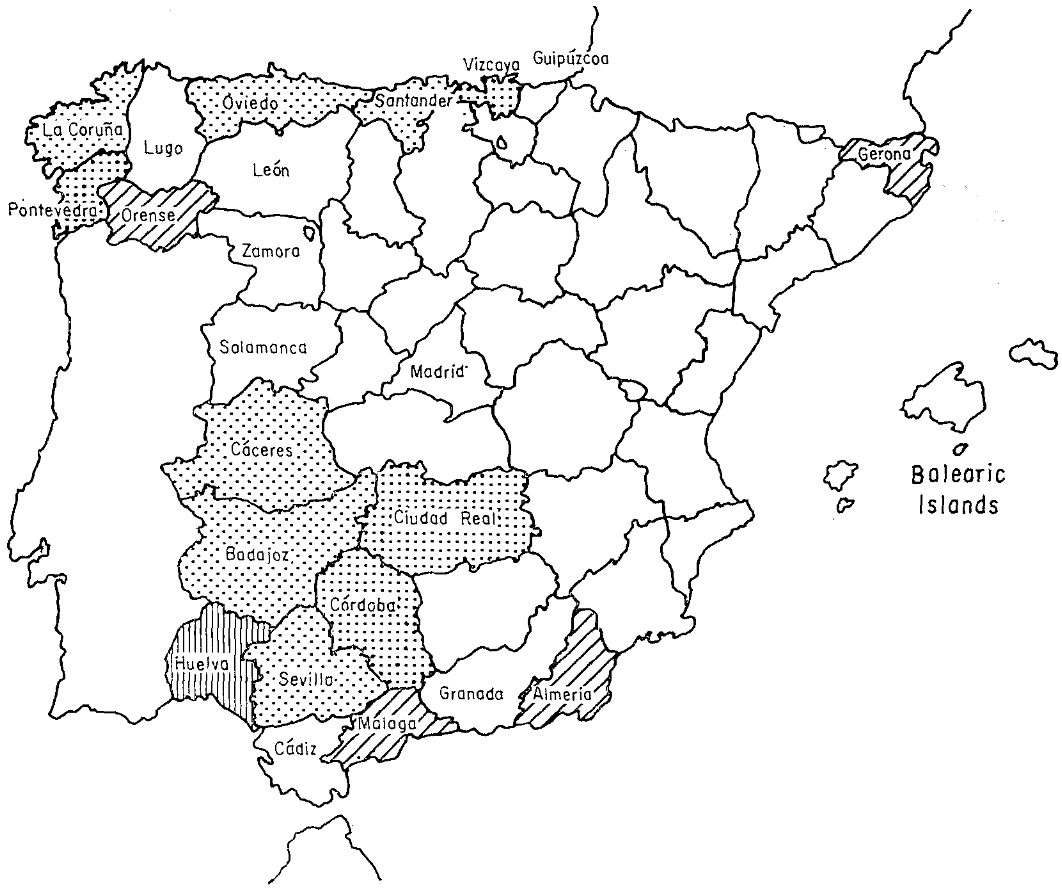
Station	Station location			Temperature (°C)				Number of days with frost
	Latitude (N)	Longitude (W)	Altitude (m)	Mean maximum (hottest month)	Mean minimum (coldest month)	Absolute maximum	Absolute minimum	
Southwest								
Albuquerque	39°13′	6°58′	506	34° (July)	1° (Jan.)	—	—6°	6
Sevilla	37°24′	6° 0′	30	36° (July)	6° (Jan.)	47°	—3°	5
Northwest								
La Coruña	43°22′	8°25′	67	22° (Aug.)	7° (Feb.)	34°	—3°	1
Santander	43°24′	3°49′	65	22° (Aug.)	7° (Feb.)	40°	—4°	4

Monthly rainfall (in millimetres)

Station	J	F	M	A	M	Jn	Jl	A	S	O	N	D	Mean annual
Southwest													
Albuquerque	123	90	56	62	56	39	1	10	28	39	57	21	581
Sevilla	64	62	57	59	39	9	1	4	20	66	70	84	535
Northwest													
La Coruña	117	78	95	71	56	47	30	44	76	89	128	139	969
Santander	113	91	78	89	87	66	55	81	112	131	146	154	1 202

E. camaldulensis was introduced later but the date is unknown.

In the southwest *E. globulus* is extensively planted in the Province of Huelva (133 000 ha) on alluvial and deluvial sites below 650 m altitude. It is also planted in Cáceres, Ciudad Real, Málaga and Sevilla. Mean annual increments vary from 4 m^3/ha/yr to 29 m^3/ha/yr depending on site quality and the degree of site preparation, subsoiling, cultivation and fertilization. In the northwest it is extensively planted in La Coruña (48 844 ha), Oviedo (30 617 ha), Pontevedra (8 800 ha), Santander (29 697) and Vizcaya (1 480 ha) mainly below 350-400 m elevation in the coastal zone and below 200-250 m further inland. Extension of planting to higher elevations is limited by frosts and low temperatures. Best growth is in La Coruña where increments of 30 m^3/ha/yr are reached and a figure of 20 m^3/ha/yr is considered



Huelva	180 887 ha	
Pontevedra	8 800 ha	
Ciudad Real	2 500 ha	
Córdoba	2 187 ha	
Vizcaya	1 480 ha	
La Coruña	50 334 ha	
Badajoz	48 300 ha	
Oviedo	30 617 ha	
Santander	29 697 ha	
Sevilla	20 000 ha	
Cáceres	14 546 ha	
Málaga	459 ha	
Gerona	250 ha	
Almeria	150 ha	
Orense	60 ha	

XIV Eucalypt-growing provinces in Spain

average. Limiting factors in both regions are frosts and low temperatures (which are particularly damaging to young trees), calcareous and saline soils, and sites which are either poorly or excessively drained. Salt spray is also harmful in coastal regions. Best development is on deep, well-drained, sandy-clay soils.

E. camaldulensis has been widely planted in the warm southwestern provinces of Badajoz (48 000 ha), Cáceres, Huelva (46 500 ha) and Sevilla (16 000 ha) and less so in Almería, Ciudad Real, Córdoba and Málaga. It is tolerant of light morning frosts of short duration, drought and poorly drained sites but is not adaptable to saline, calcareous or sandy soils of low water retention capacity. In Huelva and Sevilla it has been relegated to sites considered too poor for *E. globulus*, and growth without terracing or subsoiling is poor. Early results from a trial of 31 *E. camaldulensis* provenances planted in 1967 at Coto Bodegones in Huelva have shown superior growth of the Lake Albacutya source (Lacaze, 1970). Nonetheless, current planting programmes in Huelva, Badajoz and Cáceres have tended to replace *E. camaldulensis* with *E. maidenii*, which has a lighter coloured wood, better pulping qualities and faster growth. *E. camaldulensis* is not generally planted in the northwest, but trials in La Coruña have produced 12 m^3/ha/yr at 450 m elevation where frost restricts the growth of *E. globulus*.

Typical nursery practice in the southwest is to direct-sow into polythene pots or other containers before the onset of the summer dry season for outplanting during the fall and winter rains. In the humid northwest, both container and naked-rooted stock are used and nursery sowing is either in the spring or autumn for nearly year-round out-planting. Optimum size planting stock is considered to be 60 cm for dry areas and 15 cm for humid regions.

Intensive site preparation is common. On sloping terrain in the southwest, shrubs and *Quercus ilex* vegetation are cleared mechanically or by burning, and terraces at least 3.2 m wide are carved along the contour with D-7 or D-8 tractors. Before planting, the terraces are subsoiled to a depth of 60-70 cm. Subsoiling is also used on level terrain except on sandy soils where deep discing is preferred. Bedding is sometimes practised where clay horizons impede drainage. Optimum planting density for dry areas is 625 trees/ha. On slopes this results in an average spacing between terraces of about 5 m and a linear distance between trees of about 3.2 m. Terracing and subsoiling are also occasionally practised in the northwest, but less so than in the south. Normal site preparation in the northwest consists of winter burning during the dry southerly winds followed by manual clean-up of remaining debris. Planting is in holes 30 cm deep and 40 × 40 cm square at a density of 2 000-2 500 trees/ha which is suitable for pulpwood production. Weeding practice varies considerably in both regions but in the humid north soil is hilled up round the base of the trees after 6-10 months and two mowings a year are recommended; annual discing or hoeing at the start of the dry season is done in the drier south.

Rotations used are 10-12 years for *E. globulus* and 14-15 years for *E. camaldulensis*, generally with no thinning other than to reduce coppice shoots to two or three stems about two or three years after sprouting. Replanting is required after three or four harvests.

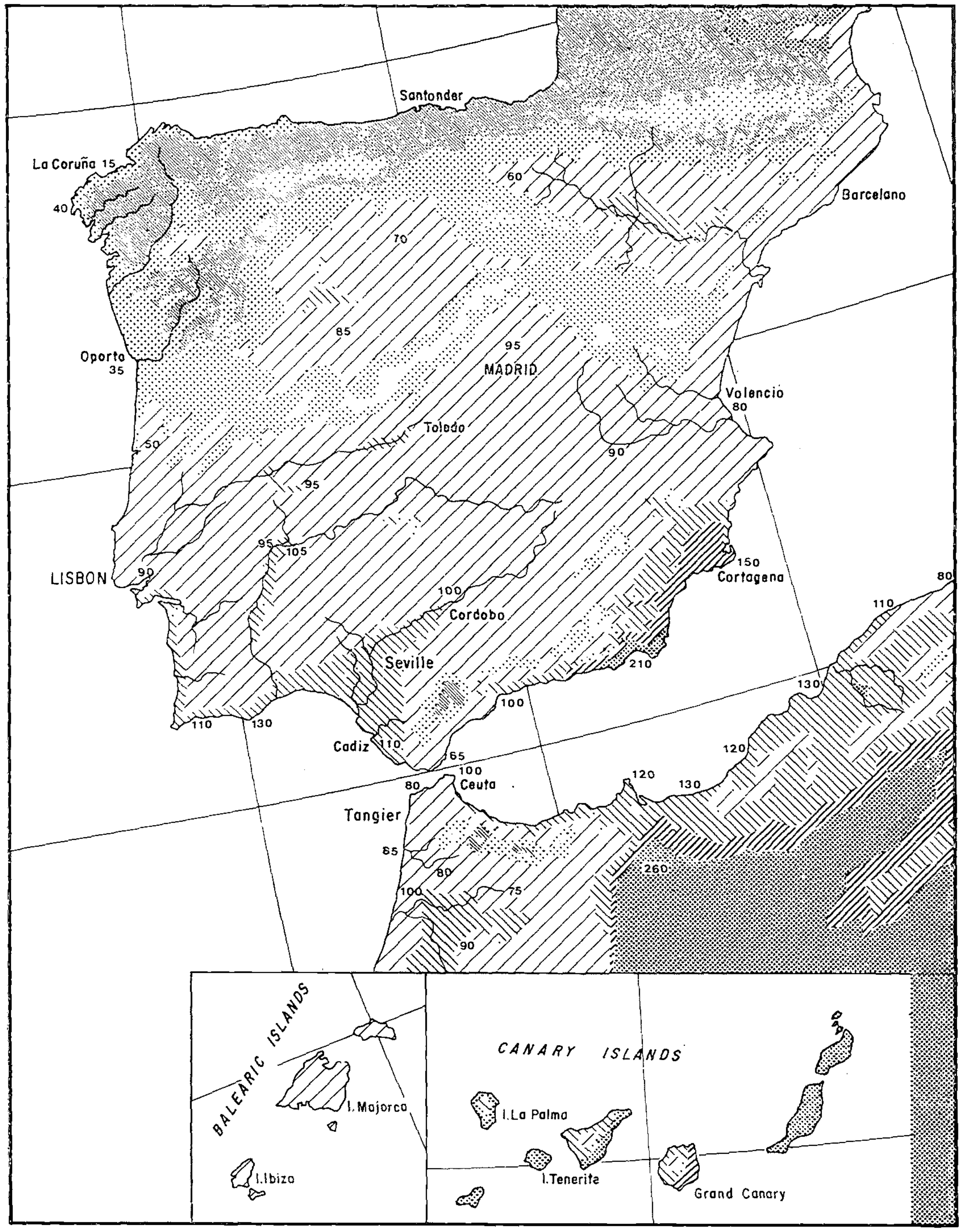
Some other eucalypts which have not as yet been planted on a large scale but which are already showing great promise in their adaptability to certain areas and climatic conditions are *E. botryoides, E. dalrympleana, E. delegatensis, E. elaeophora, E. maidenii* and *E. viminalis*. Remarks on size and location of plantings and observations on performance of these species can be found in the following pages.

Promising eucalypts

Species	Remarks
E. botryoides	Best eucalypt for the arid zone along the Golfo de Cadiz in Huelva, where 32 ha have been planted. Also promising in other southwestern provinces.
E. dalrympleana	About 300 ha planted in the northeast province of Gerona on alluvial soils from 100-800 m altitude and rainfall of 800-1 000 mm. Basic soil is an apparent limiting factor. Also promising in the northwest and in Cáceres and Badajoz.
E. delegatensis	60 ha planted in Orense; susceptible to frost. Under investigation in many northwestern provinces.
E. elaeophora (possibly a *E. elaepohora* × ? hybrid)	Planted at spacings of 3 × 1.5 m on arid, sandy sites along the Golfo de Cadiz in Huelva for the production of essential oils. Trials are also under way in other southwestern provinces and in Vizcaya and Santander.
E. maidenii	Being planted at annual rate of 2 000 ha in Badajoz (3 000 ha planted to the end of 1973), and less so in Cáceres as a replacement for *E. camaldulensis*. Also introduced to Huelva on sites too cold for *E. globulus*.
E. viminalis	Has resisted cold and 4-month dry season in northern Huelva where 1 200 ha have been planted at 650 m altitude on non-terraced and non-subsoiled sites (*E. globulus* is preferred where terracing or subsoiling is done). In La Coruña at 450 m elevation, where cold limits *E. globulus*, it has grown well in mixture with *E. camaldulensis*. The combined area is 1 500 ha and the MAI 12 m^3/ha/yr. Also promising in other northwestern provinces and in Ciudad Real, Salamanca and Zamora.

Eucalypts under trial

Species	Provinces
E. bicostata	Badajoz, Cáceres, Cadiz, La Coruña, Lugo, Orense, Pontevedra
E. gomphocephala	Almería, Cadiz
E. grandis	Huelva, Pontevedra



Bioclimate	Symbol	t	x	Season
Desert and sub-desert		> 0	> 200	U/W
Xerothermomediterranean		> 0	150-200	W
Thermomediterranean		> 0	100-150	W
Mesomediterranean		> 0	40-100	W
Submediterranean		> 0	0-40	W/U
Axeric temperate		> 0	0	U
Axeric cold		< 0	0	U

Notes:

1) t = mean temperature (0° Celsius) of the coldest month.

2) x = xerothermic index, the number of "biologically" dry days during the dry season.

3) season= the season of maximum rainfall W = winter, U = uniform

For fuller details of method see UNESCO/FAO 1963

XV Bioclimatic map of the Iberian Peninsula and northwest Africa

E. gunnii	León, Santander, Zamora
E. macarthurii	Guipúzcoa
E. niphophila	Guipúzcoa, León, Zamora
E. nitens	Guipúzcoa, Vizcaya
E. obliqua	La Coruña, Lugo, Orense, Pontevedra
E. occidentalis	Almería
E. radiata	Salamanca
E. regnans	Santander, Vizcaya
E. rubida	Badajoz, Cáceres, Ciudad Real, Guipúzcoa, Santander
E. sideroxylon	Badajoz, Cáceres, Cadiz, Huelva
E. stellulata	Guipúzcoa

Sri Lanka

Sri Lanka is a large island in the Indian Ocean off the southern tip of the subcontinent of India and is separated from India by a narrow strip of shallow water, the Palk Strait. Sri Lanka is situated between 5°55'N and 9°50'N latitudes. The greater part of the island consists of lowlands extending from the coast to an elevation of 300 m. The remainder, about 20 percent of the land area, is mountainous country located centrally toward the south of the island. The central mountain massif plays an important part in determining the climatic conditions in Sri Lanka. It is covered with montane evergreen forest and some grassland. A considerable proportion of the forest has been cleared for tea plantations.

Eucalypts have been planted in Sri Lanka for about a century and are intended to meet the following domestic requirements: sawntimber, railway sleepers, transmission poles, firewood and the supply of essential oils.

They are also planted as windbreaks and shelterbelts in the montane zones, and it is proposed to use them for the manufacture of pulp and paper in the future.

The total area planted up to the end of 1973 was 8 296 ha. The main species planted are *E. camaldulensis* in the drier zones, and *E. grandis* which is known as "saligna gum", *E. robusta, E. microcorys* and *E. citriodora. E. grandis* (*saligna*) grows very well in the higher country and hybridizes with *E. robusta.* There are very fine plantations of *E. microcorys* in the higher country and this species provides railway sleepers, transmission poles and sawntimber. The railway sleepers and poles are treated with creosote and are easy to impregnate. *E. microcorys* is more difficult to establish than *E. grandis* and requires fertile soil. Its rate of growth is somewhat less than that of *E. grandis* *E. robusta* grows very well and produces firewood and transmission poles at a rotation of 15-20 years and sawnwood between ages 35 and 50. It is normally thinned at age 15 with 15-30 percent of the basal area thinned. It has good form, makes a dense canopy and coppices very well. Other promising species are *E. deglupta, E. cloeziana* and *E. regnans*. *E. deglupta* promises to be successful in the most fertile areas of the wet zones in the lowlands. *E. regnans* has done well at elevations about 1 500 m. Fire is a danger particularly in the higher grasslands, and normal fire precautions must be taken to control the menace.

Sudan

The Sudan, extending from latitude 3°36′N to 22°N, takes water for irrigated plantations from the River Nile.

By 1969 there was a total area of 7 560 ha of eucalypts, largely irrigated plantations of *E. camaldulensis* and of *E. microtheca*, which are among the most important plantations of this species in the world.

The soils on which these irrigated plantations are established are heavy, cracking, clays with a high pH value. *E. microtheca* is well suited to this soil type; *E. camaldulensis* tolerates flooding but is not accustomed to soils of high pH. In the Sudan it develops chlorotic symptoms in the irrigated clays at an early age. *E. gomphocephala* is another species which shows early promise but is short-lived. Other species recommended for trial by Pryor (1964b) are *E. intertexta, E. melanophloia, E. largiflorens* and *E. ochrophloia.*

Apart from the Nile region the Sudan has plantations in the Nuba mountains, where *E. citriodora* is promising in a 600-mm rainfall region.

A series of trials of provenances of *E. camaldulensis* from 8 localities has been established on the piedmont or ash soils of Jebel Marra in a locality with a 6-month dry season and a rainfall of about 800 mm. The provenances are: (1) New South Wales, (2) Victoria, (3) Queensland, (4) Adelaide, (5) Western Australia, (6) Alice Springs, NT 391, (7) Alice Springs and (8) Mortagello (possibly ex-Morocco). The results of the trials, according to the locality numbers, are shown below:

Dominant height after 2 years	Straightness [1] after 11 years	Resistance to die-back [1] and survival after 11 years
(2) 431 cm	(6) 2.0	(6) 0.5
(1) 426 cm	(1) 2.3	(3) 0.8
(6) 362 cm	(2) 2.3	(5) 0.8
(4) 352 cm	(7) 2.3	(7) 0.9
(3) 351 cm	(3) 2.5	(1) 1.6
(7) 351 cm	(5) 3.3	(4) 1.9
(5) 347 cm	(8) 3.5	(8) 2.0
(8) 345 cm	(4) 4.5	(2) 2.1

[1] The plots were scored visually from 1-5 with the lower number indicating a superior position. Provenance 6 (Alice Springs, NT 391) appears the most suitable.

Swaziland Swaziland in southern Africa is a mountainous country with an average altitude of more than 1 000 m. Its latitudinal range is from approximately 27°S to 24°S. Swaziland had established by 1973 2 943 ha of *Eucalyptus* plantations, mainly *E. grandis* and *E. saligna,* to provide fuelwood, house-poles and industrial wood. Its planting practice closely follows that of South Africa.

Tanzania Tanzania, an East African country facing the Indian Ocean and extending from 1°S to 11°45′S, had by the end of 1973 established a total of 2 744 ha of eucalypts. The main species planted are *E. saligna, E. maidenii, E. grandis, E. robusta, E. tereticornis* and a eucalypt from Zanzibar which may be a hybrid between *E. tereticornis* and *E. camaldulensis* and which produces a very straight stem.

The establishment of eucalypts on the lowlands of Tanzania is made difficult by the attacks of termites. On higher land there are very fine plantations, including those at the well-known arboretum at Lushoto. Research has been carried out on low-latitude provenances of *E. camaldulensis* and *E. microtheca,* with the latter species showing promise of resistance to termites.

The eucalypt plantations serve to supply poles, firewood, windbreaks, shelterbelts and erosion control. It is anticipated that in future they will also be used for pulp and paper manufacture. Tanzania is noted for its work on honey production and the eucalypts have been found to be suitable for this purpose.

It is necessary to treat poles and fencing timber against the attacks of termites by either dip or pressure treatment. Both copper chrome arsenic (CCA) and creosote preservatives are satisfactory.

Trinidad and Tobago Trinidad and Tobago are islands in the Caribbean Sea at latitude 10°N. A number of eucalypt trials have been established, including *E. camaldulensis, E. deglupta, E. marginata* and *E. robusta.*

Tunisia Tunisia is one of the important eucalypt-planting countries in North Africa. Lying between latitudes 30°N and 37°N it has a moist climate in the north, with rainfall varying from 600 to 1 000 mm; in the central part the rainfall varies from 300 to 600 mm; the southern part is arid with a rainfall of 100 to 300 mm.

In the north there are considerable areas of young soils of a sandy or clayey nature, sometimes reddish and sometimes brownish, which are not calcareous. These are in the zones of better rainfall and suit *E. camaldulensis. E. viminalis* has been planted in the northern areas as an alternative species to *E. camaldulensis* on slightly calcareous soils. Heavy calcareous clay soils also occur which have proved unsuitable for eucalypt plantation establishment. In the central, drier parts the soils are largely calcareous. Here *E. camaldulensis* suffers from chlorosis after a few years, but *E. gomphocephala* has been successful. In addition to this species, trials of the somewhat lime-tolerant *E. leucoxylon* and *E. sideroxylon* have been recommended (Pryor, 1962). Small stands of these two species at present exist at Djebel

Mrifeg on calcareous clay soils. In the dry southern region *E. occidentalis* succeeds on soils which are slightly salty and on heavy calcareous soils, together with *E. astringens, E. microtheca, E. salmonophloia* and *E. torquata*, which are also planted. Trials with *E. salubris* and *E. striaticalyx* have been recommended (Pryor, 1962).

Recently the plantations of *E. camaldulensis, E. gomphocephala, E. maidenii, E. saligna* and *E. viminalis* have been severely attacked by the Australian beetle *Phoracantha semipunctata.* Remarkable progress has been achieved in Tunisia on restricting the attacks of this beetle by phytosanitary work in the plantations using trap trees treated with sex attractants. This work is discussed in Chapter 9. Species more resistant to the insect are also being planted at an increasing rate (e.g., *E. astringens*).

By the end of 1974, approximately 42 000 ha of eucalypts had been planted in Tunisia in the three main planting regions, broken down as follows: north, 30 000 ha; centre, 7 000 ha; and south, 5 000 ha.

Turkey

Turkey is situated in the eastern Mediterranean and is surrounded by the Mediterranean Sea, the Aegean Sea and the Black Sea. Its latitudinal range is from 37°N to 42°N.

By the end of 1973 Turkey had established about 10 770 ha of *Eucalyptus* forests, nearly all *E. camaldulensis*, and plans to extend the plantation area by 250 ha per year.

The aim of establishment of plantations is (*a*) to assist the drying out of swamps, to stabilize moving sand dunes and to protect inland country from sea winds, and (*b*) to produce fuel and posts, sawnwood for packing cases, poles for building framework and pulpwood for the paper industry.

Turkey has, in general, the characteristics of a Mediterranean climate, having dry summers, but the inland regions of Turkey are cooler than the usual Mediterranean coastal climate.

E. camaldulensis, brought to Turkey in 1885, was from the earliest days successful. Other promising species tried in experimental plots in Turkey are *E. saligna, E. grandis, E. tereticornis, E. botryoides, E. bicostata, E. globulus, E. viminalis, E. gomphocephala, E. maculata* and *E. blakelyi.*

Uganda

Uganda, an East African State lying across the equator between 1°30′S and 4°N, consists mainly of a plateau, between 1 370 and 1 520 m high, dissected by numerous lakes, streams and swamps. The plateau is bounded on the west by the escarpment falling away to Lakes Edward and Albert. Between these lakes the Ruwenzori mountains rise to 4 875 m. In the southeast the country borders on Lake Victoria. In the east the plateau continues in Kenya and is dominated by the three mountain masses of Elgon (4 300 m), Kadam (3 048 m) and Moroto (2 956 m). The country is roughly bisected by the Upper Nile.

The climate is humid and warm, with average rainfall of 1 000 mm or more. South of latitude 2°N the rainfall pattern has two peaks, in March/May (long rains) and September/November (short rains). The main dry season is December to March. The annual means of daily maximum temperature lie between 27 and 29°C, and daily minimum temperatures between 15 and 18°C; average humidity ranges from 60 to 80 percent.

Eucalypts were originally introduced to Uganda to provide fuel near administrative centres but are now grown for the following end uses:

fuel for tobacco-curing, for domestic and industrial purposes (e.g., tea and sugar drying, baking, etc., charcoal for steel and cement manufacture); to provide posts and poles for fencing and electricity transmission; for building mud and pole houses; for aesthetic uses in towns; and for shelterbelts in flatlands where wind is destructive.

By December 1975 there were 11 528 ha of eucalypt plantations in Uganda, not including small woodlots and ornamental and roadside shade trees.

Soil has not yet been found to be a limiting factor to growing eucalypts in Uganda except that waterlogged soil must be drained before planting, and after planting the drains must be kept in good condition.

Eucalypts have been established in the following vegetation types:

— Papyrus swamps where the water table is permanently above the surface. This type can be used after draining and mounding.
— Moist-deciduous forests of low altitude.
— Moist-evergreen forests of medium altitude.
— Mountain forest association.
— *Combretum/Terminalia/Albizia* associations.
— *Acacia/Combretum* associations.
— Tree and grass savannas.

Nursery and establishment practices conform to the more rigid practices described in Chapter 5. The main species used are *E. grandis, E. tereticornis, E. paniculata* and some *E. robusta.* A local hybrid believed to be *E. grandis* × *E. tereticornis* is more resistant to drought than *E. grandis.* The Zanzibar strain of *E. tereticornis* (or *E. tereticornis* × *E. camaldulensis*) is fairly widely planted. *E. urophylla* is showing promise. Many other trials have been made (Kriek, 1970).

None of the eucalypts regenerate naturally except where conditions are very good such as deep cultivated areas. The main species planted coppice well.

United Kingdom

Most eucalypts would normally be killed by the low temperatures experienced each year in the United Kingdom. Nevertheless several of the species which tolerate cold conditions in Australia survive and even thrive in protected places in parks and gardens in the southern countries of England and also in sheltered valleys in western Scotland which have the modifying influence of the Gulf Stream. Sheffield Park in Sussex has splendid individuals of *E. gunnii.* Several cold-country species included in the cold tolerance table in Chapter 13 are found in western Scotland, and a specimen of *E. urnigera* in a park there could be considered as one of the "noble trees" of the genus. Species with attractive leaves, such as *E. cinerea* and *E. perriniana*, are grown commercially in gardens or hot-houses and sold in florists' shops to supplement floral exhibits.

United States

The United States, excluding Alaska which is too cold for eucalypts, covers a range of latitude a little less than 20°N (Hawaiian Islands) to 49°N. The country has experimented with eucalypts in several of the 50 States. Initial plantings were made in California and the Hawaiian Islands in 1853. The aim of initial plantings was timber production, but there was early disenchantment with this objective because of conversion problems connected with the strain gradients along and across the trunks and the hardness of the wood — the same problems that have beset many countries. The early secondary objective of shelterbelts has usually proceeded satisfactorily and now the genus is planted for windbreaks, shelterbelts, fuelwood and as a low-cost source of hardwood fibre. There were at the end of 1973 approximately 110 000 ha of eucalypt plantations in the United States: 12 000 ha in Hawaii, 80 000 ha in California and 18 000 ha in other states. At least 60 percent of the area planted is in the form of line plantations.

In California eucalypts are planted on a wide variety of soils; the limiting factor for successful growth is temperature, not soil. In coastal areas they are planted on deep residual soils or pan soils of the valleys, also in foothills with a natural vegetation of grass or oaks. Some plantings have been made on old cut-over Douglas fir sites but for the most part the eucalypts are planted on essentially treeless areas.

In southern Florida eucalypts are planted on histosols, wet organic soils. The limiting factor is again temperature. Numerous trials were started in 1972 to identify eucalypts frost-hardy enough to survive and show satisfactory growth and form in the southeastern coastal plain on upland sites suitable for wet-weather logging. Five-year results (Hunt and Zobel, 1978) show that several species, sources and individuals within sources have demonstrated a potential for the production of large volumes of hardwood fibre. Of those tested, the four most promising species are *E. viminalis, E. nova-anglica, E. macarthurii* and *E. camphora.* The best trees of the most hardy sources are being used as a genetic base for a tree improvement programme.

In Hawaii, 82 species of eucalypts are grown on a variety of sites ranging from dry, lowland vertisols to upland histosols and inceptisols developed on recent lava and ash deposits. Most plantations were established in the 1930s to reforest deteriorated native and exotic shrubland. Some were established earlier for fuelwood in grassland areas, and in recent years for timber in native forest areas. *E. robusta, E. saligna* and *E. globulus* are the principal species currently utilized for sawnwood and for fibre.

Nursery practices and plantation establishment are essentially within the ranges discussed in Chapter 5. In Hawaii planting is posible most months of the year and bare-rooted planting may be used.

Table 4.39 Climatic data for main eucalypt planting areas (USA)

	Coastal California	Southern Florida	Hawaii
Latitude	37°37′	25°48′	18°-22°
Total rainfall (mm)	510	1 500	2 500
Number of rainy days	62	127	148
Mean maximum temperature of hottest month (°C)	22° (July)	32° (July)	25° (July)
Mean minimum temperature of coldest month (°C)	6° (January)	14.5° (January)	15° (January)
Number of days of frost	6	0	0
Occurrence of snowfall	1	0	0

Table 4.40 Eucalypt species of proven value (USA)

Species	State where used	Uses [1]
E. botryoides	Hawaii	T.W.
E. camaldulensis	California, Hawaii, Arizona	T.W.E.
E. citriodora	Hawaii	T.E.
E. dalrympleana	California	E.
E. deglupta	Hawaii	T.W.E.
E. delegatensis	California	E.
E. fastigata	California	E.
E. globulus	California, Arizona, Hawaii	S.E.T.W.
E. grandis	California, Florida, Hawaii	S.E.
E. microcorys	Hawaii	T.W.
E. nitens	California	E.
E. paniculata	California, Hawaii	S.E.T.
E. pilularis	California, Hawaii	S.E.T.
E. regnans	California	S.E.
E. resinifera	Hawaii	T.W.
E. robusta	California, Florida, Hawaii, West Indies	S.E.T.W.
E. saligna	California, Hawaii	S.E.T.W.
E. sideroxylon	California, Hawaii	S.E.T.
E. viminalis	California, Hawaii	S.E.T.

[1] Note on uses: T, Timber. — W, Watersheds. — S, Shelterbelts. — E, Environmental forestry.

When planted for fibre production a rotation of seven to ten years is now common, but as yet coppice regeneration for the next crop is not common practice.

While eucalypt wood is a minor part of the huge American fibre industry, some 16 firms in the San Francisco area use it.

The United States has experimented with approximately 250 species of eucalypt, the vast majority being grown for landscape purposes. The regions where various species are successful and their climatic factors are found in Tables 4.39 and 4.40.

Upper Volta

Upper Volta is a land-locked West African country with a latitudinal range from 9°N to 15°N, mainly savanna. The first eucalypts were introduced in 1935. The area of eucalypt plantations by 1976 was 933 ha, 90 percent of which were planted in 1975 and 1976. Provenances of *E. camaldulensis* from Gilbert River (Queensland) and May River Crossing (W. Australia) have performed best.

Uruguay

Uruguay, situated on the east coast of South America between latitudes 30°S and 35°S, is a land of rolling pastures and fertile soils. frequently of the loess type deposited by winds blown from the Andes. The climate is humid and mild with a rainfall of about 1 000 mm and no decided rainy or dry seasons.

The principal eucalypt planted is *E. globulus*, followed by *E. camaldulensis* and *E. tereticornis*. All were first planted over a hundred years ago, from seed of unknown origin, to provide shade and shelter for cattle, to serve as windbreaks, and to provide fuelwood and fenceposts. Later, introductions of *E. saligna* and *E. grandis* showed superior growth, and they are now likely to become the most important species for future industrial plantations.

Eucalyptus has become the cheapest, most abundant and most used wood grown in Uruguay. By the end of 1973, 111 123 ha of eucalypts had been established, of which 15 percent were line plantings, and *Eucalyptus* timber production reached 1 004 700 m^3 made up as follows:

fuelwood, 820 000 m^3; sawnwood, 79 000 m^3; pulpwood, 70 000 m^3; posts, 25 000 m^3; other fibre products, 10 700 m^3.

Eucalypts have been established on most soil types throughout the country, but the principal plantations are sited on deep soils south of the Rio Negro. Inferior growth occurs on poorly drained sites and shallow soils, particularly those of basaltic origin. Planting is with containerized stock in furrows or holes at spacings of 2 × 2 m to 2 × 3 m, and more usually 2.5 × 2.5 m. Rotations are from 10 to 12 years, generally without thinning, and 5 to 7 clear-felled coppice crops are obtained before replanting is necessary.

Table 4.41 Site requirements and yields of main eucalypt species (Uruguay)

Species	Area planted	Remarks
	ha	
E. globulus	55 000	Planted mainly south of the Rio Negro on many soils except poorly drained or shallow ones. On favourable sites a growth rate of 25 m^3/ha/yr is common.
E. camaldulensis and *E. tereticornis*	39 000	Planted on many soils throughout the country, but especially north of the Rio Negro. Both species, but especially *E. camaldulensis*, are adaptable to droughty shallow soils and waterlogged sites. Under favourable conditions, growth of 18 m^3/ha/yr is reached.
E. saligna and *E. grandis*	10 000	Planted throughout the country with a tendency to locate industrial plantations north of the Rio Negro. Best sites are deep, sandy soils along the Rio Uruguay where growth rates are typically 35-45 m^3/ha/yr.

Tables 4.41 and 4.42 summarize information on the site requirements and yields. Species found unsuitable for large-scale planting in Uruguay are: *E. amplifolia, E. cladocalyx, E. delegatensis, E. leucoxylon, E. macarthurii, E. regnans, E. viminalis.*

Table 4.42 Promising secondary eucalypt species (Uruguay)

Species	Remarks
E. bosistoana	Good performance in the northeast
E. botryoides	Fast-growing, adaptable species of good form
E. gomphocephala	Recommended for calcareous sites
E. maidenii	Good performance in the northeast
E. punctata	Very adaptable
E. sideroxylon	Mainly used in the south for fenceposts
E. smithii	Good performance in the northeast

Union of Soviet Socialist Republics

The USSR has experimented with the introduction of eucalypts for more than 150 years, mainly for the purpose of providing shelterbelts for tea and citrus plantations in Georgia and other southern areas. At one stage the area planted to eucalypts reached 7 000-10 000 ha but most were killed in the severe cold of the winter of 1949/50, when temperatures fell to —30°C in these areas. Some of the trees killed were *E. viminalis*, which had survived for 70 years. The species most likely to survive are *E. viminalis, E. macarthurii, E. cinerea, E. delegatensis, E. dalrympleana, E. nitens, E. robertsonii, E. urnigera, E. rubida, E. gunnii, E. aggregata, E. stellulata* and *E. coccifera*. The area planted to eucalypts was 2 300 ha in 1957, of which 1 300 ha were shelterbelts (Linnard, 1969).

Apart from using eucalypts in tree form, the USSR has done work on leaf production for essential oils by machine-cropping young coppice of important oil-bearing species. This work is described in Chapter 10.

Venezuela

Venezuela lies on the north coast of South America, adjoining the Caribbean Sea, with a latitudinal range from 0°45′N to 12°12′N. It has a wide variety of conditions, including rain forest, savanna and mountains.

Trials of a large number of eucalypt species have been conducted over the past decade. Subject to the results of these trials, there are possibilities for large-scale planting in the savanna areas north of the Orinoco for production of charcoal for the metal industry.

Western Samoa

Western Samoa consists of 11 mountainous, volcanic islands in the South Pacific between latitudes 13°S and 14°S. These fertile islands, though small in size, are interested in eucalypt plantations to provide fuel and poles and, if possible, sawnwood in the future. The administration has experimented with several eucalypts and of these *E. grandis, E. deglupta, E. robusta, E. torelliana, E. urophylla* and a provenance of *E. tereticornis* from Cook Town in north Queensland have done well in trials. *E. deglupta* has done particularly well in all trials.

Yemen Arab Republic

The Yemen Arab Republic is situated on the northern side of the entrance to the Red Sea. It has a latitudinal range of from about 13°N to 17°30′N, and has a high plateau with some of the most fertile lands in the Arabian Peninsula.

Dry-country eucalypts have been planted for environmental purposes and may become valuable plantation species for fuelwood, posts and poles as well as windbreaks and shade trees (Beskok, 1974).

Yemen, People's Democratic Republic of

The People's Democratic Republic of Yemen is situated on the northern side of the Gulf of Aden. It has a latitudinal range from 13°N to 19°N.

Twenty-seven species of *Eucalyptus* from Australia were introduced in 1965 through the Agricultural Research Centre at El-Kod. Growing stock was produced in the nursery and all species were planted in half an acre at the research farm. About one acre-foot of irrigation was given at pre-planting and a similar amount in the post-planting period. No further irrigation was given in subsequent stages. In 1968 enumeration was conducted and out of 27 species, *E. camaldulensis* was selected for propagation and planting on a larger scale and in 1970 was planted for the first time as windbreak at the Lenin State Farm, Abyan Delta. Statistical data collected on growth and yield of six-year-old plantations of *E. camaldulensis* gave an average height and diameter of 15.1 ± 4.6 m and 19.2 ± 3.1 cm, and a coefficient of variability of 30 and 16.1 percent respectively. An average of wood production per kilometre of standing trees' overbark was estimated at 117 m^3 under irrigated conditions. Similarly, the same species planted in November 1973 at Amgibla State Farm at 960 m altitude showed superiority over other species. In areas having strong winds, *E. camaldulensis* was harmed on the windward side at the incipient stages.

In 1973 a new experiment was laid out for *E. camaldulensis* from four provenances (Pakistan, Syria, India and local); statistical analysis has showed no significant differences between them. Possibly all of the provenances belonged originally to the same population in Australia.

In 1974 another 18 species were introduced and planted in randomized plots and blocks. Statistical analysis showed that *E. camaldulensis*, Iraq provenance, and *E. cornuta* and *E. occidentalis* are better, faster growing and most adaptable. However, these are preliminary results and further research is still going on. It may be concluded that the climatic and edaphic conditions of the country are suitable for growing *Eucalyptus*, but introduction trials under different climatic zones are needed to determine the most appropriate species for various products.

Zaire

Situated in central Africa, with a latitudinal range from 5°N to 13°S, Zaire has large areas both of closed tropical forest and of savanna. The area of eucalypt plantations reported as established by 1965 was 5 000 ha (FAO, 1967a).

Trials of several eucalypt species have been made on infertile, acid sandy soils near Kinshasa, for supply of fuelwood to the city. The most promising species was *E. camaldulensis* (provenances from Gibb River in Western Australia, Irvinebank and Maxwelton in Queensland), followed by Queensland provenances of *E. tereticornis* and *E. torelliana*. *E. citriodora* performed poorly on these soils, although it grows well as an ornamental tree in the city.

Zambia

Zambia, a large land-locked republic in southern central Africa, has a latitudinal range of from 8°15′S to 18°S. It is an elevated country lying on the plateau of Central Africa and its climate is less tropical than might be suggested by its latitude. The natural vegetation is savanna woodland of *Brachystegia* spp. (and others).

Eucalypts are of great interest to Zambia to provide sawtimber, transmission poles and fenceposts for the Copperbelt area. The quality of the wood obtained from the eucalypts is often poor and it is intended that as pine plantations come into production in the next ten years pine will take over as the major sawtimber source, and that eucalypt wood will be largely used for poles of different categories and possibly wood products such as particle board and wood pulp. Apart from the requirements of the industrial Copperbelt, eucalypts will be required to supply fencing poles, building poles, tobacco poles and fuel for local communities. The potential production of essential oils for local use is also being examined.

18. 3-year-old plot of the Zanzibar "C" provenance of *E. tereticornis* in Mombo Arboretum, Tanzania (latitude 4°53′, altitude 410 m, rainfall 750 mm)
R.L. Willan

By 1973 Zambia had a total area of 7 556 ha planted with eucalypts, of which 5 750 ha were industrial plantations and 1 806 ha provincial plantations.

Zambia has a long dry season from May to September in the north and from April to October in the south. On the northern plateau the mean annual rainfall is about 1 200 mm; on the central plateau it is 806 mm; on the southern plateau it is 850 mm; in the lake basin it is 1 380 mm and in the Zambesi valley 725 mm. The mean maximum temperatures of the hottest month vary from 30.1 to 35.1°C in the different sectors; the mean minimum temperatures of the coldest month from 3.3 to 10.4°C; and the absolute minimum temperatures from −6.1 to +3.9°C. The climate is suitable for eucalypt plantations of species from the summer rainfall regions of Australia.

Soils are mainly eluvial, heavily leached, with a low base status and low organic content, and frequently boron deficient.

Nursery practice is along the lines discussed in Chapter 5, with much larger containers used to support the seedlings in the provincial areas than in the better supervised industrial areas.

Coppice rotations vary from four years or more in the provincial areas to eight years in industrial plantations. The mean annual volume increment culminates at 12 years, but does not change much between ages 8 and 12.

The principal species grown are:

- *E. grandis*, which has given good results; there is little difference between the provenances tried.
- A sporadic hybrid between *E. grandis* × *E. tereticornis*, planted extensively in the southern and central plateau. It is more drought-resistant than *E. grandis* but very much less so than *E. tereticornis*.
- *E. cloeziana*, which is very similar to *E. grandis* in behaviour. Excellent form.
- *E. tereticornis*, which is the most drought-resistant species and the best volume producer in the southern plateau areas, but of poor form. There are very significant differences between provenances with regard to form and further work into this aspect is being undertaken.

Many other species are being tried. Plantation costs for Zambia are summarized in Chapter 12.

Zimbabwe See pages 119-121.

5. Establishment and management of eucalypt plantations

This second edition of *Eucalypts for planting* reports a total planted area of nearly 4 million hectares. The cost of establishing one hectare up to the third year has been reported by major planting countries as being between 300 and 600 US dollars per hectare, excluding the cost of the land. Including land costs the total investment on the first rotation must approach $2 000 million, a very substantial sum.

The greater part of the money spent on eucalypt plantations is for production forestry. Ornamental and landscape plantings, or protective plantings, such as windbreaks, important as they are, account for less of the total expenditure.

A plantation intended for production requires good seedling stock of a suitable species, adequate site preparation, sound planting methods, effective weed control and a satisfactory nutritional status in the soil. The planted trees should be able to gain rapid control of the site and should be as uniform as possible throughout areas of similar site quality. The aim should be for uniform heights and diameters during the seedling stage of the crop. There will always be some variation, but if it can be kept minimal it will add to the average quality of the end product and enable it to be harvested and marketed with greatest efficiency by the processor, and this should permit the best return to the owner.

Most eucalypt plantations will be coppiced and harvested again at intervals of from four to ten years. Coppicing may be repeated three or four times. Uniformity in the seedling stage of crops intended for coppicing is particularly important because irregularity in the seedling stage tends to be progressively exaggerated in the first and subsequent coppice crops.

Eucalypt coppice crops produce large volumes of smallwood, which in itself does not usually have a high value per unit of volume. Substantial added value is obtained if the smallwood can be processed into paper or other reconstituted products. If it is used for domestic or industrial fuel its value to a community may be high, but difficult to quantify.

Eucalypts may also be managed on longer rotations, with periodic thinning. Provided that local markets exist, thinnings may be sold for pulpwood, poles or particle board, while the final crop is used for sawtimber, plywood or veneer.

Seed

COLLECTION AND PURCHASE

Seed collecting is most cheaply done following felling in production forests. It will be found that, in an area, most seed (at least 85 percent) will be concentrated on the dominant and co-dominant trees. If collecting is done from dominant trees there will automatically be some selection for vigour (but not for form), which will not increase the cost of collection.

In seed collecting following felling the inflorescences (umbels or panicles) should be picked by hand from the branches and placed as quickly as possible in a strong bag of closely woven fabric. In warm weather the seed and chaff may shed from mature fruits in less than an hour. The bags of capsules should then be emptied out onto a clean flat surface or a tarpaulin in a warm dry situation and stirred regularly to make the seed and chaff drop out. After a few days the capsules may be sieved from the seed and chaff, which can then be stored until required for sowing in the nursery.

In natural eucalypt forests in Australia seed collectors sometimes hang fairly large branches over ropes or wires stretched between two trees and collect the seed as it falls on tarpaulins under the branches. This method may suffer from the vagaries of the weather. Other collectors cut smaller seed-bearing branches and carry them back to a protected seed-extracting unit.

The method of collecting the fruits might well depend on the wages paid to workers able to pick the individual inflorescences. Picking individual inflorescences and quickly packing them in strong tightly woven bags is the best way if it is practicable.

Seed collection from standing trees of superior phenotype in order to preserve them for future collections is becoming increasingly common. Possible methods include climbing, shooting and the use of tree shakers, extension platforms and pruners, ropes and flexible saws operated from the ground (Turnbull, 1977).

Eucalypt seed is normally stored and sold together with the "chaff" or unfertilized ovules. There are many more unfertilized ovules than fertile seed. Even the weight of unfertilized ovules is usually much more than the weight of fertile seed. Purchasers of commercial seed should understand that this is the case and ask suppliers for a statement of the unit weight (grams or kilos) of seed and chaff which will yield a given number of viable seeds.

It has become the custom over many years to buy and sell *Eucalyptus* seed on the basis of weight of seed plus chaff. A very sensible custom has also developed in recent years to send the seed internationally by air freight. A winnowing system can be arranged which will remove much of the chaff (and the weight) from the seed of most eucalypt species. This could probably be done for less than the cost of sending the chaff by air freight. There is a case for examining the advantages and disadvantages of changing the traditional system of sale. This would, of course, include the examination of whether the removal of the chaff has any deleterious effect on the fertile seed. The business of production plantations of eucalypts has become such a big business in the world that a critical examination of traditional customs would be reasonable.

Storage

The seeds of most eucalypts are not difficult to store; most can be held for several years if they are air-dried and then stored in the dark in sealed containers at a temperature of 1-4°C. An acceptable germinative capacity can be maintained for a year or two in unsealed containers at room temperatures.

Eucalypt seed is an attractive food to mice, squirrels and a variety of insects. It is advisable to clear storage bins of insect pests by applying a chemical such as paradichlorbenzene or phostoxin tablets.

Seed sold internationally may require a phytosanitary certificate from an approved authority that it has been treated against pests and pathogens.

Dormancy

Most eucalypt seeds will germinate satisfactorily at the optimum temperature, providing the seeds are viable and mature (Turnbull, 1977). A few species, particularly mountain species, such as *E. delegatensis, E. dalrympleana* and *E. pauciflora,* exhibit dormancy and require pretreatment. Dormancy is accentuated if the seed is moistened and re-dried, also if it is exposed to high temperatures and too much light.

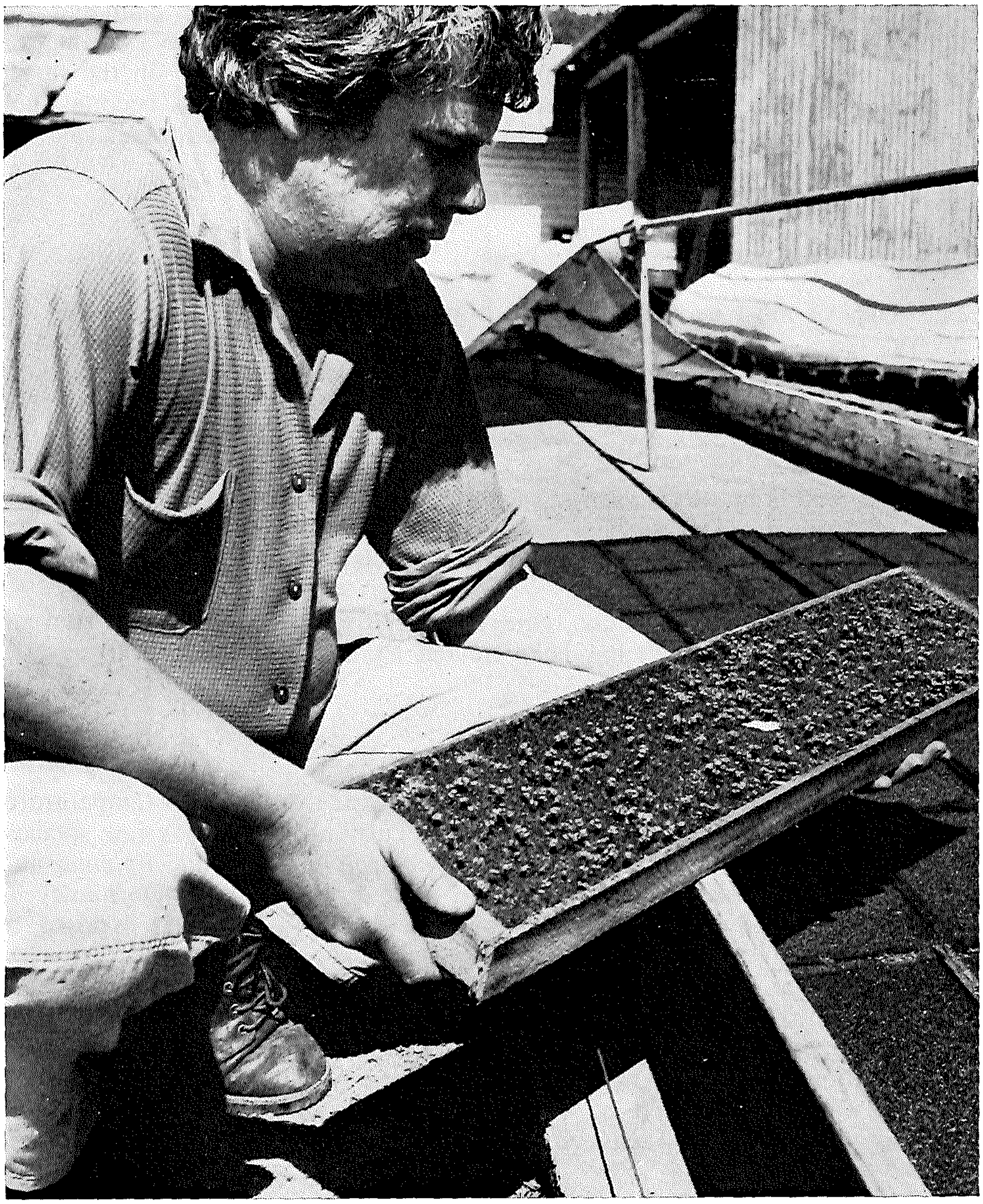
Dormancy in these species can usually be broken by storing the seed in moist dark conditions for four weeks at a temperature of 1-4°C. After this the seed should germinate in a few days. Once the seed has been treated to break dormancy it should be sown immediately, otherwise its germinative capacity will be severely reduced.

Treatment prior to sowing

Eucalypt seed may be dusted with insecticide and fungicidal powders prior to sowing, but protection against these pests is best done in the seedling trays or beds. In India it is standard practice to apply 100 g of 5 percent Aldrex dust per cubic metre of nursery bed or container soil.

Methods of raising seedlings

Eucalypt seeds are classed as small to very small tree seed. They have little reserve food to draw upon in the critical early stages after germination. Because of this they are rarely broadcast-sown in capital-intensive production plantations, although in Australian native eucalypt forests pelleted seed may be broadcast from fixed-wing aircraft or helicopters to supplement



19. Seedling trays containing germinated seedlings of *E. regnans* which will be pricked out into individual tubes (Gippsland, Victoria)
Forests Commission, Victoria

natural regeneration. For production plantations the seedlings are best raised in well-protected and well-serviced nursery establishments.

In nurseries eucalypts may be sown in trays and the germinated seedlings pricked out into the containers in which they will be taken to the field; they may be sown directly into the containers (e.g., earth pots, polythene tubes or peat pots); or they may be sown in lines in carefully prepared beds and

20. Planter boxes of *E. grandis* ready for transport after clipping back to 20 cm (Coff's Harbour, Australia)
CSIRO, Canberra Australian Paper Mills

21. Open-rooted nursery bed of *E. regnans* in New Zealand. Each bed is 1.85 m wide, contains 6 rows of plants 30 cm apart and is raised 20-24 cm above alleyway level. Trees are thinned at 4- to 6-leaf stage
New Zealand Forest Products

later root-pruned before being used as bare-rooted planting stock. Easily the commonest method is to raise the plants in some form of individual container.

Container-raised stock

The large investment in eucalypt plantations in the last two decades has stimulated research and exchange of information on nursery practice in many countries. There is now considerable uniformity in practice. Most countries make use of containers made of polythene filled with soil. Peat pots of one kind or another are gaining favour in some countries. These pots are prepared from a mixture of wood pulp and peatmoss and have the advantage that the roots pass through the walls of the pots without any tendency to root binding.

Polythene containers vary in type and size. The main distinction is between the "tube" or "sleeve," which is cylindrical when filled with soil and open at both top and bottom, and the "pot" or "bag," which is closed at the bottom. Material for tubes is supplied in rolls and can be cut to any desired length by the user. The pots are usually perforated at the bottom and sometimes also at the sides. In most countries the polythene containers are removed before the seedling and root/soil mass are planted in the field, great care being taken to ensure that the mineral soil in the field is in contact with the soil around the nursery plant.

The earth pot ("torrão paulista") described in the first edition of this book gave excellent service in Latin America for half a century, but is gradually being replaced by other containers, usually the polythene tube.

The advantage of container planting is that it gives the roots of the young seedlings an adequate volume of soil in which to survive until they can proliferate in the soil in the field. This permits the planting operation to be carried out over a reasonably long season.

Bare-rooted stock

Bare-rooted planting stock is used successfully in some moist climates, usually in fairly high latitudes; in low latitudes it is best used at fairly high altitudes. Well-known examples come from New Zealand (*E. regnans, E. fastigata, E. nitens* and *E. bicostata*); Kerala, India (*E. grandis*); Hawaii (*E. robusta*); and Australia (*E. regnans* and *E. delegatensis*). In Portugal north of the Tagus, and in the more humid regions of Spain with only a short summer drought, bare-rooted planting stock is standard practice.

If seedlings are to be planted bare-rooted, it is important that they should be carefully root-pruned for a month before planting out so that a mass of fibrous roots is stimulated. Moreover, sturdy plants and not weaklings are required, as they have more reserves to help recovery from the shock of transplanting.

In favourable localities in higher latitudes, such as New Zealand, bare-rooted planting should be done if practicable "in front of a front" — that is, just before the next low-pressure cell is expected to pass the planting area. This should give two or three days of cloudy or showery weather before the next frosts. Frosts are damaging to newly planted bare-rooted seedlings.

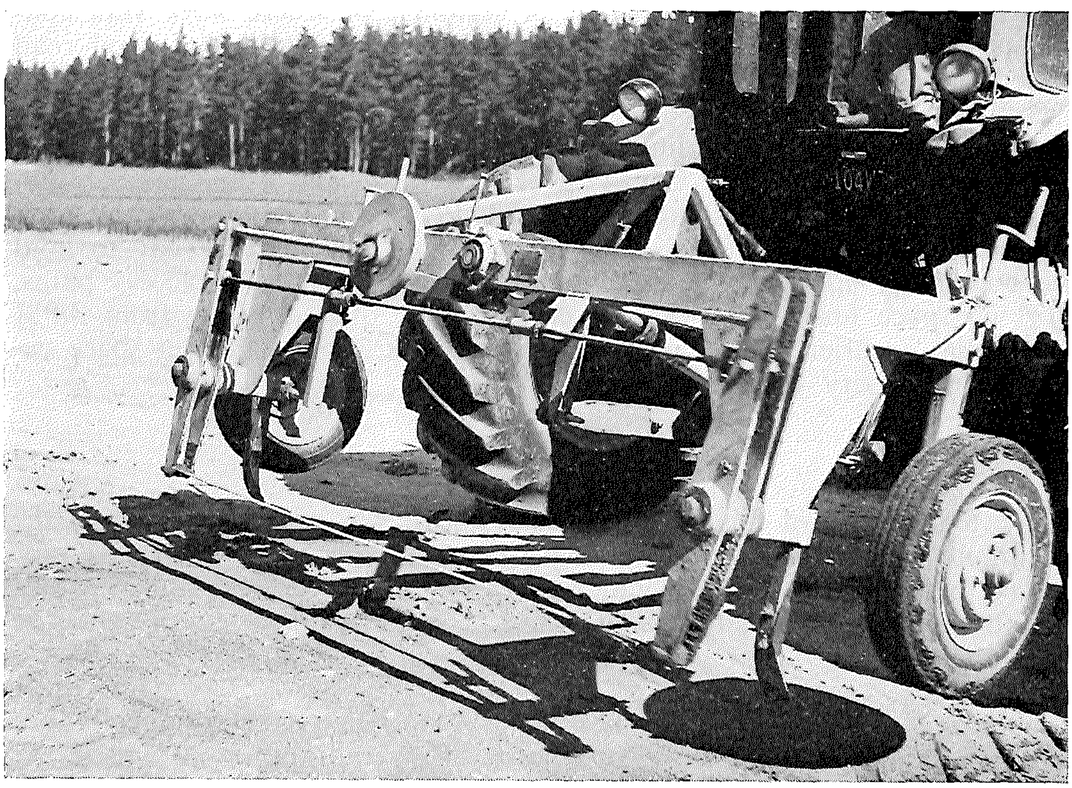
Bare-rooted planting stock is much cheaper than container-raised stock. Different Country Reports indicate that it is one third the cost of container-raised stock, an important saving. However, even if the climate is favourable enough to permit bare-rooted planting stock to be contemplated, container-raised stock might offer other management alternatives. It might prove possible to plant container-raised stock at almost any season of the year and remove the pressure of eucalypt planting at the time of another important operation, such as bare-rooted pine planting. Work might have a more favourable spread in the nursery organization. Naturally, these advantages must be balanced against the higher cost of container-raised stock.

Nursery management

MANAGEMENT FOR CONTAINER-RAISED PLANTS

General

A eucalypt nursery should be situated on a slight slope with unimpeded water and air drainage. It should have an adequate supply of water suitable, if practicable, for filtration and use in automatic fine sprinklers. It will use a considerable volume of soil each year to fill containers. It needs protec-



22. Root-pruning machine used for open nursery beds in New Zealand
New Zealand Forest Products

23. Site preparation in Nigeria: pioneer ploughing by heavy-duty offset disc-harrow plough towed by crawler tractor
T.G. Allan

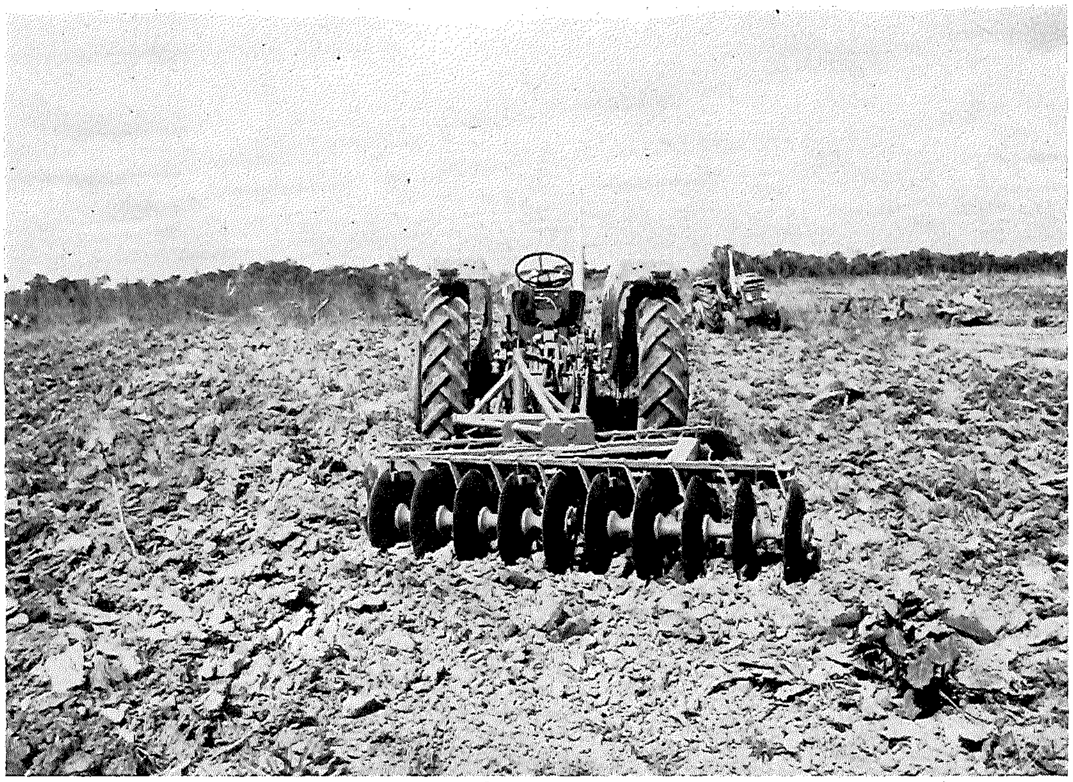
tion from animals and weeds. It must have regularly laid out beds which can be shaded from the sun when the young plants are becoming established, and protected from storms, rain or hail. It is an advantage if it is furnished with a plant house for holding trays of seedlings or where work with containers can be carried out in adverse weather. It must have a good road system to allow easy access for lorries to the container beds.

The beds (or bays) for holding container stock should be made of a convenient width and levelled. A width of 1 to 1.2 m and a maximum length of 10 m are used in Zambia (Greenwood, 1977). A low wooden or brick barrier (with a height of 4-5 cm) should be built around the bay to hold the containers upright. Plenty of space should be left for access paths, working space for labour, etc. In the example quoted below from APM (Australia) experience, the gross nursery space is 3 times the net space occupied by nursery stock.

Container size

In the first edition of this book (Métro, 1955) it was recommended that the minimum size of the "root ball," which corresponds to container volume, should be 300 cm^3. This would require 0.3 m^3 of soil for 1 000 plants. Country Reports have indicated that there is still a wide variety of container sizes.

The volume of soil in the containers is an important practical point. More soil gives added safety to the plants but is heavy to transport to and in the



24. Site preparation in Nigeria: following ploughing, tilth can be improved by preplanting harrowing with offset disc harrow drawn by wheeled tractor
T.G. Allan

field. Sometimes exceptionally large seedlings are required for planting in grassy areas (e.g., Uttar Pradesh, India). These must be grown for 8-9 months in the nursery and a large polythene pot or bag, 15 cm in diameter × 25 cm deep, is required. Even larger ones are used for growing special stock for amenity planting.

In New Zealand the Forest Service uses polythene tubes 10 cm in diameter and 20 cm long. At planting time in the field the bottom 2 cm of the tube are cut off, which removes curling roots and reduces the danger of root binding. The net nursery area required for 1 000 plants would be about 10 m^2 and the soil volume required for 1 000 plants about 1.6 m^3.

In Zambia polythene tubes 10 cm in diameter × 7.6 cm deep for industrial plantations and 15 cm in diameter × 12.7 cm deep for provincial work are used. The larger tubes are preferred for small provincial nurseries as a safeguard against less skilled nursery and plantation practices. These sizes would require 0.6 m^3 of soil for the smaller size and 2.2 m^3 for the larger size per 1 000 plants. The net bay areas for 1 000 plants would be 10 m^2 for the smaller size and 22.5 m^2 for the larger size. In South Africa the preferred polythene tube size is 6.5 cm in diameter with a depth of 10 cm giving a unit volume of around 330 cm^3. The type requires 0.3 m^3 of soil for 1 000 transplants and 4.2 m^2 of net bay area.

The peat pots used by APM in Australia, in an area with favourable planting conditions, contain only 90 cm^3 of soil. About 0.1 m^3 of soil is required per 1 000 pots. A bay covering 460 m^2 holds 171 072 pots, from which at least 154 000 plantable plants are expected. This is equivalent to a gross

25. Clean-weeded young eucalypt plantation in Nigeria
T.G. Allan

bay area of 2.7 m^2 per 1 000 pots compared with a net pot area of 0.9 m^2 per 1 000 pots.

In Nigeria, tests were carried out on the effect of pot size on *E. camaldulensis*. Pots of 25 × 8 cm (1 260 cm^3), 15 × 8 cm (760 cm^3) and 15 × 5 cm (290 cm^3) were used. It was demonstrated that, while survival and height growth declined slightly with decreasing pot size, the reduction in cost justified an immediate change from their standard 25 × 8-cm pot to the 15 × 8-cm size. Further tests were to be carried out with the 15 × 5-cm pot (Laurie, 1974).

As a result of experiments, there has been some tendency to reduce container size in order to save costs, but the most satisfactory size will still depend on the severity of local climatic conditions. The more difficult the conditions, the larger the minimum size of container.

Filling containers with soil is one of the most time-consuming nursery operations. Various devices are employed to facilitate the operation, such as using multiple funnels for individual containers and the filling of a length of tubing with soil before cutting it to final size (Barrett, 1978).

Soil mixtures and fertilization

Soil mixtures used for eucalypt nursery containers depend very much on what is available locally. Examples of different mixtures have been given by Jackson (1975) and Doran (1977). Table 5.1 is reproduced, with a few additions, from Doran who observes: "A light, permeable, non-calcareous soil or mixture which has adequate water-holding capacity, whilst still allowing good drainage, is generally recognised as the most suitable medium to grow eucalypts." Addition of organic or inorganic fertilizers is common, but not universal, practice.

The finding of suitable soil for containers and its cartage to the nursery, then the filling of containers and the transport of plants to the field are a major item of nursery costs. Foresters undertaking a substantial eucalypt-planting project should carefully examine the available possibilities and experiment with those which may improve practice or reduce costs.

Soil sterilization

Heat or steam sterilization is still reported by some countries and it works well if done well. More countries are now sterilizing moist soil with methyl bromide at a rate of one kg for two cubic metres of soil. This is an effective sterilizing agent which also kills the seeds of many weeds. The gas is applied to beds or heaps which are covered by plastic sheets for one or two days and then left uncovered for a week before use. The gas is very poisonous.

Mycorrhiza

Evidence for mycorrhizal associations in eucalypts is summarized in Chapter 9. Relatively little work has been done in this field and it would appear to be a useful area for further research. There is evidence that in the subgenus *Monocalyptus*, an ectomycorrhizal symbiont is beneficial, and this may be true for species in other subgenera. However, experience in introducing countries is that vigorous nursery stock of most eucalypt species can be raised without deliberate inoculation of the soil.

Seedling trays

One of the most common and effective ways to raise eucalypt seedlings is to germinate the small seed in trays and then to prick out the young seedlings at the stage when they are showing the second pair of leaves above the cotyledons, and plant them into containers of one kind or another. The transplanted seedlings are then held in the containers until they are ready to be planted in the field. The trays should be of a convenient size to permit rapid pricking out into the containers. A convenient size is about 53 × 20 cm. They should be filled with sterilized soil or a sterile medium such as vermiculite or perlite. If the only purpose of raising seedlings in the trays is to allow the seed to germinate and to bring the seedlings to the

Table 5.1 Examples of nursery potting mixtures for eucalypts

Country	Site	Description
Australia	Australian Capital Territory	CSIRO Div. of Forest Research - 1 part sandy loam: 1 part river sand: 1 part organic matter.
		City Parks Branch, Dept of Capital Territory uses the expensive University of California soil mixes (Baker, 1957; Boden *et al.*, 1969).
	New South Wales	APM Forest at Coffs Harbour uses a local decomposed granodiorite after finding sand unsuitable (Clarke, 1975).
	Queensland	Department of Forestry at Gympie uses a soil of sandy texture with some clay and/or organic matter.
	Tasmania	AFH in northern Tasmania uses a local sifted, basalt derived, kraznozem soil mixed with slow-release fertilizer pellets (8%N, 40%P, 14%Mg) at the rate of 2 kg per 1 000 paper pots (de Boer, pers. comm.).
	Victoria	APM Forest at Traralgon uses a fine, weed-free, sand over a complete slow-release fertilizer (18%N, 9%P, 10%K, 6%Mg_2O) placed in the bottom of the pots at the rate of 154 g per 1 000 pots (Cameron, pers. comm.).
		The Forests Commission recommends an open loam or sandy loam mix for seed trays; and for potting, a composted mixture of 3 parts black or red loam: 2 parts coarse river sand: 1 part well-decayed animal manure.
Iran		The use of clay or silt soils is sometimes unavoidable. In difficult climatic conditions a mulch of rice bran prevents drying out and cracking of the soil.
Israel	Ilanot	A sandy soil is used without fertilizer (le Roux, 1975).
	Gaza	A sandy loam soil is mixed with 25% of a well-balanced mixture of compost and fertilizer (le Roux, 1975).
Italy		90% topsoil, 10% cow manure, no artificial fertilizer (Mikola, 1969).
Lao		Mekong silt is used. Experiments showed jiffy pot stock responded well to NPK fertilizer mixed at the rate of 1.5 kg per m^3 (LARP, 1972).
Nepal		A sandy loam mix is used without fertilizer.
New Zealand		60/40 mixture of peat and sandy pumice loam. "Magamp" fertilizer (Mg,NH_4,K,P) incorporated at the rate of 2 kg/m^3.
Nigeria	Bukuru	5 parts river sand: 4 parts composted town refuse with the addition of 590 g 'Totafert' (15:15:15 NPK), 590 g ammonium sulphate, 118 g dieldrin 2% dust, and 295 g borate per m^3 of soil (Jackson, 1975).

Table 5.1 Examples of nursery potting mixtures for eucalypts *(concluded)*

Country	Site	Description
Nigeria	Samaru	2 parts river sand: 3 parts rotted cow dung, plus 2.9 kg superphosphate per m^3 produced the best results.
		If topsoil was used instead of cow dung it was necessary to add N at the rate of 2g N per seedling (Jackson, 1975).
Pakistan		A fine river sand is used in seed beds, while a mix of 3 parts fine river sand: 3 parts silt: 2 parts decomposed leaf mould is used for potting (Quadri, 1971).
South Africa		50/50 mixture by volume of sieved topsoil and sieved, partially decomposed sawdust. 3 kg NPK (3:2:1) plus 15 g borax per m^3 of soil (Barrett, 1978).
Spain	Huelva	75% forest humus (pH=6): 25% organic fertilizer are used (le Roux, 1975).
	Rueta Chica	Peatmoss (pH=5.5) is used with a mixture of 0.15% each of NPK (le Roux, 1975).
Sri Lanka		A fine sandy loam is recommended, and soil sterilization with methyl bromide when propagating *E. deglupta* (Ranatunga, 1972).
Sudan		50% sand: 50% river silt are used (Laurie, 1974).
Tunisia		Topsoil from local bush is used with no fertilizer (Jackson, 1975).
Zambia		Sandy humic topsoil from *Brachystegia* woodland is used, to which 2.06 kg of NPK (9:12:9) fertilizer are added per m^3. If seeds are sown direct into pots, no fertilizer is added to the potting mixture, but liquid fertilizer is applied at fortnightly intervals after sowing (Jackson, 1975).

4-leaf stage quickly, vermiculite, with or without sphagnum moss, is a safe and satisfactory media.

Sowing densities of 3 000 to 10 000 seeds per square metre of seedling tray are commonly used (average spacing 1-2 cm). The production of seedlings suitable for pricking out is reported as between 1 000 and 2 000 per square metre in Malawi, India and Portugal (average spacing 2-3 cm). Thus 25-50 percent of the seeds sown should produce seedlings which reach the pricking out stage, with most species and with good nursery technique. Calculation of the weight of seed plus chaff which should be sown per square metre can easily be done from seed weight figures (see Chapter 14). For *E. grandis* (average 630 000 viable seeds per kilogram of seed and chaff) a sowing rate of 12 g/m^2 is recommended (Barrett, 1978). Sowing density may need to be modified in accordance with the degree of risk of damping off; in areas of high risk sowing density should be decreased. Because of the small size of most eucalypt seed, it should be mixed with 2-3 times its volume of fine dry sand for broadcast sowing. A thin layer of sand or vermiculite should be added to ensure that the seed is covered.

The seedling trays are best held in a protected plant house where they can be watered at frequent intervals by a fine spray regulated by an electrical time switch. The watering frequency might be 5 to 10 seconds every 10 minutes. The seed should start to germinate within four days to one week and the seedlings should be ready for pricking out in about four weeks. As media such as vermiculite or perlite are sterile, the seedlings should be assisted by a weak solution of a complete fertilizer about twice a week. India and Nepal advocate a light mulch to prevent disturbance or wash-out of seeds. Finely chopped grass or paddy straw is commonly used. It must be removed as soon as germination takes place.

Pricking out

Pricking out, or transplanting the young seedlings from the seedling trays into the individual containers, is most conveniently done on benches under shade in the plant house containing the seedling trays. Pricking out must be carefully done. The seedlings in the trays should have two to four pairs of leaves and should only be handled by their leaves by holding the upper leaf pair together. A thin scalpel should be inserted into the soil of the tray and the seedling to be removed loosened in the soil. It is then pulled out and placed immediately into a hole in the container made by a sharp-pointed instrument (a "dibble"). The roots of the seedling must not be exposed to direct sunlight, and in any case should be exposed for as few seconds as is possible. The roots should not be permitted to curl upward in the dibble hole; if necessary they can be shortened with the scalpel but the roots should not be touched with the hands. The sides of the hole should be firmly pressed against the root of the seedling along its whole length, using the scalpel blade if necessary. The key points are a minimum of handling, a minimum of exposure, and adequate firming in the container.

After pricking out, the containers should be kept under shade (and if possible under automatic mist spraying) for about two days and then stored in bays until required for field planting 3-6 months later.

Damping off should not be a problem if prescribed sterilization measures have been taken, but if it is suspected, spraying with an appropriate fungicide is recommended.

Direct sowing in containers

Many foresters prefer to sow eucalypt seed directly into the containers, whether polythene pots or sleeves, peat pots or other containers, rather than to raise an earlier stage of seedlings in seedling trays. The advantages of direct sowing are lower cost and avoidance of damage to seedlings through careless pricking out. Main disadvantages are the greater amount of seed required and the possibility of low stocking through uneven and poor germination (Doran, 1977).

The aim is to sow an average of two to three seeds per container. Because of the small seed size, special methods need to be used to regulate the amount sown. In Lao and in Queensland a shaker is used, made from a small bottle with graduated holes in the lid set to allow a given number of seeds to drop per shake, while in New South Wales a "Nordland" seed sower (a mechanical but hand-carried sower designed for agricultural seeds) is used for *E. grandis* (Doran, 1977). In Nigeria a method was devised by J.W. Bride whereby a needle coated with starch is dipped into the seed. The number of seeds adhering to the needle is proportional to the depth to which the needle is inserted (Jackson, 1975). The sowing rate recommended for *E. grandis* (average 630 000 viable seeds per kg of seed plus chaff) is 1 g per 85 containers compared with 12 g/m^2 broadcast (Barrett, 1978).

After sowing, the containers are watered and covered against strong sun or storms until germination appears complete. The containers are then given full sunlight during the day but covered at night or if storms are imminent. When the seedlings are in the second or third leaf-pair stages, they are thinned by hand to one per container. This thinning is important; there is a likelihood of windblow if two individuals grow out of a single container.

Shade and shelter

Some form of shade must be available for the container beds when required, to protect them from excessive sunlight and storm rains. Several different types have been reported from successful eucalypt-growing countries. Some authorities prefer high shades, others, a low emergency cover. Both types have produced large quantities of satisfactory eucalypt seedlings. Shade screens are made of a variety of materials including reeds, bamboo, hessian and plastic cloth (Doran, 1977).

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

Nursery watering

The amount of supplementary watering will depend upon local climatic conditions, the texture of the nursery soil, the size of the container and the age and size of the plants. In most places where eucalypts are grown, facilities for watering are essential in a nursery. For large nurseries automatic watering has considerable advantages. Watering twice a day, morning and evening, is desirable in many countries. In Spain and Portugal one watering per day is sufficient in the more humid temperate zones, but two a day are essential in the hot dry areas. Watering in the hottest part of the day should be avoided. Local experience will show how many minutes, for example, each watering should take. The purpose is to keep the containers moist but not sodden.

In South Africa, from 55 to 75 litres of water per day, given in two applications, are required for every 1 000 container plants of *E. grandis* being raised (Wattle Research Institute, 1972). For the size of container used (6.4 cm diameter) this corresponds to 13-17 mm a day. Somewhat lower rates of watering are reported by other countries, e.g., 7 mm a day in Zambia and about 5 mm a day in Malawi. In Uganda, Ball (1977) reported that *E. grandis* grown in tubes in a clay soil required 10 mm a day in the dry season, whereas the same rate of watering during the rains caused waterlogging and reduction of growth.

Protection against weather, animals, insects, fungi

Bays should be provided with covers which can be pulled over the plants if hail storms are imminent. Hail can cause great damage to eucalypt seedlings. Covers are also required particularly on the seed beds or when the plants are small, to protect against heavy rainfall, wind or excessive insolation. In Nepal and Portugal, special precautions have to be taken against frost. At high elevations, the use of protective plastic covers also hastens germination by raising the temperature in the beds.

Birds are not usually a danger. Large animals should be kept out of nurseries by fencing. Small animals such as rodents do not usually harm stock in the nursery but may be troublesome in the field.

Many insects may damage eucalypt seedlings. They are usually insects which also damage garden plants and can be combated by chemicals sold to control these pests. Some of these are described in Chapter 9.

Damping off is the most serious disease in the nursery. The fungi which cause it are described in Chapter 9. Cultural practices, e.g., low sowing density, avoidance of overwatering and overshading, and of alkaline soil or excess organic matter in the seedling trays, can do much to reduce its incidence. In certain areas soil sterilization or use of fungicides may be needed as an additional preventative.

Bay hygiene

As an example of regular annual treatment of container bays to maintain good hygiene, the practice developed by APM Forests in Australia and applied in their nursery at Coffs Harbour, where large quantities of *E. grandis, E. saligna, E. pilularis* and *E. dunnii* are produced in peat pots, is given below. The main features are:

(*a*) Cleaning of the bay by chipping or weedicide. Each bay is about 460 m^2 in area. Application of a pre-emergence weedicide spray, "Domatol 44," 1-2 kg in 200 litres of water on the bay surface.

(*b*) Sterilization by applying formalin to the bay surface.

(*c*) Application of insecticide — 0.5 litre of "Maldison," 50 percent in 200 litres of water — to bay surface.

(*d*) Sterilization of planter boxes by covering boxes with a tarpaulin and applying formalin through a master nozzle under the cover at a strength of 0.5 litre formalin to 6 litres water.

(*e*) Laying out the peat pots in the planter boxes in the bays. There are 171 072 peat pots per bay. Application of "Dexon" to peat pots one week before sowing (250 g Dexon to 200 litres of water for each bay).

(*f*) Sowing 3 kg *E. grandis* and *E. saligna*; 8 kg *E. pilularis* in each bay.

(*g*) Fertilizing during growth in bay. Application of a weak solution of "Aquasol" (4 g in 10 litres) at the rate of 300 litres per bay, twice weekly. Strength of Aquasol solution increases to 12 g in 10 litres as the plants grow.

(*h*) Fungicidal treatment. Application of a "Benlate" solution (1 g per litre) with a knapsack mist spray every 14 days or more frequently if conditions favour damping off. In extreme conditions application of a "Captan" mix, 25-50 litres per bay (4 g to a litre) once only, and then return to normal spraying with Benlate.

(*i*) Treatment of algae and mosses. Application of a solution of "Lantox," 2.6 kg of chemical to 200 litres of water, per bay, once only.

This standard practice shows how much importance a large company places on continued hygiene in the substantial investment it is making.

Size and quality of plants

The period spent in the nursery and the average size of plant at planting vary greatly from country to country. At one extreme Papua New Guinea close to the equator needs only two months to raise *E. deglupta* 25-30 cm high. At the other extreme Ireland at over 50°N latitude needs 12-15 months to raise plants of the same size of cold-resistant species. In much of the tropics and subtropics average height at planting is in the range 15-30 cm and plants of this size can be raised in 4-5 months. In more arid areas with a Mediterranean climate larger plants of 30-50 cm are more often used and need 6-10 months in the nursery.

Although root-pruning is less essential for container than for bare-rooted stock, several countries have reported methods to prevent rooting into the substrate or from one container to the next. These include the periodic pulling of a wire below the containers from one end of the bay to the other, or the lifting of containers individually. Some countries, e.g., Malawi, reduce the amount of watering a few weeks before planting in order to "harden off" the plants, while most countries report a heavy watering immediately before the plants leave the nursery for transport to the field. The need for culling of weak seedlings in the nursery applies as much to eucalypts as to other genera.

If planting has to be delayed because of unfavourable conditions or if sowing has been done too early, oversize plants can be clipped. In Australia overgrown plants of *E. grandis* shortened to 20 cm in height can be telescoped together by facing one planter box into another as shown in Figure 20. Without telescoping, a 1.5-ton truck with a specially designed frame can transport 9 000 plants to the field. With telescoping the same truck can transport 27 000 plants.

Management of bare-rooted stock

General

The growth habits of eucalypts are not basically favourable to the production of bare-rooted planting stock. The leafy parts of the plants readily reproduce new shoots which grow and transpire actively throughout the year. On the other hand the natural rooting habit is for a long taproot and a poorly developed fibrous root system (Bunn and Van Dorsser, 1965, 1969). This accounts for the preference in most countries for container stock. Nevertheless substantial plantings of bare-rooted eucalypts have been successfully established in favourable climates in New Zealand, Kerala (India), Hawaii and Australia. The most extensive plantings have been made in New Zealand, so the information which follows will be drawn in the main from the New Zealand experience.

The main locality in New Zealand where bare-rooted eucalypt planting stock is raised is in the Rotorua/Tokoroa area where New Zealand Forest Products have a target eucalypt planting programme of 800 hectares per year, essentially with bare-rooted stock of *E. regnans, E. delegatensis, E. fastigata* and *E. nitens*. Planting stock of all four is raised successfully, but in planting in the field best establishment is obtained with *E. delegatensis* and *E. nitens*. *E. fastigata* gives reasonable results but there is some difficulty with *E. regnans*, which is the preferred species of the company because of its excellent paper-making properties.

Beds

The soils from which the nursery beds are made are pumice soils and very favourable for the purpose. The beds are raised about 20 cm above the general level of the nursery so that the paths between them can carry away water from flood rains. The bed width is 1.85 m. Up to 1974, vertical root-pruning only was practicable between sowing lines which were 15 cm apart. The distance between sowing lines has now been extended to 30 cm to allow more complete wrenching of vertical as well as lateral roots to be achieved.

Sowing

Sowing is done in October (spring in New Zealand) for plants to be planted out 8-10 months later. Sowing is by machine and is very regular.

Watering during germination period

Seed beds are kept moist by shading (50 percent shade cloth) and frequent light overhead irrigation.

Fertilizing

The basic treatment is an application of 200 kg per ha of an NPK fertilizer twice during the growing season.

Weed control

This is achieved as much as possible by chemical means. There is a post-sowing application of "Nitrofen" at 7 kg/ha and a post-emergence application of "Propazine" at a maximum of 0.6 kg/ha when the seedlings are a minimum of 15 cm tall. Later in the season a supplementary application of Propazine at a rate of 1 kg/ha may be made. Hand weeding is done as necessary to supplement chemical control.

Spacing

Bare-rooted planting can only be satisfactorily achieved with sturdy stock. Plants are thinned out to a spacing of 5 cm, aiming at planting stock with a minimum diameter at the root collar of 5 mm at time of planting out.

Disease treatment

E. delegatensis is subject to a leaf-blotch fungus in its young stages. In the nursery it may be sprayed at twice-monthly intervals between mid-December and the end of April with 0.3 kg of cuprous oxide in 465 litres of water (+1 percent surfactant).

Watering

Overhead irrigation is used if necessary to supplement natural rainfall and for several days following lateral root-pruning if this is done under dry conditions.

Root-pruning

The taproot should be cut as clearly as possible about 75 mm below ground level about February. This halts height growth and multiplication of the leaves. Subsequent root-prunings should aim at keeping top growth in check and allowing the existing leaves to mature and harden. Successive root-prunings should be at deeper and deeper levels so that the callus formed over the first cutting of the main taproot is not injured.

Transport to field. After lifting, bare-rooted eucalypts should be bundled and transported to the planting site in polythene bags kept in the shade. Puddling of the roots, e.g., in a mud slurry or in alginate compounds, is sometimes advantageous.

Establishment techniques

The massive investment in eucalypt plantations throughout the world has enabled a great deal of knowledge to be accumulated on the subject of fast-grown production plantations of these trees. Many species have been tried out, but by far the greater part of the 4 million hectares has been planted with no more than 16 species and most of this with eight species. Of the eight main species planted, only one, *E. camaldulensis*, is among the 10 most important eucalypts in the timber industry of Australia.

The plantations are monocultures. Most of them are coppice forests which are clear-cut every five to ten years. The coppice crops quickly regain dominance of the site, but every few years there is an opportunity for some damaging agent to gain entry into them when they are clear-cut and in a juvenile stage. Plantation managers keep a constant watch over the health of the forests, which could provide a source of food to pests and pathogens. There are some potentially dangerous pests, but these have been controlled to date by biological or other means. By and large it can be said that the plantations are a demonstration that the risks of monocultures are less than the advantages they bestow, if the plantations are properly sited. It is also interesting to reflect that *E. camaldulensis*, the one species that is also significant in the timber industry of its homeland, is outstandingly the best example of a species forming pure natural stands.

The experience with eucalypt plantations gives confidence that the most profitable way of handling them is as monocultures, but it also demonstrates very clearly that the way to profit is good nursery technique and continuing sound plantation practice.

Clearing

A considerable part of the earlier and present plantations was established on grassland or other treeless land which may or may not have had trees on it in recent times. In the more distant future most new plantings must be made on land from which a tree crop has just been cleared. The presence of the stumps of an earlier crop makes the preparation for a new crop appreciably more difficult. For a recent description of techniques, see Chapman and Allan (1978).

If a planting area has an old crop of trees and scrub on it which has no value, clearing the trees with a tractor and attachment is one way to get the land ready for ploughing, ripping and discing. A good tractor can push many trees over and leave the stumps and root balls partly or completely out of the ground. Scrubby growth can be completely removed. The material may be heaped or stacked in windrows and burned. A much better burn will be achieved if a light tractor is used to push the stumps and logs together as the heaps or windrows burn down.

If extensive areas of degraded forest are to be cleared some of the more sophisticated clearing equipment may be justified. These include heavy chains or wire rope, sometimes held above ground near its centre by a huge steel ball, and dragged at each end by a heavy tractor. This equipment can clear large areas quickly. Another piece of equipment which deals effectively with scrub is a very large heavy cylinder with flanges along its surface, which rolls the scrubby growth over and cuts it into pieces when hauled by two tractors, or when allowed to run down a slope on rolling country. Equipment of this type is frequently illustrated in forestry magazines or publications issued by major equipment manufacturers, such as "The clearing of land for development" (Caterpillar Tractor Company, 1974). These guides to land clearing cover many machines and illustrate how they may be used in a wide range of conditions.

If the area to be prepared for planting is an earlier eucalypt plantation, care must be taken that the stumps of the earlier plantation have been killed and will not coppice. This may be done by poisoning them by 2,4,5-T or other poisons.

There is a very considerable volume of wood below the ground in the stumps of an old eucalypt coppice plantation. Stump wood is very good fuel, but the stumps and their roots are awkward to break up into an even type of fuelwood product, so the prospect of selling the stumps if they are removed is poor. Foresters are always apprehensive that stump wood could form the host material from which a disease could spread, and, indeed, eucalypt stumps can harbour many fungal pests, including the shoe-string fungus, *Armillariella mellea*, which is dangerous in some forest crops. Nevertheless, serious difficulties have not been encountered up to date, and so the stumps are usually left in the ground.

Preparing the ground

Following a previous plantation crop

Ripping, ploughing and discing of the site should be carried out if it is 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.

On old agricultural land

If old 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 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.

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. Pits should be dug to a depth of at least 25 cm.

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

The preparation of dry-country plantations involves 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.

Initial espacement

A wide range of initial spacing has been tried in countries which plant eucalypts (see Table 5.2). The more stems per hectare the greater is the total volume yield in the early stages, and, of course, the greater the cost of planting stock and planting. Owners must decide on a spacing which suits their objects of management and the fertility of the site. In general, poor sites should have wider spacings and good sites a closer spacing but one which permits the rapid development of good useful crops of pulpwood. Another important factor which should influence an owner's decision on spacing is the likely use of mechanical equipment for cultivation and harvesting.

Table 5.2 Range of espacements used by the main eucalypt-planting countries

Initial espacement	Trees/ha	Object of management
m		
2 × 2	2 500	Pulpwood, mine-timber, light posts
2 × 2.5	2 000	"
2.5 × 2.5	1 600	"
3 × 2	1 670	Pulpwood, light and heavy posts
3 × 2.5	1 330	"
3 × 3	1 110	Sawlogs, light and heavy posts, mine-timber and pulpwood
3.33 × 2.25	1 330	"

Among the countries which have published figures, in Australia APM Forests use an espacement of 3.33 × 2.25 m; Brazil uses largely 3 × 2 m, 2.7 × 2.7 m, 3 × 1.7 m and 2.5 × 2.5 m; South Africa is tending to a normal espacement of 2.4-2.7 m with a wider row of 3.7 m at intervals of 10 rows to admit trucks; New Zealand Forest Products Limited, planting for pulpwood, aims at an initial stocking of 1 700 stems per hectare with bare-rooted stock which permits the widths between rows to be up to 3.3 m to allow better access for treatment, and will consider an initial stocking of 1 100-1 200 per hectare when establishment techniques have improved. The New Zealand Forest Service, aiming at sawlogs, may mix eucalypts in pine plantations or have a relatively wide spacing.

It will be seen that countries which consider that the use of mechanical equipment will be necessary in the future allow for special access rows at intervals or a minimum spacing between rows of 3 metres. Mechanical weeding in two directions needs minimum spacing of 3 × 3 m. Nevertheless all countries aim at a total initial stocking of at least 1 000 trees per hectare on good sites so as to ensure satisfactory production.

Planting procedure

Marking the planting spots

In order to promote uniform growth and facilitate mechanical tending and harvesting, the lines of trees should be regular and straight and the spaces between the trees even. This can be achieved by a planting chain having markers at the intervals of the required spacing along the chain. The planting holes are clearly indicated on the ground by starting the hole with a hoe or mattock or by the insertion of a thin wooden stake if these are locally available.

Timing

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 wet season 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 container planting stock is that the moist soil in the container should carry the plant over difficult periods such as this. The larger containers having a minimum of 300-1 500 m^3 of soil should achieve this, but there may be difficulties with peat pots having as little as 90 cm^3 of soil. It is preferable to delay the planting of peat pots until the main rains have started. In cold areas planting after the frost season may be necessary.

Planting

If the area for a plantation has been ploughed and disced, and particularly if it has been possible to rip it along the planting lines, the actual task of planting involves taking the seedlings and containers to the field, or alternatively taking bare-rooted planting stock to the field, and inserting the planting stock into their appropriate positions, and firming the field mineral soil against the roots or mineral soil of the containers. If the containers are polythene pots, they are usually removed before planting to avoid rooting failure but some countries using tubes or pots with perforations in the bottom and sides do not remove them. Peat-pot stock is planted pot and all.

In recent years there has been increasing concern about the risks of root coiling and root strangulation as a result of raising stock in polythene containers. Examples of basal stem snap in pines have been given by Ball (1976) and there is some evidence that similar damage may occur in eucalypts. Coiling of lateral roots around the top root as a result of the constriction of the polythene leads to the death of the taproot. This results in reduced mechanical stability and a risk of uprooting or breakage at the root collar, which may occur some years after planting. The risk of root coiling can be reduced by removing the tubes or pots (either the whole or at least the bottom half), cutting off the bottom 2 cm of the root ball and making two vertical cuts on either side of it to sever coiled roots, immediately before planting. In Malawi all tubes are recovered and re-used for 2-4 years.

In old cultivated ground it may be possible to use planting machines, both for container stock or bare-rooted stock. This is a great advantage if it can be achieved because the soil around the roots and in the containers is heavy. The planting machines make their own final place for the seedlings and good machines firm the soil around the plants very well.

If planting machines cannot be used, a spade, hoe or planting dibble is necessary to prepare the final planting hole and the planter should then insert the plant and make sure that it is firm in the ground without air spaces around or below the plant, and that field mineral soil is in contact with the roots of the stock. This firming of the soil and avoidance of air spaces are vital to the success of planting.

In termite-free areas plants should be planted so that the root collar is level with the surface of the field soil or a little below it rather than above it. The recommendation from APM Forests Limited in Australia is that peat-pot stock, which has a rather small ball of soil, should be planted 2.5 cm below the surface of the soil or a little deeper if soil moisture is declining. This prescription does not apply in termite areas (see below).

Blank-filling and watering

The principal eucalypt-planting countries aim to get a take of 90 percent or better in their plantations. Sometimes, usually because of adverse weather conditions, but sometimes because of poor planting stock or land preparation, the percentage take falls sharply. If the deaths are caused by adverse weather early in the planting season, re-filling should be undertaken as early as possible in the same season, when there may be little loss of growth. If the deaths are caused by other factors such as abnormal frosts or pest damage, they should be replaced later in the season with stronger plants if possible. It is advisable to hold a reserve of planting stock for this purpose. If the deaths are caused by faulty land preparation the fault should be corrected — before re-filling by reserve stock. The refills might be assisted by an additional application of fertilizer if they are planted after the general fertilization of the compartment.

Re-filling in the year following the original planting is not usually very successful in the case of eucalypts unless substantial sections of compartments have died. In such cases they should be prepared for planting again and replanted.

If new plantings are subjected to abnormally dry conditions before they have become established, and if the plantation 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 save the trouble and expense of blank-filling.

Fertilization

On some sites young eucalypts respond quickly and generously to fertilization. Foresters have noted and measured the response and many of them make use of the technique both in the nursery and in young plantations. The use of fertilizers in the nursery has been discussed in earlier sections of this chapter.

Where fertilizers are used in the field, it is common practice to apply them a few weeks to three months after planting, in a circle or in two small patches on either side, and 15-30 cm from the plant. The amount of fertilizer and the balance between different elements need to be determined for a given soil by research and by weighing the increased yield against the cost of the fertilizers and their application. On some soils response to fertilizers may be insignificant or not worth the cost.

Examples of fertilizer schedules:

Australia (New South Wales). 50 g per plant of N 15/P30 fertilizer. Neither element alone gave 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.

New Zealand. On pumice soils 60-80 g of urea per plant, followed by 200 kg/ha urea in second year. No response to P or Mg.

Sri Lanka. Normally planted without fertilization. If nutrient deficiencies appear, 57 g NPK (15.15.15) applied 2-3 years after planting.

Zambia. 90 g per plant of NPK (11.22.11) plus 60 g boron. NPK may be discontinued because research has indicated it has little effect.

Malawi. 50-75 g NPK compound 321 (25) plus 25-50 g boron per plant. Dosage is adjusted according to the climatic zone.

South Africa. 150 g NPK (3.2.1) per plant.

Portugal. On sandstones *E. globulus* is fertilized with NPK. On schists the K is omitted and replaced by Ca.

Brazil. 70-200 g per plant of either N6/P14/K5 + Ca + S, or N9/P30/K5 + micronutrients. Other examples may be found in Jackson and Ojo (1973), Jackson (1977), Kadeba (1977).

Boron may be in low supply in some tropical savanna soils (Laurie, 1974). Experiments carried out in Zambia, Nigeria and elsewhere have amply confirmed the necessity of applying boron fertilizers in such cases. Not only are the symptoms of boron deficiency completely eliminated, but considerable increase in 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.

Insecticides

Eucalypts are notoriously susceptible to termite attack in the first year or two after planting. Where termites occur, use of insecticides at planting is a *sine qua non* for successful establishment. It is customary to include an insecticide in the soil mixture in the nursery to provide post-planting protection. The insecticides commonly used are either dieldrin or aldrin and they may either be mixed with the soil (e.g., 0.8 kg of 2 percent dieldrin powder per cubic metre of soil); or they can be mixed with water as a suspension and watered on. In Zambia 200-400 g of aldrin wettable powder in 24 l of water are applied to 1 000 plants in standard pots three times, namely one, two and three weeks after pricking out, so that the insecticide can accumulate in the soil before the foliage is large enough to deflect the watering. When planting, it is important to keep the top of the pot a centimetre or two above soil level in order that a "bridge" of untreated soil will not cross to the stem. Leaving a 1- to 2-cm frill of the container above ground level is an additional precaution.

Both dieldrin and aldrin are persistent organochloride insecticides which may pollute the ecosystem and their use has been banned in some countries for agricultural purposes. In eucalypt planting the quantities used are small in relation to the areas concerned and no immediate effects are likely to be observed. In view, however, of the cumulative effect of such chemicals, research is urgently required to find some alternative substances that are effective but at the same time are ultimately broken down into harmless compounds in the soil.

Weed control

The eucalypts thrive when they are free-growing and are most sensitive to competition during their first year in a plantation.

Control of weed growth is greatly helped by good site preparation but there are likely to be many weed seeds in the soil and other seed will blow in from outside. The weeds which compete with the plants during the first year must be controlled by hand-pulling, hoeing or disc-cultivating. Clean tending near the young trees themselves by hand-pulling is not a difficult operation when the soil is in good condition. Between the rows the weeds can be controlled by disc-harrowing. It is important to remove weeds before they seed and thereby multiply the problem. The first year of growth is the important one in a plantation that has been well prepared and well fertilized. Weeding should be continued until canopy closure. Eucalypts are very sensitive to grass competition, particularly *Imperata* in the tropics. The importance of clean weeding for maximum establishment and early canopy closure cannot be overstressed.

Management of coppice crops

General comment

In preparing this section, special use has been made of the *Handbook on eucalypt growing* (WRI, 1972), by courtesy of the Wattle Research Institute, Pietermaritzburg, South Africa, in addition to the Country Reports submitted to FAO in 1974-75.

Most of the 4 million hectares of eucalypt plantations in the world will be managed as coppice crops to provide large quantities of pulpwood for paper industries and processing plants which reconstitute chipped or defibrated wood in other forms, to provide mine packs which enable the deep mines of the world to function, to provide a wide variety of posts and poles for the communities around the coppice forests and to provide heat energy for industrial and home use. However, the use of coppice regeneration cannot be relied upon in all eucalypt species, either because the coppicing power of the particular species is poor, or because the coppice shoots produced are not of sufficiently good form to produce the required lengths of straight stems. When coppice regeneration cannot be relied upon, complete replanting must be done, with a commensurate loss of time. Among the species reported to have poor coppicing ability the following can be mentioned: *E. astringens, E. botryoides, E. deglupta, E. fastigata, E. gomphocephala, E. nitens, E. oreades, E. pilularis* and *E. regnans.*

Early treatment

Thinning before the first cutting of the crop is rarely carried out in large plantings. Sometimes species become mixed in the nursery and if, e.g., a hybrid becomes obvious in the early years, it should be removed to prevent possible crossing with the main crop. Highly defective stems should also be removed.

Sometimes a young eucalypt is broken or damaged by animals or storms. If these trees are cut close to the ground, that is, in effect coppiced, a strong new shoot develops which is much more suited to the objects of management than the damaged shoot. This type of treatment is strongly recommended.

Another circumstance where early treatment before the first projected cutting of the coppice may be advisable is when the whole of a compartment or a large part of it is severely damaged by fire, snow or wind storm. Felling all the stems by chain-saw close to the ground may lead to a satisfactory even crop much more quickly than replanting.

Felling the first crop

In most eucalypt coppice plantations the first (seedling) crop is felled between the ages of 7 and 10 years. The felling of eucalypts is the most important operation in relation to the survival of the plantations through successive coppicing of the stumps, which can be repeated for three or four more rotations. The period of felling, type of equipment used and techniques are all important. The felling period should be planned to avoid dry periods and heavy frosts which can loosen the bark from the stumps. This will vary according to locality, and research is necessary to gain information. In cold areas the early growing period after the heavy frosts is probably the best period, as the shoots will be established before the next winter. If a very dry season occurs, felling should be done at the beginning of the rainy season to ensure enough moisture in the ground.

Felling tools are also important. Experience in Australia and South Africa has shown better results in coppicing and growth of the coppice from the use of chain-saws than of axes. With the axe there is a higher probability of loosening the bark on the stump. The bow-saw and the two-man crosscut saw can also be used to advantage; these hand tools have sometimes been reported to give better results than the chain-saw.

Attention should also be paid to the felling level. If the stump is too high the chances of survival are lower. If the cut is at ground level the bark may loosen. The recommended height is 10-12 cm. The cut should be as smooth as possible and slanted so as to facilitate water run-off. The accumulation of water on the stump increases the risk of fungus attack.

After felling, lop and top should be removed from the stumps, so that the young coppice can develop without interference. The instructions given to fellers and supervisors should thus request a stump height no greater than 12 cm and fellers should be provided with chain-saws or bow-saws. This stump height of 12 cm should provide an adequate number of coppice shoots. The use of bow- and chain-saws reduces the degree of bark damage and allows the rapid formation of protective callus tissue around the circumference of the cambium of the stump.

If the stems felled at the first cutting are to be sold unbarked, the crop can be felled and cut into the lengths required by the market without much danger to the stumps. Many crops, however, are barked before being sold and it is advantageous to do some or most of the barking while the trees are still standing. Strips of bark are pulled away from the trunks by the workers while the trees are still standing, and it is quite remarkable to see the considerable height, perhaps 20 m, to which the bark can be stripped in coppice crops of, e.g., *E. grandis*. It is most important that this bark stripping should not proceed in a downward direction, as this would be most likely to damage the bark at the base of the tree and so destroy the dormant buds which produce the coppice shoots. When bark stripping is done on standing trees there should be strict instructions that a light cut should be made right around the tree at a height of, say, 25 cm, and the bark stripped upward from this cut. Then, when the bark is loosened as high as the workers can pull it, the tree should be felled by chain-saw at a maximum height of 12 cm. These prescriptions on bark stripping and stem felling will also apply to every successive cutting of the coppice crop.

The mechanism of coppicing

Coppice shoots develop from dormant buds situated in the live bark or from lignotuberous buds found near the junction of root and stem in many eucalypt species (see Chapter 2). While the trunk is growing vigorously the buds are inhibited from developing by the flow of auxins down the trunk. As soon as the stem is felled this inhibition is removed and the buds will start developing. Sometimes a great many shoots grow from a stump but gradually they thin themselves out. The self-thinning is of interest. It is not necessarily the vigorous shoots which become permanent. The shoots crowd together and form knobs called "epicormic knobs" in which many of the individual shoots may not be at all stable. Frequently the larger ones fall or are blown outward. This phenomenon may happen two or three times in as many weeks in vigorous coppice, but finally two, three or several remain fairly firmly attached to the stump. It is from these that the owner must select his next coppice crop, and it is a very important stage in growing a good coppice crop.

Effect of season of felling

As long as there is an adequate supply of soil moisture during the cool season of the year, this season will usually produce the greatest number of coppice shoots. Nevertheless the cool season may not be the best season for cutting in frost-prone areas as heavy frosts may cause the separation of the bark from the stump. Sharp dry periods may also be unfavourable for coppice and tend to increase mortality among the stools. Probably felling early in the growing season, but after the worst part of the frosty season, will give the best and most prolific coppice; moreover, this coppice will have the best chance to harden before the next winter and also will be able to dominate newly germinating weeds better than later coppice. This being stated, it should be said that there is rarely need to interrupt employment or production because of the danger of failure of eucalypt coppice. Most species are fairly flexible and generous in their response to season of treatment.

Height of the stool

The recommended stool height of not more than 12 cm will usually result in a good coppice crop with adequate shoots. Without adequate supervision there is a tendency for stump height to increase. This results in loss of wood to the owner and defective coppice. All eucalypt trunks have numerous dormant buds on every decimetre of their length. Shoots from all of these will develop when the tree is felled, and the upper ones will tend to develop more quickly than the lower ones and soon suppress the lower ones. These upper shoots are much less stable than shoots from stumps cut to the recommended height of 12 cm or less. The callus developing at

26. Coppice shoots of *E. grandis*, showing perfect covering of old stump. *Above*, 2-year-old single shoot; *below*, well-matched pair of 2-year-old shoots
Wattle Research Institute, Pietermaritzburg

27. Two-year-old coppice shoot of *E. grandis*, showing normal attachment to stump
Wattle Research Institute, Pietermaritzburg

28. Windthrow of one of a pair of 2-year-old coppice shoots of *E. grandis*, showing poor attachment to old stump. The shoot had grown through dead bark
Wattle Research Institute, Pietermaritzburg

some distance up the stem is weaker and cannot give such good support to a new trunk as callus from a low cut.

There is also a tendency for the stool height to increase with successive cuttings of the coppice. It is easier to fell the trees a little higher. This tendency is never necessary and should be prevented by supervisors. The eucalypts have adequate dormant buds low on the original stump and these will develop if a correct felling procedure is adopted.

In Australia, fire-damaged and otherwise deformed eucalypts of nearly all species (*E. regnans* being the main exception) with stumps up to 20 cm in diameter are felled in timber stand improvement operations and permitted to develop coppice shoots with the objective of these shoots becoming large poles or mill logs. In most cases the objective is achieved. The coppice shoots start off with the advantage of the root systems of the parent stump and usually outgrow seedling regeneration. Nearly a century of experience in Australia justifies the practice, and it can also be observed when quite large *E. diversicolor* is coppiced for sawlogs in South Africa and large *E. grandis* coppiced for the same purpose in Brazil.

Effect of stump diameter on mortality

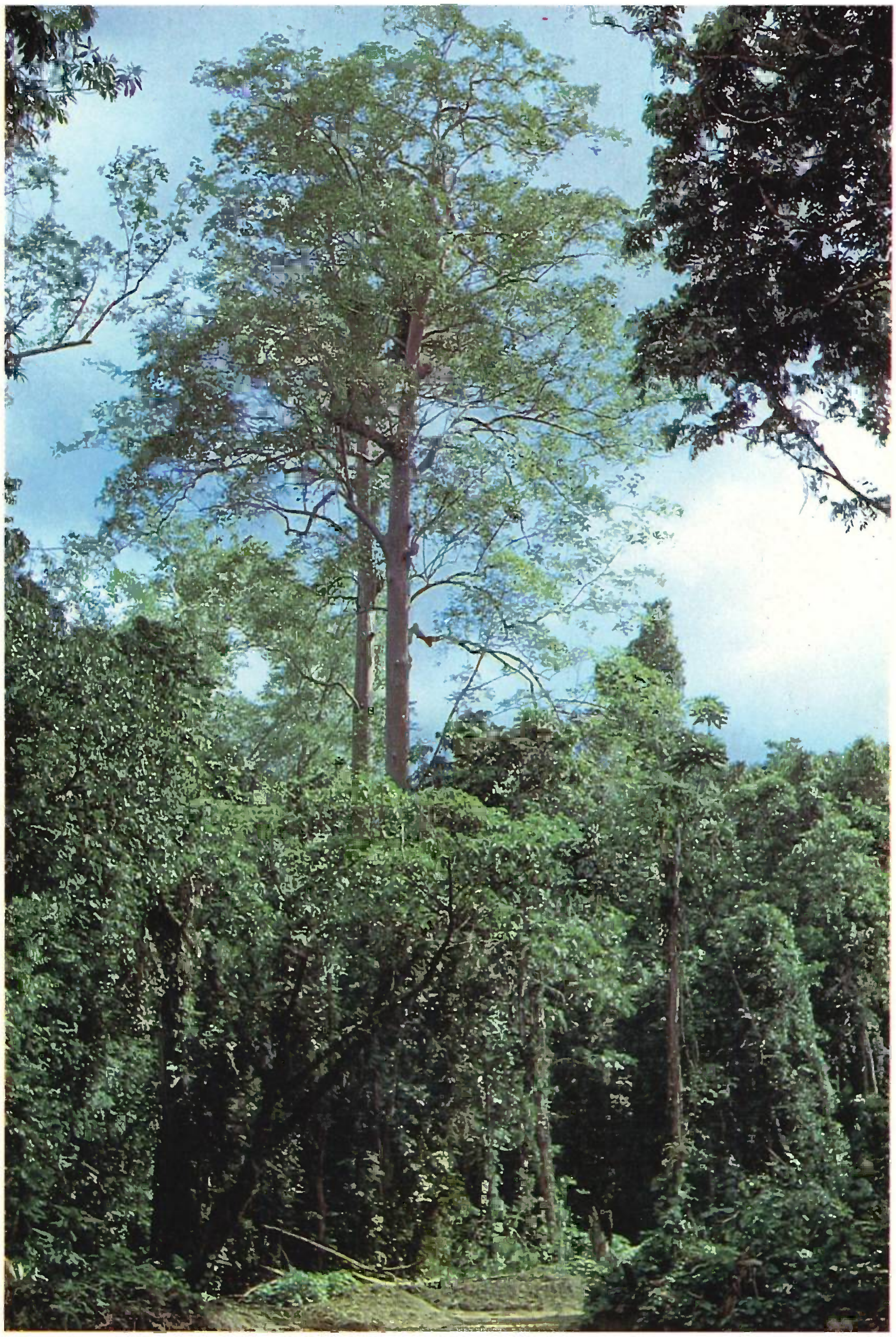
Observations in Natal, South Africa, on a 7-year-old first cutting of *E. grandis* indicated that there were lower and higher stump diameter groups where stump mortality was greatest. The smaller stumps (3-10 cm) and the very large stumps (20-38 cm) had a high mortality whereas the stumps between 10 and 20 cm in diameter had a low mortality rate. General observations show that the more uniform a plantation is and the smaller the range of stump diameters, the better the survival of the stumps and the better the volume production of the coppice crop.

Number of rotations

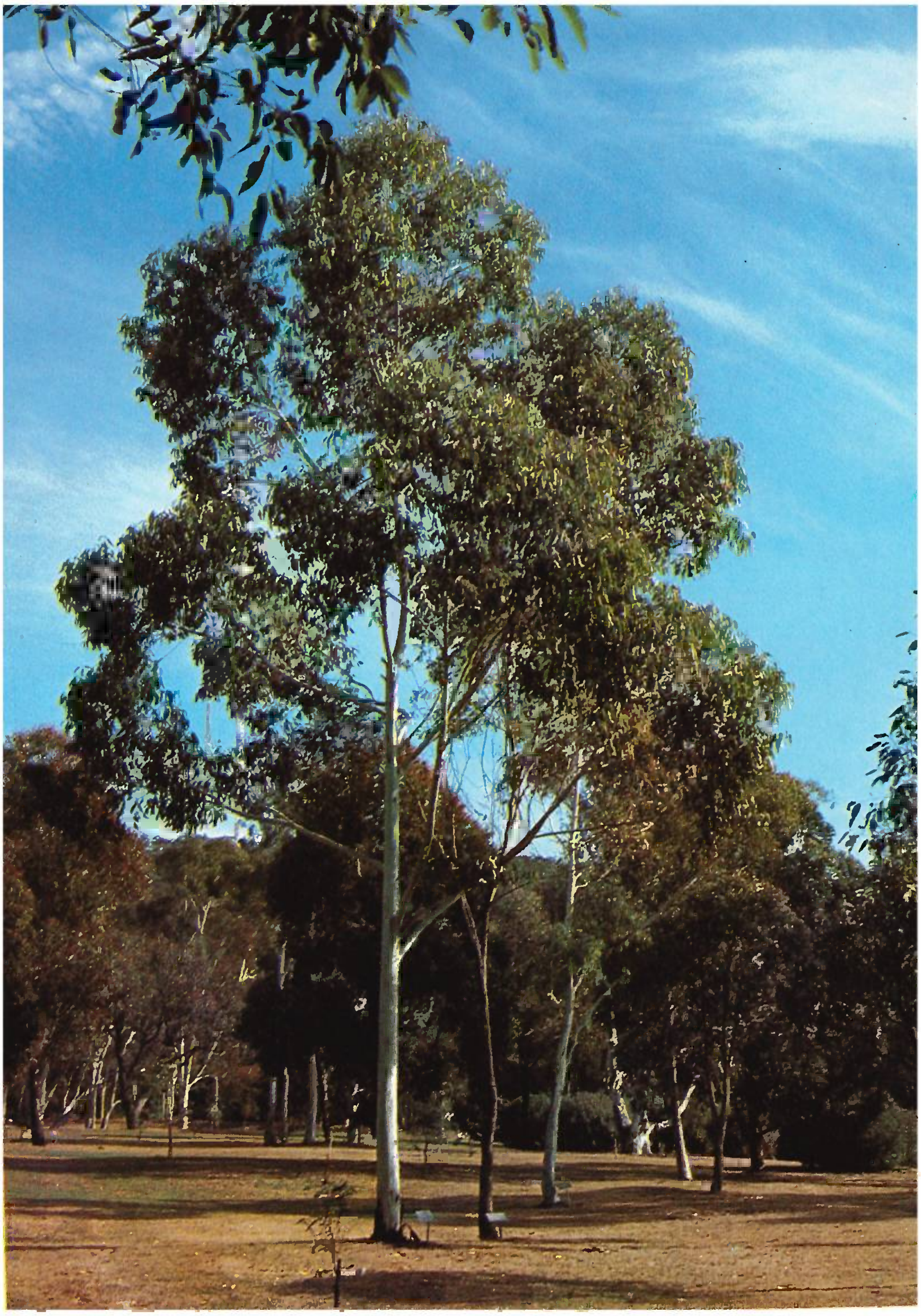
In each successive coppice rotation a percentage of stumps fails to produce another coppice crop after felling. Finally there are too few stumps to produce a reasonable mean annual increment and it is advisable to re-establish a seedling stand. In South Africa, the natural mortality in *E. grandis* coppice plantations averages between 3 and 5 percent. It is the effect of the loss of stumps, rather than loss of vigour in living stumps, which causes unsatisfactory mean annual increment in long-continued coppice rotations.

E. globulus has been coppiced in the Nilgiri hills in India on more or less 10-year rotations for nearly 100 years and still gives very good returns which are frequently referred to in forestry literature. In Israel five successive 10-year coppice rotations of *E. camaldulensis* have been established successfully.

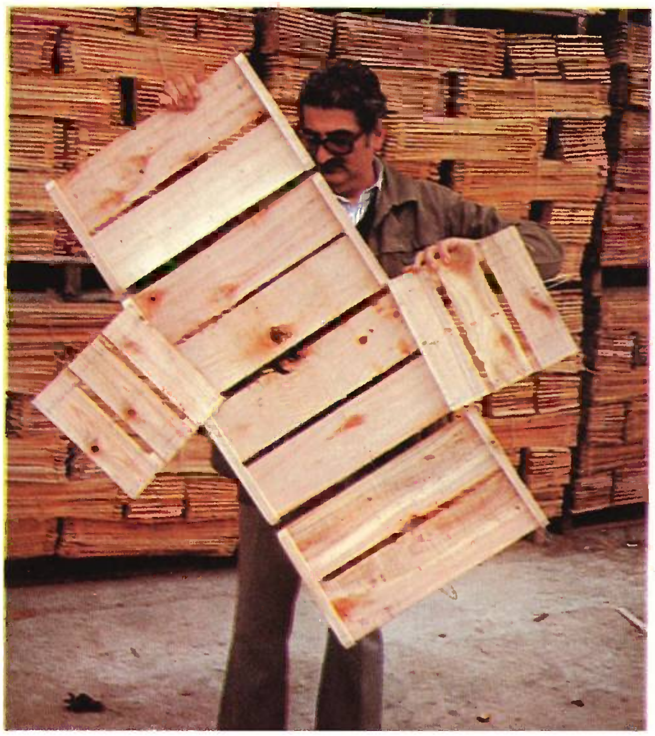
On reasonable sites it can be assumed that at least two satisfactory coppice crops after the original seedling crop can be obtained if the crops are on short rotations of up to 10-12 years. This applies to *E. grandis*, *E. sa-*

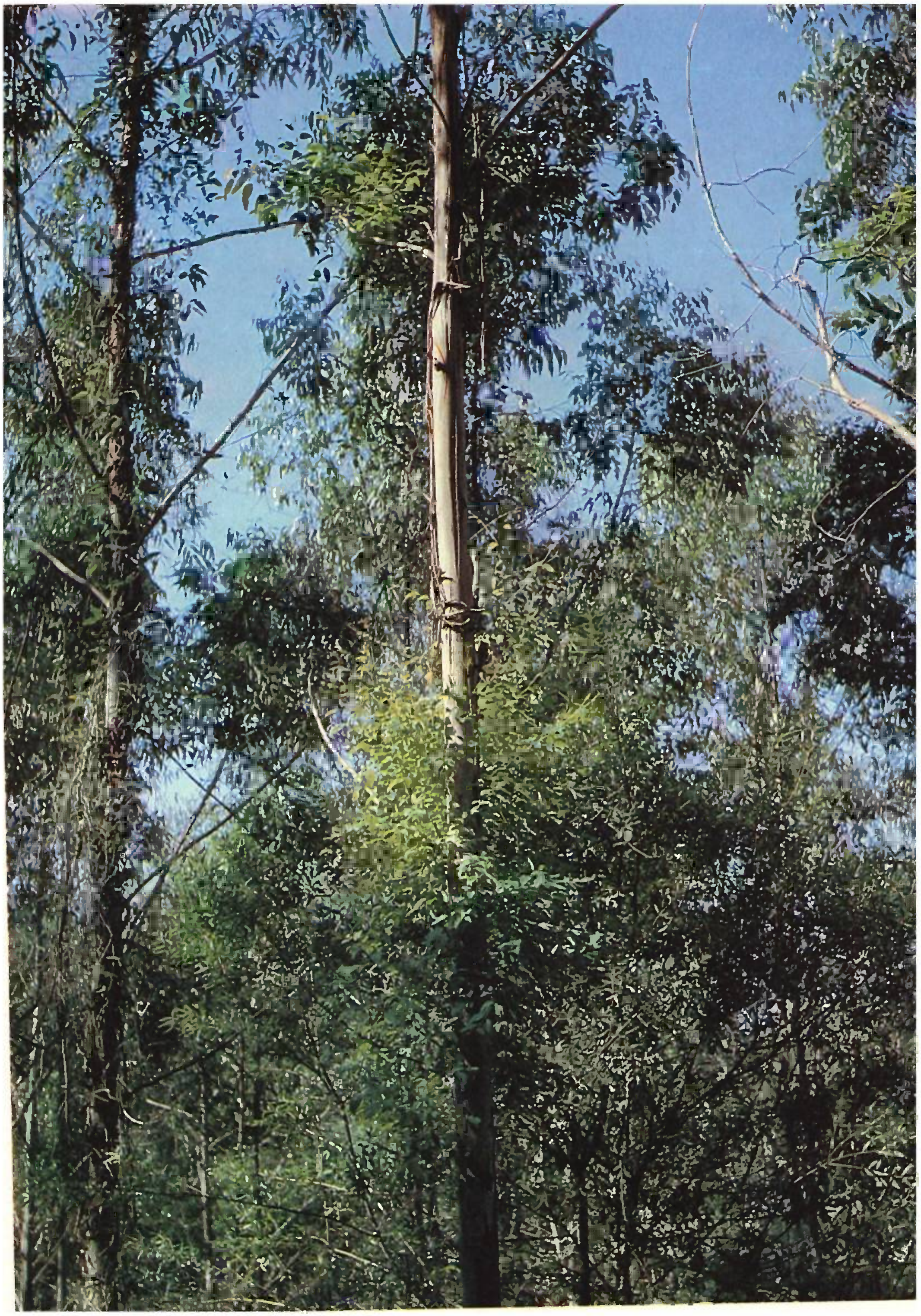


Eucalyptus deglupta, Kerawat,
New Britain
L.D. Pryor



E. grandis. This page, in Canberra Botanical Gardens (*C. Palmberg*).
Opposite, above: logs ready for peeling for manufacture of fruit boxes; *below*, completed boxes. Concordia, Argentina (*L.D. Pryor*)



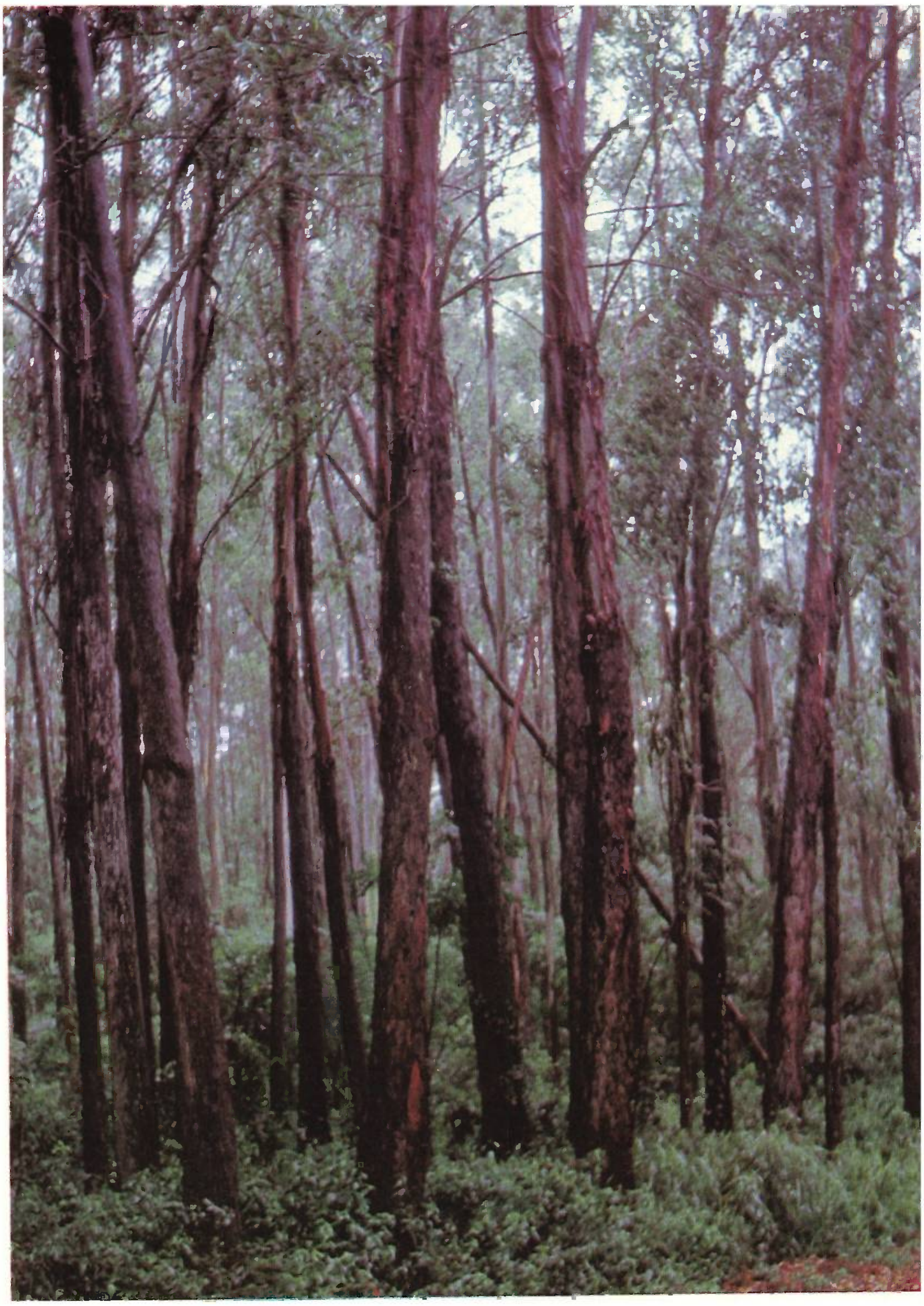


E. grandis plantation, epicormic shoots following drought.
Coff's Harbour, New South Wales

L.D. Pryor

E. microtheca, Gezira, the Sudan.
Above: small-size sticks yielded from coppicing; *below:* coppice thinned to 2 stems per stool

L.D. Pryor

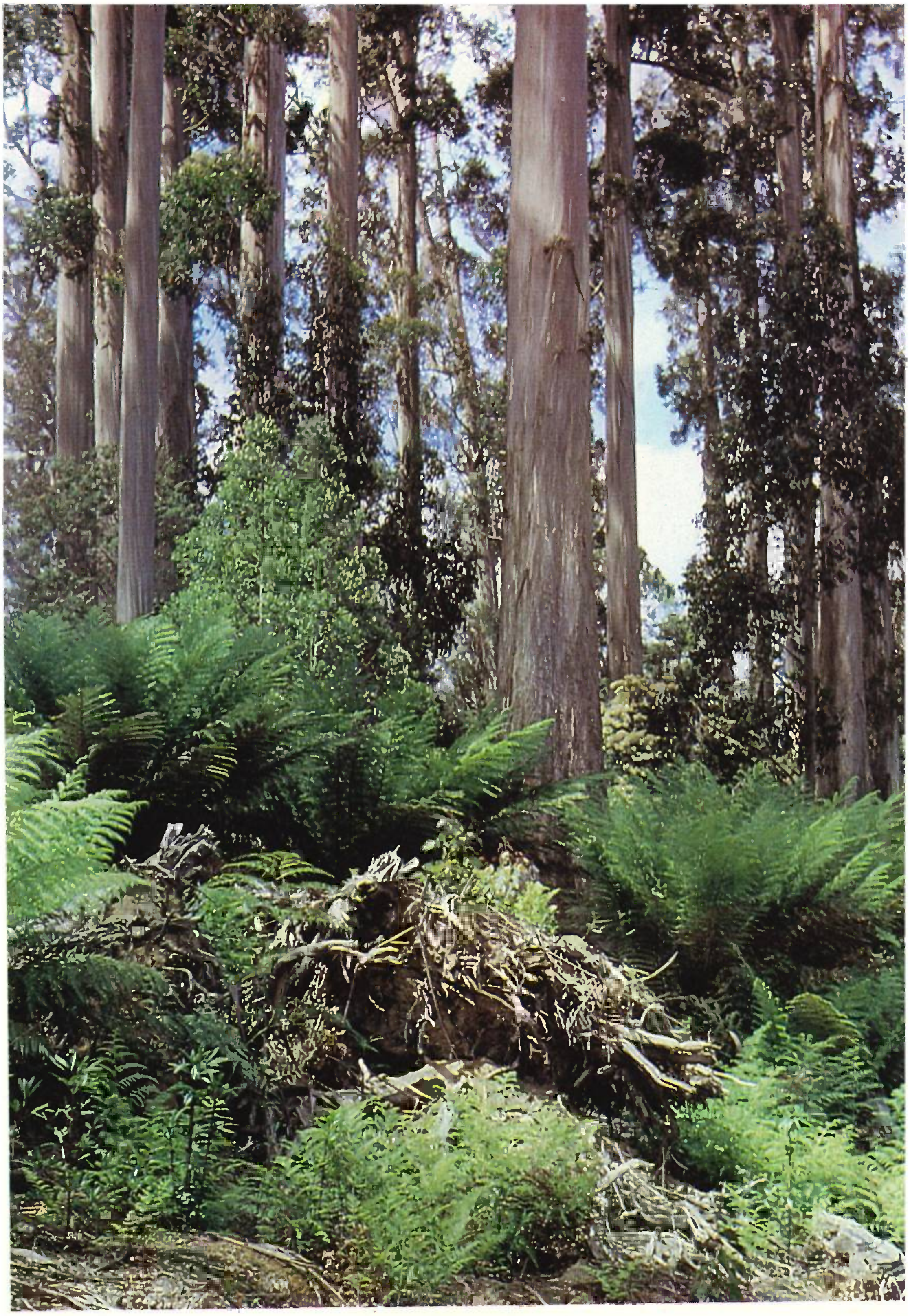


E. urophylla, original stand, Rio Claro, São Paulo, Brazil

L.D. Pryor

E. urophylla, degraded stand owing to interspecific hybridization. Santa Maria area, São Paulo, Brazil

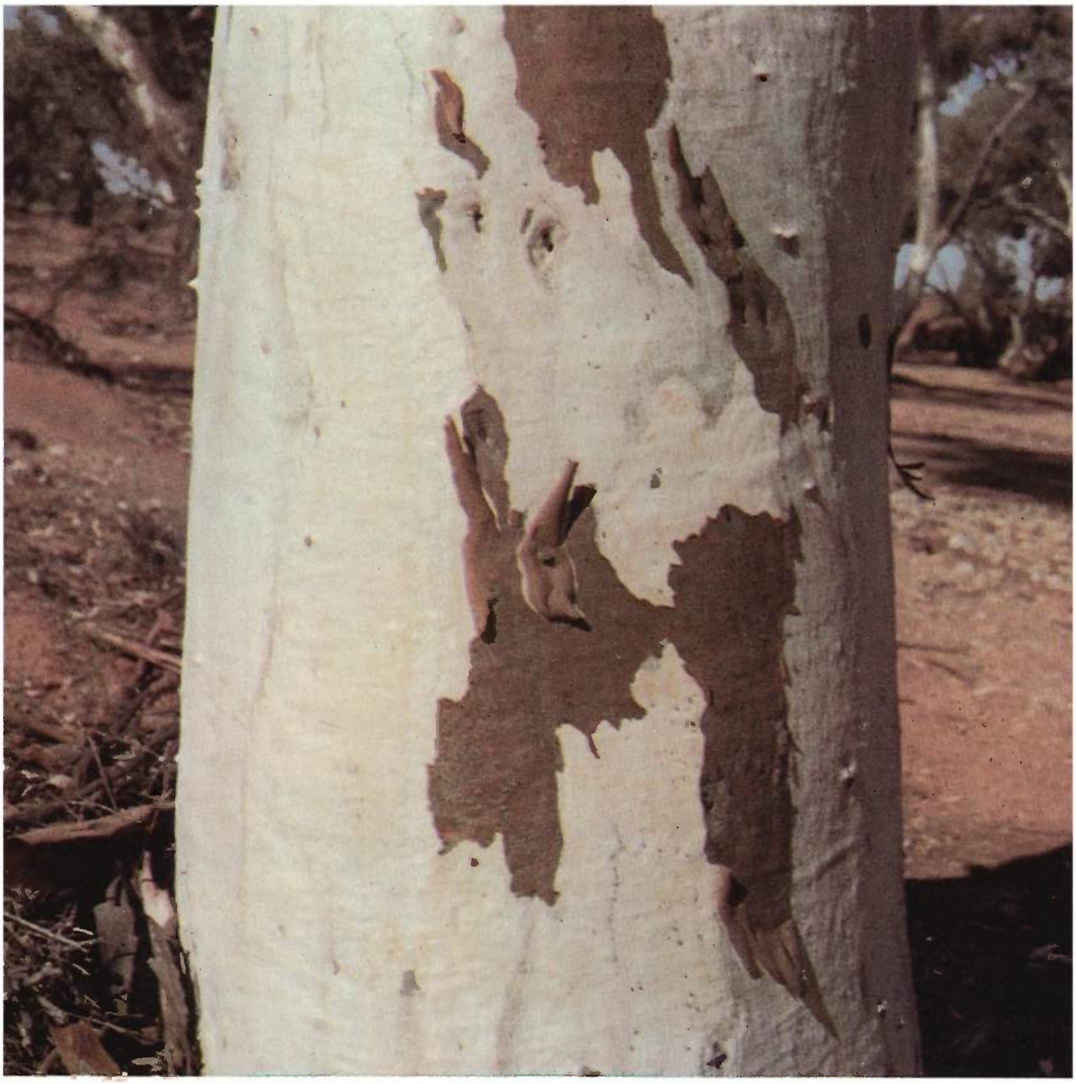
L.D. Pryor



E. regnans, natural
forest, Maydena, Tasmania

L.D. Pryor

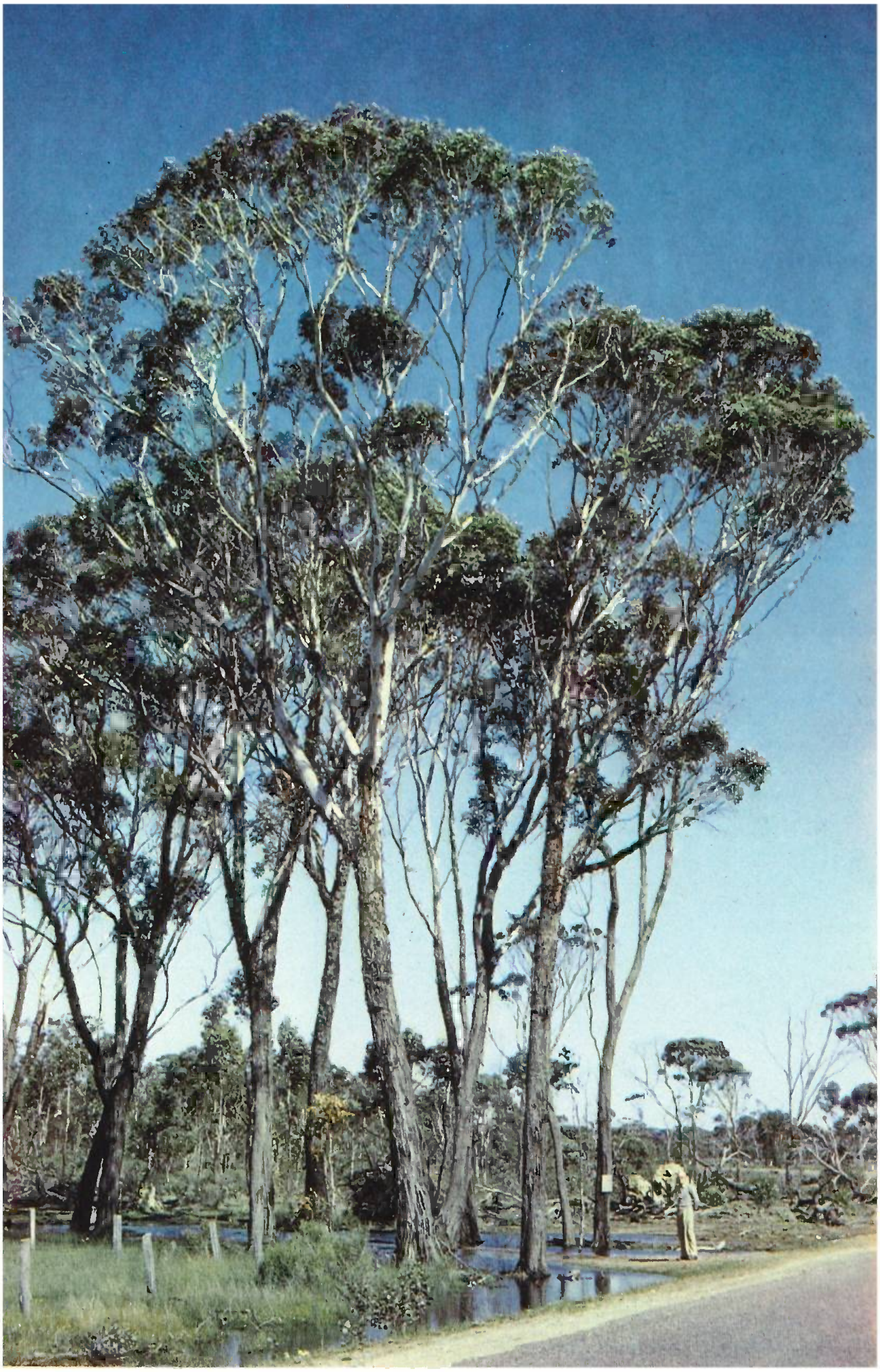
E. camaldulensis, tree form
CSIRO
Division of Forest Research,
Canberra, ACT, Australia



E. camaldulensis, bark form
CSIRO
Division of Forest Research,
Canberra, ACT, Australia

Natural stand of *E. camaldulensis* growing in a dry river bed in central Australia

L.D. Pryor



E. occidentalis, Western Australia
L.D. Pryor

Above and below: E. tetrodonta,
sucker from root. Darwin, Northern Territory, Australia

L.D. Pryor

E. gunnii, frost-damaged crowns,
Sochi, USSR
L.D. Pryor

E. cinerea, frost cracks, Sochi, USSR

L.D. Pryor

ligna, E. cloeziana, E. maculata, E. paniculata, E. globulus, E. camaldulensis and *E. tereticornis*. If the rotations are shorter, more than two coppice crops may prove satisfactory. A common assumption used to be a total of four crops in 22 years, with cuttings at 7, 12, 17 and 22 years. Later it was considered that the third coppice crop might be inadvisable, but now that better attention is being given to chain-saw cutting of stumps, three coppice crops may return to favour.

Treatment of site between crops

A great deal of slash is left on the ground when a seedling or coppice crop of eucalypts is felled. If this slash is spread irregularly over the area, it impedes access and becomes a severe fire hazard. If it is burned by a broadcast burn the resulting fire is likely to kill a substantial proportion of the stools required for the next coppice crop. It is best to pile the slash between every third or fourth row of stumps. The slash may be burned on damp and windless days or left to decay.

Treatments such as ripping or harrowing the land between the rows of stools have been tested experimentally with inconclusive results. Retaining the slash protects the soil to some extent and reduces weed growth. Burning in wettish weather reduces a possible dangerous fire hazard but is expensive. Cultivation of any kind encourages weed growth.

Reducing number of coppice shoots

In most cases a number of shoots will commence development on each stool. These are likely to be reduced to five or six by the phenomenon described above ("Mechanism of coppicing"). If five or six shoots are left on a stool they will always be bowed and capable of producing inferior products only. If straighter and more valuable stems are required the coppice must be thinned to three or two stems per stool or even one single stem. This should be done by the time the coppice shoots are 18 months of age.

The more stems left on a stool, the smaller will be their ultimate diameters but more stems may produce more volume on very short coppice rotations. If the rotations are up to 10 or 12 years the volume per hectare produced from one stem per stool is close to the volume produced by more than one stem, and the potential value of the material produced by one straight, well-selected stem per stool is likely to be considerably greater. The sooner the final number of stems per stool is attained, the larger the stems will be by the end of the coppice rotation, but too early reduction may cause the loss of small material which might have a good sale in another year. Very small straight eucalypt stems have a value as fence droppers in many places. If this return can be obtained at, say, age 2 or 3 of the coppice crop, the financial advantage may be considerable, and still leave a full coppice return at age 10 from which many straight poles of high value may be obtained.

The shoots left on the stools after reduction by mutual competition should be in a stage where they have demonstrated form, wind firmness and vigour before final selection of the one or two stems to be left can be made.

Stems which have come from dormant buds below the top of the stump and which are giving promise that the callus developing from them will grip the top of the stump as shown in Figure 28 should be chosen. Stems growing on the windward side of the stumps are to be preferred because they are less liable to windthrow than stems growing on the lee side.

If overall plantation management makes it practicable, it is preferable to coppice stems in the seasons least liable to severe frosts and strong winds. Thinning of coppice shoots should be done carefully, but light axes or machetes may be necessary, as chain-saws cannot be used around the congested shoots on the stump.

The final number of stems per hectare retained in the thinned coppice crop should not be less than the original stocking. When some of the stools have died, adjacent stumps should be left with more than one stem.

Killing old stumps

If an old crop is to be replanted the stumps should be removed or killed. Otherwise shoots from an appreciable proportion of them will interfere with the new crop and spoil its uniformity. The old stumps, which will take many years to decay, could also harbour or develop pathogens which might attack the new crop.

It there are 1 000 or more stumps per hectare in the old crop, the stumps and adjacent large roots represent a considerable volume of wood that would make excellent fuelwood for the local market. However, the process of removing and stacking, or alternatively removing and burning them, is difficult and expensive. At the present stage it is therefore not possible to envisage more than a very small percentage of old eucalypt coppice land where the removal of stumps will be undertaken.

If they cannot be removed, the stumps must be killed. This involves destroying the numerous dormant buds near the surface of the ground and also possibly below ground level, because the lignotubers of eucalypts are often buried in the soil. The buds may be killed by completely de-barking the stumps by axes or chisel bars or by poisoning the stumps. If the stumps are to be poisoned it is preferable for a frill cut to be made around them to receive the poison, rather than an attempt at complete de-barking.

The poisons used may be a common commercial one such as a 5 percent solution of sodium arsenite in water or a hormone-type poison such as 2,4,5-T. Sodium arsenite is poisonous and dangerous to animal life. Proprietary chemicals based on 2,4,5-T are more expensive than sodium arsenite. Oil-miscible 2,4,5-T (40%) diluted to 5% by dissolving in fuel oil has proved an effective inhibitor of coppice. Poisoning old stumps is an expensive operation and an owner may prefer to send workmen along the lines of the previous crop to bash off coppice shoots from the old stumps. This could be done at the same time as weeding. Two or three treatments may be necessary before the new seedling crop completely overtops weeds and old coppice.

Thinning plantations

Coppice crops intended for the paper industry, fuelwood and even sometimes for mine-timbers may receive little or no treatment between cuttings, but these crops have a low value per unit of volume. Unthinned coppice crops cover by far the greatest proportion of the world's eucalypt plantations, so information on thinning schedules is sparse.

If it is intended to develop a higher value crop of progressively larger stems, the stocking on a compartment should be reduced as the height of the trees increases. The first thinning might be best made by extracting every third row. This would give a utilizable yield of pulpwood and some small poles equal to one third the total volume of the stand, as well as facilitating access to the stand for extraction.

Table 5.3 summarizes thinning schedules reported for *E. grandis* in South Africa (Wattle Research Institute, 1972) and *E. grandis* in Zambia (Appendix 3). An earlier thinning schedule for South African *E. grandis* is in Appendix 3 (Table A 3.11). For *E. globulus* Uruguay reports two thinnings at ages 6-7 and ages 10-11 which together remove 70 percent of the number of stems established. Final felling for the remaining 500 stems/ha is at age 16.

Table 5.3 Examples of thinning schedules for *E. grandis*

Age in years	Stems remaining per hectare after thinning	Percentage thinned	Estimated diameter at breast height of thinnings (cm)
		South Africa	
0	1 330	—	—
6-7	990	25	11-17
9-10	740	25	18-20
12-13	490	33	22-24
15-16	250	50	25-28
18-19	150	40	29-30
21-22	100	33	32-36
30	0	100	56-61
		Zambia (Copperbelt)	
0	720	—	—
2	496	31	9.2
5	329	34	20.1
9	220	33	26.7
12	0	100	33.5

For *E. deglupta*, Papua New Guinea reports an initial stocking of 480 stems/ha, a cleaning thinning at age 5, a thinning to 244 stems/ha at age 10, to 99 at age 15, and clear-felling at age 25.

Stumps of eucalypt thinnings of many species will produce coppice shoots. In some countries, if there are good local markets for small produce, the coppice understorey may be allowed to grow for later harvesting. In other countries the stumps are poisoned. This simplifies management and prevents competition by the coppice, which would cause a decrease in the growth rate of the more valuable crop of large poles, sawlogs or veneer logs.

Mini-rotations; silage harvesting

In recent years there has been some interest in the possibility of growing crops of trees without wasting the leaves, the branches and the bark. The thought has been that a dense crop could be grown on a very short rotation of two or three years and the whole crop machine-harvested, chipped and pulped. The proposals have not been made specifically for eucalypts, but could be suitable for them.

The difficulties seen in these proposals are:

(*a*) The expense of establishing a plantation at spacings of 1 × 1 m or less. An enormous quantity of planting stock would be required.

(*b*) The high percentage of bark, branches and leaves. In small eucalypt stems there may be 30 percent of bark. Can this material be made use of?

(*c*) The short length of the fibres in very young wood of any species.

Silage harvesting could be very valuable when fires occur in plantations. Even when excellent protection is maintained within a plantation it can be severely damaged by wild fires from outside.

If a eucalypt plantation is burned while it is fruiting, it is likely that tens of thousands or even hundreds of thousands of seedlings per hectare will become established on the burned areas. This has happened in a number of different localities in several countries. What to do with the resulting jungle of small tree stems becomes a difficult problem. It would be a great help if the dense crop could be silage harvested before it seeded again and further complicated the situation.

Should silage harvesting become truly promising, it could be started from one normal coppice rotation of a suitable eucalypt species, cropping perhaps 75 percent of it and deliberately burning the remainder.

6. Farm plantations, shelterbelts and ornamental plantings

The greater part of this book deals with the use of eucalypts in commercial plantations which involve governments, companies and individuals in substantial investments of capital. The present chapter is concerned with the contribution the genus can make to the beautification of properties and the amelioration of the effects of sun and wind. Many trees of the world have been used for these purposes, but the eucalypts must rank highly among the genera which have assisted particularly in the middle and lower latitudes.

The eucalypts have favourable and unfavourable growth habits for ornamental and shelterwood plantings. What might be called the "noble" species of the genus grow quickly, shed most of their lower branches, and develop an attractive mature form within the term of occupancy of a property by a substantial owner or family, say 30-50 years. The term "noble" is meant to describe those species which will make large, isolated individuals and which can withstand the onslaughts of any normal storm likely to strike a locality. Large park trees of equivalent quality from most other genera would take 100-300 years to make a noble park tree equal to the better eucalypts which have been meticulously cared for over 30-50 years.

The eucalypts do not cast a heavy overhead shade, but they cast a good side shade throughout the year. The average life of their leaves is not long; leaves, twigs, branches and bark drop from the trees throughout the year as they are replaced by new growth. The eucalypt owner is faced with a minor, but continuous, task of cleaning up, whereas the owners of deciduous trees have this problem for two or three weeks only in the autumn.

If eucalypts are planted under telephone or power lines they race upward and interfere with them. Their active roots may damage concrete driveways and house foundations.

Farm plantations

The attitude of a farm owner to eucalypt plantations would depend on the overall size of the farm and the availability of labour and equipment to service the plantations.

If the owner is a substantial landholder and adequate labour is available in the locality, it might be advisable to allocate a specified section of the property to eucalypt plantations and to manage it along the lines described in Chapter 5, possibly employing a consultant to supervise preparation for planting and subsequent treatment and utilization. If the annual planting is not extensive, planting stock might be purchased if available in the locality. In such a case the plantation on the property is just part of the local forested area, perhaps some added advantage being obtained by siting it in a favourable position from the aesthetic point of view.

If an owner has a property of reasonable size but not large enough to manage part of it as a normal commercial eucalypt plantation, he might grow specially selected eucalypts to produce products with a higher unit market value, giving the trees careful individual attention to ensure a crop that will meet stringent standards. The growing of crops such as *E. cloeziana* and *E. paniculata* for the preserved transmission-pole market is an example. *E. cloeziana* requires care in the nursery, and the coppice on the stools must be thinned to make acceptable poles in the first coppice rotation.

Another special purpose to which a moderately sized eucalypt-growing area can be devoted is as a shade area for stock. For this purpose the better-crowned eucalypts should be chosen, species depending on climate. In a moist cool area with a winter rainfall of 1 000 mm or better, *E. diversicolor, E. delegatensis, E. oreades* and *E. dalrympleana* will make very satisfactory shade areas and provide valuable poles and sawlogs as they grow. In summer rainfall climates with a rather similar rainfall at middle latitudes, *E. pilularis, E. grandis, E. tereticornis* (of suitable provenance), *E. microcorys* and *E. urophylla* have made excellent shelter paddocks for cattle. In lower latitudes (lower than 15°) and preferably with a rainfall of 1 500 mm, *E. urophylla*, the north Queensland provenances of *E. grandis, E. tereticornis* and *E. pellita*, and also *E. torelliana* (in particular), *E. brassiana* and *E. microcorys* make good shady groves. All of the species referred to in this paragraph should provide commercially valuable thinnings.

Farm parks

There are some properties in Australia and Timor which have been managed as farm parks for a hundred years or more. The scattered trees have been carefully protected but not utilized for timber unless killed by lightning strike or other accident. Here the noble species may be seen at their best and set a very high standard. A number which grace properties in different parts of Australia and Timor are listed below:

Type of locality and climate	Proved noble species
1. Tasmania: Latitude 41°-44°S Rainfall: 600-1 000 mm, mainly in winter	 *E. dalrympleana* *E. globulus*
2. South Australia, Mount Lofty Ranges: Latitude 35°S Rainfall: ca 1 000 mm, mainly in winter	 *E. rubida* (Mt Lofty provenance) *E. camaldulensis*

3. South Australia, Southern Flinders Ranges: Latitude 33°-34°S Rainfall: ca 500-625 mm, mainly in winter	*E. camaldulensis* *E. cladocalyx*
4. Western Australia, coast south of Perth: Latitude 32°-34°S Rainfall: ca 1 000 mm, mainly in winter	*E. calophylla*
5. Western Australia, Manjimup area: Latitude 34°S Rainfall: ca 1 100-1 500 mm, mainly in winter	*E. diversicolor*
6. S.E. Victoria: Altitude 300-500 m Latitude 38°-39°S Rainfall: 1 200-1 500 mm, mainly in winter	*E. regnans*
7. N.E. Victoria and S.E. New South Wales: Altitude 500 m Latitude 37°S Rainfall: 1 200-1 500 mm, well distributed	*E. nitens* *E. maidenii*
8. N.E. Victoria and S. New South Wales: Altitude 1 000 m Latitude 36°-37°S Rainfall: 1 200 mm, mainly in winter	*E. dalrympleana* *E. delegatensis* *E. blakelyi*
9. New South Wales tablelands: Altitude 600-800 m Latitude 33°-37°S Rainfall: 500-750 mm, well distributed	*E. maculosa* *E. melliodora*
10. Inland slopes of New South Wales and Victoria: Altitude 300-400 m Latitude 34°-36°S Rainfall: 500-750 mm, mainly in winter or uniform	*E. melliodora* *E. polyanthemos*
11. South coast, New South Wales: Latitude 35°S Rainfall: 750-1 000 mm, well distributed	*E. maculata* *E. pilularis* *E. botryoides*

12.	North coast, New South Wales and south coast, Queensland: Latitude 28°-32°S Rainfall: 750-1 500 mm, mainly in summer	*E. maculata* *E. pilularis* *E. saligna* *E. grandis*
13.	North coast, Queensland: Latitude 15°-20°S Rainfall: 1 200-2 500 mm, mainly in summer	*E. tereticornis* (certain provenances) *E. grandis*
14.	Atherton Tableland, Queensland: Altitude 1 000-1 500 m Latitude 17°S Rainfall: 1 500-3 000 mm, mainly in summer	*E. tereticornis* (certain provenances) [1] Probably *E. brassiana* [1] Probably *E. torelliana*
15.	Eastern Timor (above village of Maubisse): Altitude 2 000 m Latitude 9°S Rainfall: 1 500-2 000 mm or more, on northwest and southeast	*E. urophylla* (provenance from above Maubisse with a smooth upper bark; this provenance is preserved outside the houses of chiefs)

There may be other species which would deserve the classification of noble trees in private parks but have not yet been selected and preserved by owners for a sufficient number of years.

It will be noted that stringybarked species have not been listed among the noble trees. This is because cattle tend to strip and chew the barks of the stringybarked trees when pastures are lush. For this reason, smooth-barked, box-barked and bloodwood-barked trees make the outstanding park trees.

Shelterbelts

Eucalypts are not naturally good shelterbelt trees because of their branch-shedding habit. This permits the wind to blow under the crowns of one row of trees. Some Australian graziers consider that this is dangerous to cattle taking shelter under the trees. One way to overcome this problem is to plant the trees as several rows. About one third of the trees are felled each third year and allowed to coppice. This method of planting and coppice-cutting makes a reasonable shelterbelt and also provides a useful crop of poles and fuelwood for farm purposes. Many species can be used as shelterbelts in this way. *E. cladocalyx* has served a useful function on the largely treeless plains of western Victoria in Australia by providing fuel-

[1] The word "probably" has been inserted here because properties containing these trees have not as yet been managed as farm parks in Australia; whereas in Timor, chieftains have maintained *E. urophylla* in this state for centuries.

wood and farm timbers from coppiced shelterbelts. In Uganda *E. microcorys* has proved a preferred species because lower branches of edge trees are persistent and downward sweeping (Kingston, 1977).

Better shelterbelts can be made by combining plantings of eucalypts, pines, *Acacia* and other shrubs.

A wide range of eucalypts are available as shelter for a variety of conditions. For very cold frosty conditions, *E. gunnii*; for cold frosty conditions, *E. bridgesiana*. For dryish winter-rainfall sites, *E. cladocalyx*; for moist winter-rainfall sites with not much frost, *E. diversicolor* and *E. ficifolia.*

For rather dry storm-rain sites, *E. salmonophloia.*

For sites such as good Australian sheep country, *E. melliodora, E. polyanthemos* and *E. moluccana.*

For well-distributed rainfall or well-watered sites in the higher latitudes (30°-40°), *E. botryoides*; in the middle latitudes (20°-30°), *E. maculata, E. microcorys* and *E. pilularis*; in the low latitudes, *E. torelliana.*

For high-rainfall equatorial sites, *E. deglupta.*

If a property owner wishes to use eucalypts as a coppiced windbreak it is important that species which coppice reliably should be chosen. Of the species mentioned above for shelterbelts, all should coppice for at least two cuttings of the coppice except *E. deglupta*, which would only be suitable for high-rainfall equatorial sites in any case. Although not usually considered a coppicing species, *E. diversicolor* has coppiced well in South Africa. The same is true of *E. pilularis*, which coppices well in its native forest.

Roadside plantings

Eucalypts can be used for highway plantings designed to reduce traffic noise. Then the relatively densely crowned species should be used. Deliberate design for noise abatement automatically restricts the view of the countryside for passengers, which may be justified in closely settled urban areas but not in rural districts, where lightly crowned species are preferable, as they permit a better view of the countryside. A range of crown types is listed below.

Usually dense crowns: E. gunnii, E. cinerea, E. ficifolia, E. polyanthemos, E. torelliana.

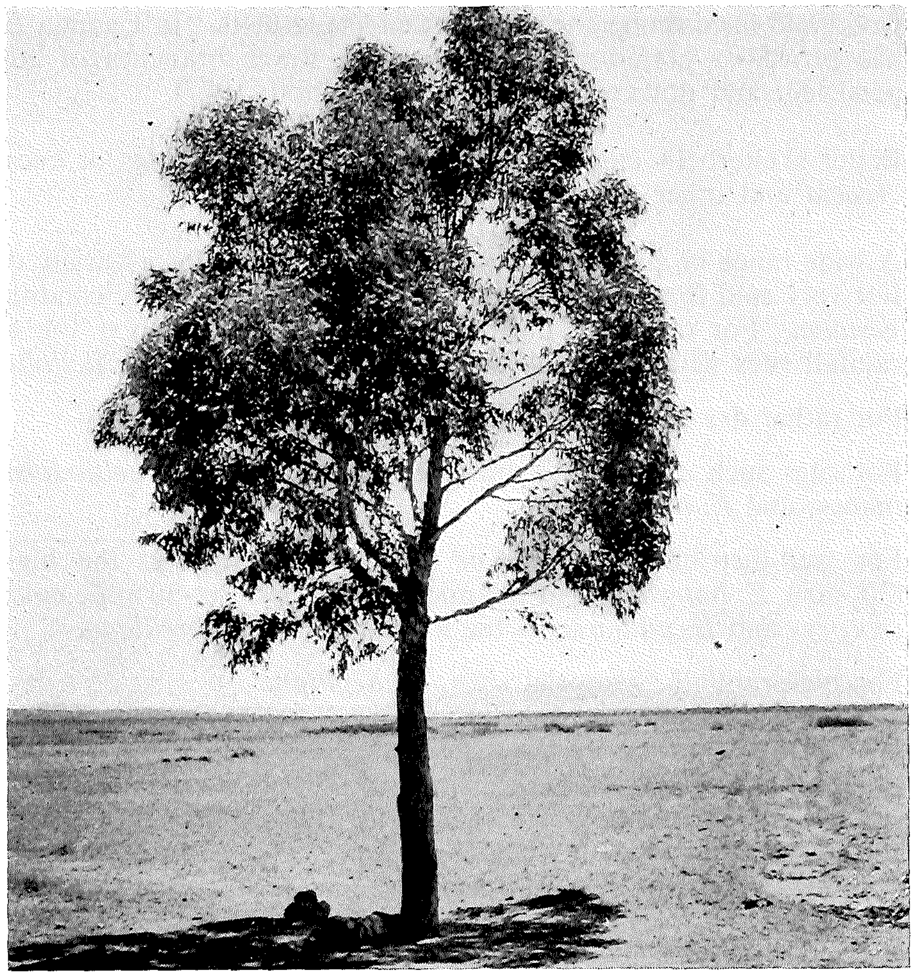
Fairly dense crowns and short boles: E. bridgesiana, E. botryoides, E. globulus and *E. bicostata* (when used as roadside trees).

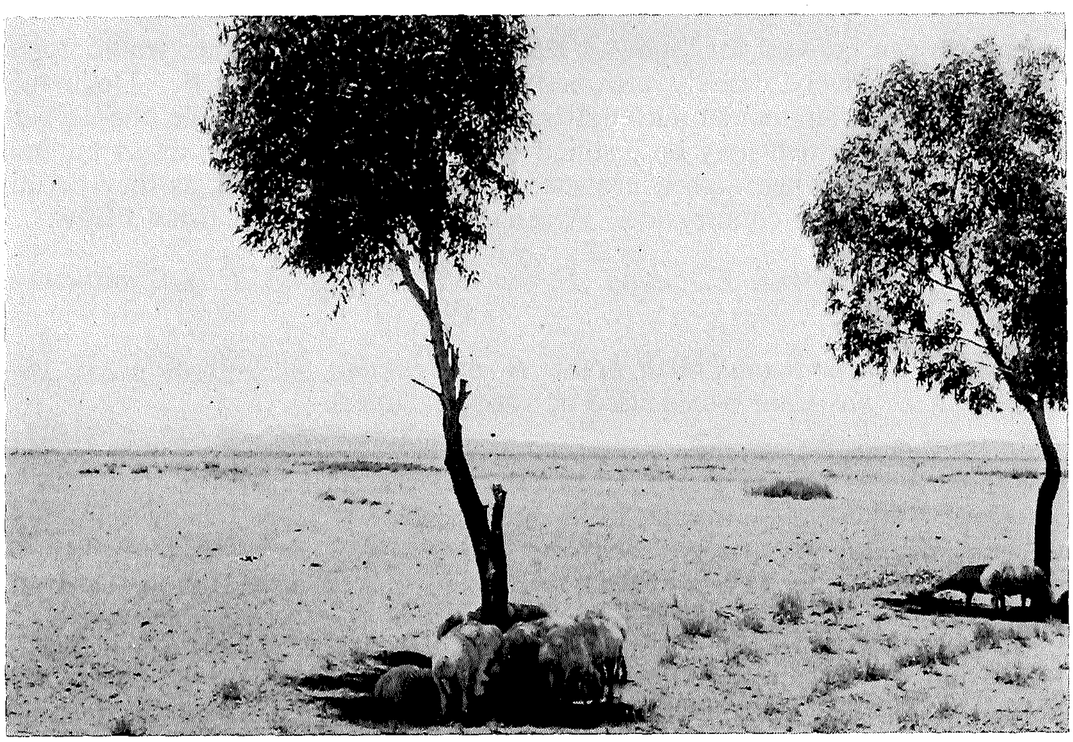
Light crowns: E. cladocalyx, E. salmonophloia, E tereticornis, E. saligna.

Ornamentals

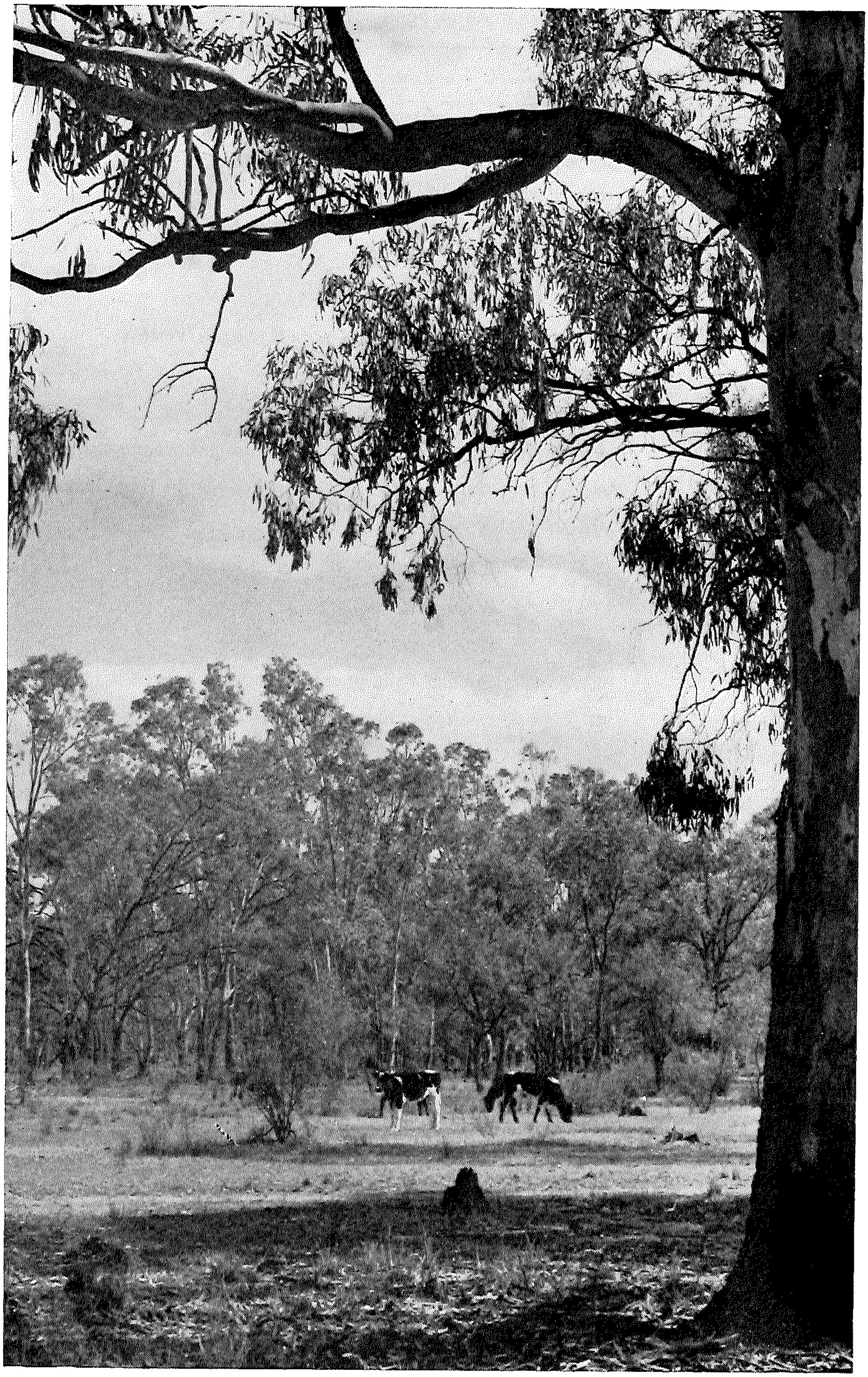
Eucalypts should not normally be planted in the soil close to house foundations. They can be attractive against a house wall, and in California are planted in large wooden or concrete tubs and moved on a transporter from one position to another.

House-plot trees should be species with a low natural height growth or the height should be carefully controlled. They take kindly to pollarding. A list of species worth experimenting with is shown in Table 6.1.





29. *Above* and *below*, roadside planting of *E. gomphocephala* giving much-needed shade to man and animals
M. Reynders



30. *E. camaldulensis* as an amenity tree in an area which combines timber production, recreation and grazing (Barmah, Victoria)
Forests Commission, Victoria

Table 6.1 Ornamental species of *Eucalyptus*

Species	Originating in	Description
E. bridgesiana	NSW [1]	Young foliage
E. caesia	WA [2]	Pink flowers
E. calophylla	WA	Particularly the pink-flowered variety
E. cinerea	NSW	Silvery foliage
E. erythrocorys	WA	Buds, flowers and fruits
E. erythronema	WA	Particularly the pink-flowered variety
E. ficifolia	WA	Dense, spreading foliage and pink flowers
E. forrestiana	WA	Scarlet buds
E. kruseana	WA	Young foliage and curious inflorescences
E. laeliae	WA	Small tree; very attractive white bark
E. lane-poolei	WA	White bark
E. lehmanii	WA	Buds, flowers and fruit clusters
E. lesouefii	WA	Buds and fruits
E. miniata	NT [3]	Pink flowers
E. perriniana	NSW	Silvery foliage and opposite leaves
E. phoenicea	NT	Crimson flowers
E. polyanthemos	NSW	Glaucous foliage and quivering leaves
E. ptychocarpa	NT	Large, discoloured leaves, pink or white flowers
E. pulverulenta	NSW	Young foliage
E. pyriformis	WA	Huge buds, flowers and fruits
E. sideroxylon	NSW	The pink-flowered variety with striking black bark
E. stoatei	WA	Scarlet buds; flowers and fruits
E. torquata	WA	Pink flowers; buds and curiously shaped fruits
E. woodwardii	WA	Yellow flowers

[1] New South Wales. — [2] Western Australia. — [3] Northern Territory.

At the Forest Research Institute at Rotorua in New Zealand, there are examples of *E. ficifolia* grown in tubs and then bud-grafted with mature-shoot buds. They have developed into drooping shrubs covered with the scarlet flowers characteristic of this species. Equal in decorative qualities to tub-cultivated rhododendrons, they flower for a much longer period. It is likely that similar cultures of the attractive species listed in Table 6.1 could also be made.

7. Tree improvement

Over hundreds of years man has greatly improved his crop plants by the selection of desirable individuals as the source of seed for the next crop, by vegetatively multiplying desirable individuals, or by producing new strains by controlled crosses. During the past twenty years many tree-breeding programmes have been started on the same lines. The knowledge and experience accumulated over the years provide a good basis for planning new programmes, and for correctly orienting established ones.

This chapter will not discuss the general theory of genetics, tree improvement and breeding strategies, as that information is available elsewhere (e.g., Wright, 1976; van Buijtenen *et al.*, 1971; FAO, 1974c; FAO, 1964, 1970, 1978; Stern and Roche, 1974; Namkoong, 1972; Faulkner, 1975). Special consideration will instead be given to the methods most appropriate for the improvement of eucalypt species.

Eucalypt characteristics that affect tree improvement

SPECIES AND SPECIES HYBRIDS

The formation of spontaneous, interspecific hybrids is rare in forest trees. Although a few recognized cases of hybrid populations ("hybrid swarms") in eucalypts have been described (Barber and Jackson, 1957; Heiser, 1973; Pryor and Johnson, 1971), each species normally retains its own identity in natural conditions. The genetic integrity of species is due to geographical, ecological, phenological and physiological barriers. When, however, species from varying regions or conditions are planted next to each other outside their natural habitat, these barriers may be diminished or totally eliminated.

Predictions can be made of the number of hybrids likely to result from populations of interbreeding species planted in close vicinity to each other. If all the members of a related group comprising *n* number of species can interbreed, the number of potential F_1 hybrid combinations can be calculated according to the formula:

$$n_{C_r} = \frac{n!}{r!\,(n-r)!}$$

where: n_{C_r} = the potential number of different combinations

n = the number of taxa in the group

$n!$ = the factorial of n

$r \quad = 2$ (i.e., the male and female parents)
$r! \quad =$ the factorial of $2 = 2$
$(n - r)! =$ the factorial of $(n - 2)$

The factorial of 100 (100!) is 9.3326×10^{157}. In the subgenus *Monocalyptus* there are 106 taxa, which can all interbreed; if the number were exactly 100, the potential number of F_1 hybrid combinations would thus be:

$$n_{C_r} = \frac{100!}{2 \times 98!} = 4\,950$$

In the first generation, species hybrids generally exhibit hybrid vigour, i.e., more vigorous growth and higher yields than either parent. It should, however, be noted that this vigour is often due to non-additive gene effects, and that seed collected from F_1 hybrids and from subsequent generations generally produces unacceptably variable stands because of segregation of the genes. It is therefore advisable to restrict adjacent plantations from which seed will be collected to subgenera that do not interbreed, and to establish plantations only from seed of known source and genetic purity.

Provenances

To utilize and conserve the vast eucalypt gene resources available, exploration, classification and evaluation work is needed, as our knowledge of the genetic variation in many species is still insufficient.

Depending on the natural distribution, variation within eucalypt species may be either clinal or ecotypic. This provenance variation is usually recognized on the basis of morphology, but it is almost always accompanied by variation in important physiological characters (Pryor, 1978). Some species of eucalypt are found over a wide range of environments and cover extensive areas (e.g., *E. camaldulensis, E. tereticornis, E. microtheca*). Variation within these widely distributed species may sometimes be as great as the variation found between closely related species. Other species have a more limited distribution which, however, may sometimes consist of isolated provenances adapted to specific environmental conditions (e.g., *E. globulus, E. cloeziana, E. bicostata*). Others again, like *E. dunnii,* may occur naturally on very limited areas but still be genetically variable, and adaptable to a variety of conditions when planted as exotics.

During the last two decades many detailed studies have been made on the natural variation of eucalypts, partly prompted by the increasing interest in growing these species in plantations outside their natural range. Species-specific details on these studies can be found in Chapter 14. In addition to the results already reported there, studies are in progress on the natural variation of *E. alba, E. cloeziana, E. grandis* and *E. sieberi.* However, there still remain many important commercial species, such as *E. delegatensis, E. microtheca, E. saligna* and *E. tereticornis,* which have received little attention (Turnbull, 1978).

MODES OF REPRODUCTION

Sexual reproduction

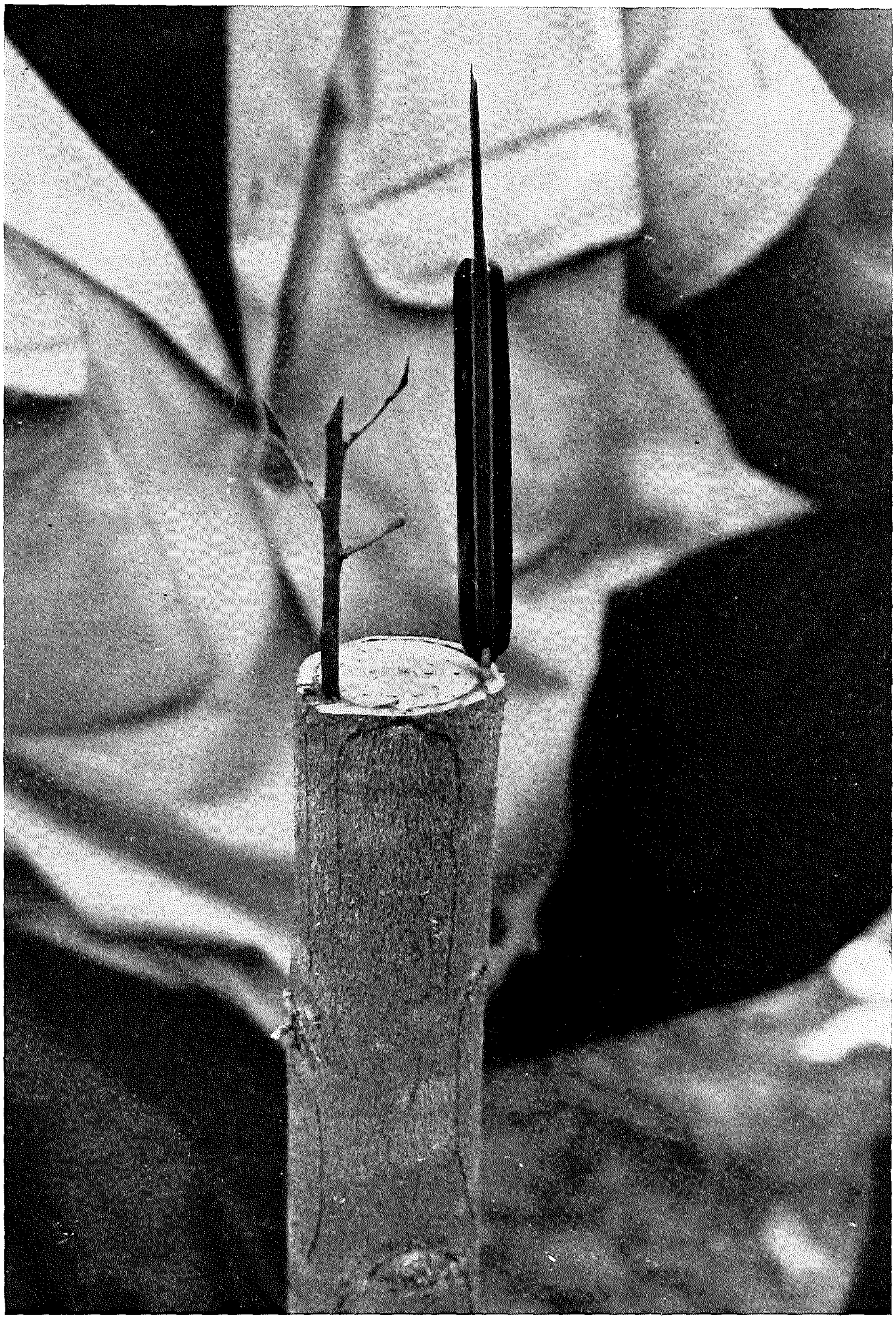
As in many woody genera, regeneration of *Eucalyptus* in nature is generally by seed. Flowers of all species are bisexual with fertile male and female organs found in the same flower. Pollination is generally dependent on insect or animal vectors.

In spite of the fact that most species are to some degree self-compatible, eucalypts seem to be predominantly outbreeding (Hodgson, 1976d; Pryor, 1978). Outbreeding is favoured by mechanisms operating at two different developmental stages, reducing the degrees of self-pollination and self-fertilization. Self-pollination within one flower is diminished by protandry of the flowers. Whereas most of the pollen is shed within hours of the shedding of the operculum, the stigma generally does not become fully receptive until four to seven days later. As the stigma is not sticky and therefore does not retain pollen well during the first few days after the opening of the flower, and as eucalypt pollen on the other hand starts losing its viability after three to four days, the probability of intra-floral selfing is small (Eldridge, 1970; Hodgson, 1976a; van Wyk, 1977). As, however, all the flowers in the same flower cluster and in clusters in different parts of the crown do not open simultaneously, a considerable amount of self-pollination is known to occur within one tree in spite of protandry.

Self-fertilization is diminished by the fact that pollen tubes of foreign pollen grow relatively faster on the stigma and therefore have a better chance of fertilizing the ovule. It is also likely that there are gene-controlled incompatibility systems which operate at the embryo stage; these would account for the poor seed set observed in inbred trees (Chaperon, 1978b; Eldridge, 1976; Hodgson, 1974; Pryor, 1961, 1978). Estimates of the percentage of selfed seed in eucalypts, derived from the use of marker genes or, more recently, isoenzyme techniques, range from 8 to 40 percent (Brown *et al.*, 1975; Eldridge, 1970; Hodgson, 1974; Krug and Alves, 1949; Phillips and Brown, 1976). The percentage of selfed seedlings will be further decreased by the often low germination capacity of selfed seed, and the low vigour of inbred seedlings (Hodgson, 1976b; van Wyk, 1978).

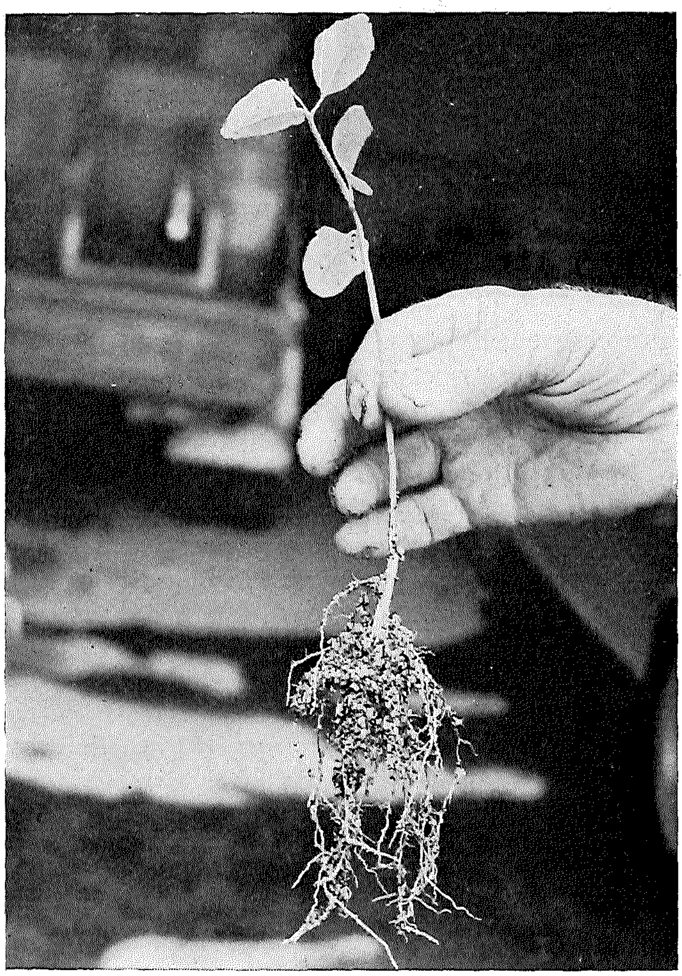
For many eucalypt species, generation time is from four to seven years from seed to the production of the first seed crop, although there are exceptions in which flowering and seed set may take place as early as in the second or even the first year. Seedlings of *E. deglupta* are reported to flower at the age of 6 months in the Congo. Seed for most species takes from six to twelve months to ripen (Chaperon 1978b; Davidson 1978a; Hodgson, 1976c; Martin and Cossalter 1976; Pryor, 1978).

The frequency of good seed years varies among species. Under natural conditions, species such as *E. camaldulensis*, *E. grandis* and *E. saligna* usually bear heavy seed crops every two to three years. In *E. regnans*, heavy seed crops are produced every two to four years. Species such as *E. gomphocephala* and *E. maculata* produce heavy seed crops at longer and more unpredictable intervals (Turnbull, 1977). Since crown size is an



31. Eucalypt grafting for the establishment of seed orchards in the Congo
Centre technique forestier tropical, Nogent-sur-Marne

32. *Above* and *below:*
E. grandis — successful rooting (within one month) of cuttings from coppice shoots, Coff's Harbour
Australian Paper Mills/CSIRO, Canberra



33. *E. grandis* fruits ready for harvesting 30 months after planting out of rooted cuttings from coppice shoots
Australian Paper Mills/CSIRO, Canberra

important factor in determining the quantity and quality of seed produced, large quantities of seed are often difficult to obtain in highly stocked eucalypt plantations, and seed production areas should therefore be heavily thinned.

Vegetative reproduction

Although eucalypts generally regenerate from seed, supplementary survival through vigorous vegetative reproduction of damaged individuals is frequent in nature. Vegetative propagation of selected individuals by man is a fairly recent, promising means of directly utilizing on a large scale gains achieved by tree breeding.

Coppicing. Many species of eucalypt coppice readily, and coppicing is often used as a method of regenerating plantations (see Chapter 5). Once the first (seedling) generation has been established, no genetic control is possible, as all coppice regeneration will be genetically identical to the parent.

Grafting. Methods used in eucalypts are bottle grafting, top-cleft grafting, approach-grafting and budding. Although initial take may be as high as 80 percent, grafted eucalypts often display a high proportion of immediate or delayed graft incompatibility. This can partly be overcome by grafting onto stock plants derived from open or self-pollinated seed of the same tree as the scion (Burgess, 1974; Campinhos and Ikemori, 1978; Davidson, 1974a, 1978c; Pryor, 1961, 1978; Suiter Filho and Yonezawa, 1974; van Wyk, 1977, 1978).

Cuttings and air-layering. The ease of striking cuttings varies from species to species and, to a lesser degree, between individuals. The majority of eucalypts will not, however, strike from cuttings or form roots on air-layers once the plant has proceeded beyond the juvenile stage. The rate of decrease in the capacity to strike varies between species. Generally the ageing effects start to manifest themselves when the seedling has six to eight pairs of leaves, although, e.g., in *E. deglupta* cuttings can still be taken from seedlings three years old.

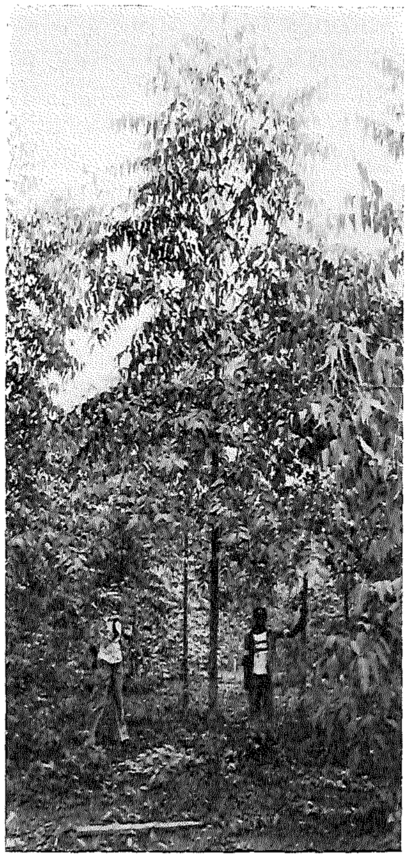
In practice the effects of ageing can be overcome by using adventitious, epicormic, or lignotuberous shoots for the production of cuttings. Formation of these can be promoted, e.g., by felling adult trees, by decapitating seedlings or young trees some distance from the ground, by partial girdling of the tree, or by hormone treatment. Hedging, i.e., the regular cutting back of shoots to promote the development of numerous vigorous new shoots to replace each shoot removed, is also sometimes used to secure abundant quantities of material suitable for cuttings. On an experimental scale, rejuvenation of older trees can be accomplished by repeatedly subculturing from grafts or from the small percentage of initially successful cuttings, thus gradually overcoming the effects of topophysis (Chaperon and Quillet, 1978; Davidson, 1974b, 1978a; Franclet, 1970, 1977; Martin and Cossalter, 1976; Martin and Quillet, 1974; Paton *et al.*, 1970; Pryor, 1969, 1978).

Possible breeding strategies

The first step in planning a tree-improvement programme is to ascertain the types of products likely to be required from the wood that will be grown, and the future aims of forest management (Brown, 1977). These factors will ultimately determine what species should be used and what breeding strategy should be followed.

Most countries starting tree-improvement programmes for eucalypts have adapted methods and breeding strategies developed for temperate species. Only recently have new strategies been formulated which take full advantage of the specific characteristics of the eucalypts and of the environmental conditions in which they are grown. The most promising strategy at the moment makes use of recent advances in the techniques of vegetative propagation for the mass production of genetically improved material, produced by traditional tree-breeding methods.

Based on responses to a questionnaire, Davidson (1975-76) listed five tropical countries in which national eucalypt-breeding programmes were being vigorously pursued. These were South Africa (*E. grandis*); Brazil (*E. grandis* and *E. urophylla*); Zambia (*E. grandis* and *E. tereticornis*); Philippines (*E. deglupta*); and Papua New Guinea (*E. deglupta*). In addition to these, the Congo has developed an advanced breeding strategy, based mainly on species hybrids. Hybrids are also considered for large-scale planting in India. In the temperate region, countries actively engaged include Australia (*E. globulus, E. grandis, E. obliqua, E. pilularis* and *E. regnans*); Portugal (*E. globulus*); and the United States (*E. grandis* and *E. robusta*). Eucalypt breeding on an experimental scale is practised in many more countries than those listed, but published information is scarce. In relating experiences from eucalypt improvement a certain bias is inevitable in favour of those species and areas for which information is readily available.



34. *Left,* outstanding performance of a provenance of *E. urophylla* from M. Lewotobi, Island of Flores, in trials at Loudima, Congo; mean height at 1 year, 7.18 m *Right,* another provenance of *E. urophylla* (from 2 300 m on Timor Island), also 1 year old, in Congo trials. Both growth and form are much inferior
Centre technique forestier tropical, Nogent-sur-Marne

STEP 1: SPECIES AND PROVENANCE SELECTION

Although substantial stands of eucalypts exist in many countries, early introductions were often haphazard and systematic species trials, in which a range of potentially valuable species are included, are therefore necessary. The importance of using the right provenance as a base for breeding work has been generally recognized, and provenance trials are often carried out in parallel with species trials.

The most important characters to consider at the time of species and provenance introduction are generally those related to climatic and edaphic conditions. Studies made on the natural variation of eucalypts will give indications on the ecological amplitude of the species, and on the range and type of genetic variation available. Results from these studies cannot, however, be directly applied when the trees are grown in a different environment and under plantation conditions. Caution must also be exercised when applying results from eucalypt plantations in one country or one region to another, especially as introduced species tend to be less predictable in behaviour patterns than native species. Replicated experiments on a range of representative sites are indispensable for determining the best species and the best seed source for a given area (Burley and Wood, 1976).

Although many of the existing trials are still young, a considerable amount of information is available on species and provenance trials of eucalypts (see Chapter 14 for species-specific information; see also Burley and Nikles, 1973; CSIRO, 1978; Davidson, 1975-76; Eldridge, 1975a). For example, in Brazil, where eucalypts are planted on a large scale, provenances of more than 80 different species have been tested; species of which more than 20 provenances have been tried include: *E. alba, E. brassiana, E. camaldulensis, E. cloeziana, E. grandis, E. microcorys, E. pilularis, E. saligna, E. tereticornis* and *E. urophylla* (IBDF, 1977; Palmer, 1975).

STEP 2: SELECTION AND MANAGEMENT OF SEED STANDS

Collection of seed from better-than-average stands, which have been thinned early to remove inferior phenotypes and to promote the development of large crowns capable of heavy seed production, is often the best and fastest interim measure for the production of bulk quantities of genetically somewhat improved eucalypt seed to meet immediate needs.

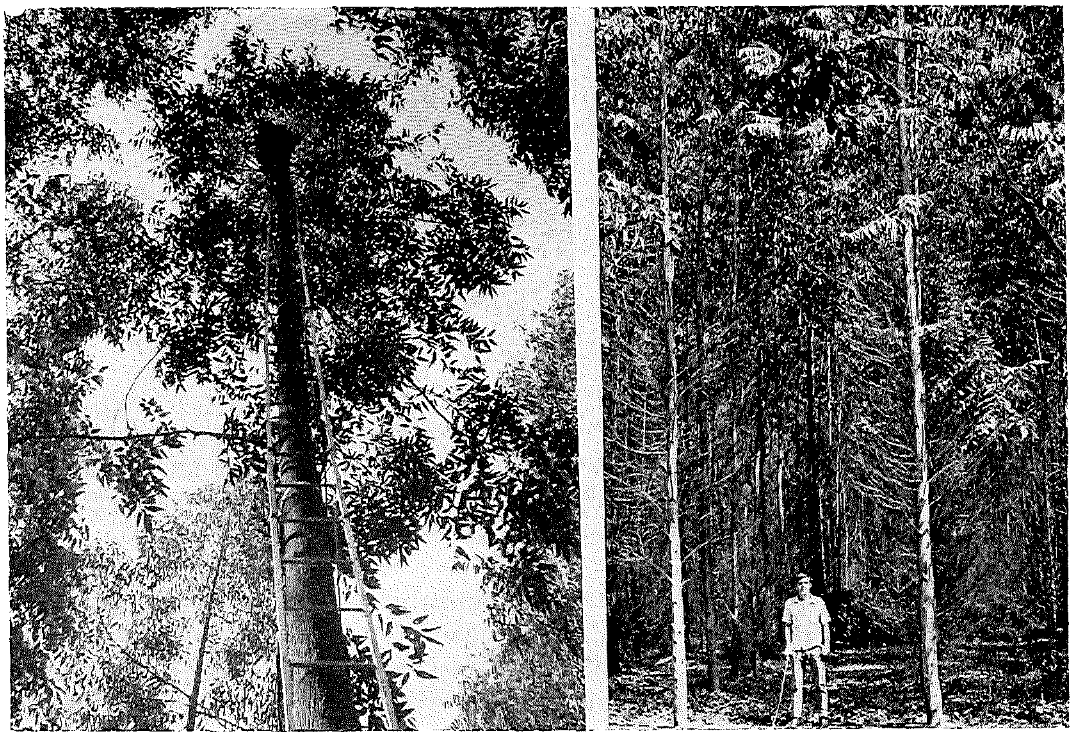
One of the most important criteria for eucalypt seed stands is that the origin of the stand be known. The main reason for this is that early overseas plantations are often based on seed from relatively few trees (Larsen and Cromer, 1970) and, although the stand itself may be of superior growth and form, the quality of the seed collected from it is likely to be poor because of a high degree of inbreeding. The eucalypt called '12ABL' grown in Madagascar and in West Africa is a good example of the narrow genetic base in many existing plantations and of the consequences of collecting seed in such plantations. This eucalypt is believed to be a north Queensland provenance of *Eucalyptus tereticornis*, but present-day plantations are thought to be derived from only one or two trees in Madagascar. While several countries report its good growth, second generation plantations in the Congo are suffering from high seedling mortality and a high incidence of dwarfing (Martin, 1971).

In addition to a narrow genetic base, existing eucalypt plantations often have a high incidence of hybrids; these are particularly common in stands which have been established using seed from exotic plantations. The implications of collecting seed from hybrids have already been discussed, and any individuals suspected to be of hybrid origin should be removed from seed stands in early thinnings.

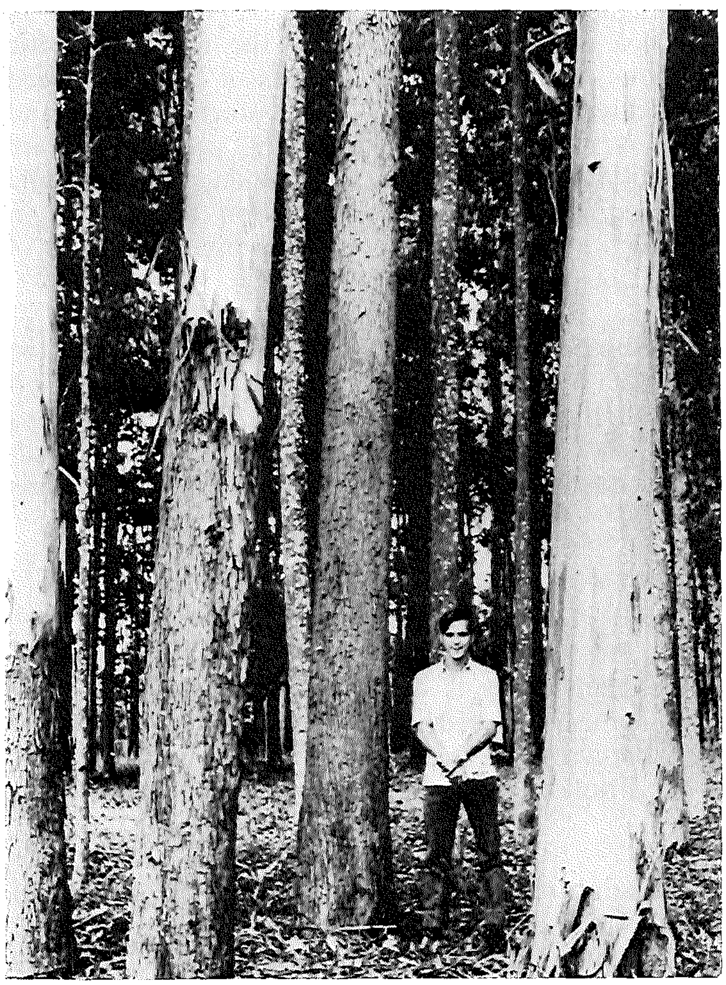
STEP 3: INDIVIDUAL SELECTION

The identification of desirable phenotypes is a step common to most tree-improvement programmes. The use of seed from phenotypically superior trees selected in plantations is known to have produced notable improvement in eucalypts (Eldridge, 1976; Franklin and Meskimen, 1973; Marsh and Haigh, 1963).

Phenotypically selected individuals are generally used for (*i*) the collection of open-pollinated seed for the establishment of plantations; (*ii*) the collection of open- or control-pollinated seed for progeny trials, through which genetic



35. *Left,* seed production area of *E. urophylla,* age 6 years, at Salto, Brazil (latitude 23°11′S, altitude 520 m, rainfall 1 400 m, mean annual temperature 21.3°C); *Right,* 2-year-old plantation of *E. grandis* at Mogi-Guaçu, Brazil (altitude 630 m), grown from improved seed, source Coff's Harbour, Australia. Note uniformity in diameter and height
L. Golfari



36. F_2 hybrids from *E. urophylla* × (probably) *E. saligna* growing at Santa Barbara, Minas Gerais, Brazil (altitude 850 m), showing segregation of bark characters
L. Golfari

37. 26-month-old plot of the hybrid '*E. platyphylla*' (thought to be *E. alba* × *E. urophylla*) planted from cuttings at Pointe-Noire, the Congo, and thinned once. Note uniform growth as a result of the use of cuttings
Centre technique forestier tropical, Nogent-sur-Marne

parameters such as heritability, combining ability, and genetic correlations are determined; (*iii*) the collection of scions for grafts or cuttings. These can be used for progeny or clonal trials, for the establishment of seed orchards for the production of genetically improved seed, or for clone banks in which observations or controlled crosses can be carried out close to the ground in a few, concentrated areas.

Although specific objectives vary, eucalypt-breeding programmes generally aim at producing healthy, vigorous trees of good form. Depending on the species used in the breeding programme and on the end uses of the wood grown, specific characters such as reduced growth stress (leading to decreased occurrence of splitting in sawn- and roundwood), uniform wood density, or good branch shed and knot occlusion to help minimize fungal and insect attack may be included in the characters selected for. Selection for frost and drought resistance is often done at the individual level, as well as at the species and provenance levels (Burgess, 1973a; Christensen, 1973; Davidson, 1968; Dillner *et al.*, 1971; Lacaze, 1962; Martin, 1978; NCSU, 1974, 1976; Pryor, 1957; Sherry and Pryor, 1967).

STEP 4a: PROGENY AND CLONAL TESTING

Progeny and clonal tests can be established either by using open-pollinated seed from plus trees through which additive gene effects can be estimated, or from control-pollinated seed or grafts or cuttings which will give information on both the additive and on the non-additive components of inheritance. For example, for culling of first generation seed orchards, the information from half-sibs is generally enough, as the purpose of seed orchards is to capture the additive variance by mass selection. Non-additive gene effects are of practical importance to the breeder only if controlled crosses or vegetative propagation are to be used as a means of multiplying selected individuals on a large scale.

Published data on progeny tests and on genetic parameters in eucalypts are scarce. In a study of *E. regnans*, Eldridge (1972) found narrow-sense heritability (h^2) for height to be about 0.5, but remarked that standard errors were too large for a reliable estimate; h^2 for diameter, branch angle, and stem straightness which all had acceptable standard errors was 0.2. The trees studied were 5-10 years of age. Franklin and Meskimen (1973), studying 4-year-old *E. robusta* seedlings in Florida, found h^2 for height to be 0.22; for diameter 0.13; and for volume 0.68. Kedharnath and Vakshasya (1978) found h^2 in 4-year-old *E. tereticornis* to be 0.26 for height, and 0.25 for diameter. Van Wyk (1978), studying *E. grandis* in Florida and in South Africa, arrived at a heritability estimate of 0.16 for height of 6-month-old seedlings.

From the above evidence it seems that values for narrow-sense heritabilities of characters like height and diameter are of the same order of magnitude as those found in temperate species. Although further data are needed to confirm this, there is reason to expect that genetic gain can be achieved by mass selection, especially if family and individual selection are combined (i.e., only the best individuals in better-than-average families are chosen).

STEP 4b: SEED ORCHARDS

Types of orchards

Seedling seed orchards. The relative merits of seedling versus clonal seed orchards have been discussed in depth in, e.g., *Silvae genetica*, Vol. 13 (1964) and Faulkner (1975).

Seedling seed orchards are generally established from open-pollinated plus tree seed. These orchards are relatively easy to establish, and are suitable for most eucalypt species. The orchards can later be culled according to information gained from progeny tests; this should considerably increase the genetic gain obtainable from them. If heritability values for desirable characteristics are not known, provision should initially be made for culling both among and within the families included in the first generation seedling seed orchard.

Open-pollinated seedling seed orchards have been established for *E. deglupta, E. diversicolor, E. grandis, E. maculata, E. regnans, E. robusta, E. tereticornis* and *E. urophylla.* No reports of the establishment of control-pollinated seed orchards have been received. This is partly due to the laborious methods of control pollination in eucalypts, partly to the lack of information on genetic parameters and thus on the predictable gains from such orchards (Davidson, 1975-76; Eldridge, 1975b).

Clonal seed orchards. Grafted orchards of most widely grown eucalypt species have been established in numerous countries. The degree of success of these orchards has been largely dependent on rootstock/scion compatibility.

In South Africa, two or three grafts are planted in each planting position to meet expected losses from incompatibility. With the development of reliable techniques for striking cuttings it is foreseen that orchards in the future will be established by cuttings in species which regularly display a high proportion of stock/scion incompatibility.

One basic defect in the design of several established eucalypt seed orchards is the relatively small number of clones that have been included (generally 10-30 clones, or less). Production orchards should initially contain at least 50 clones; this will permit up to 50 percent culling based on progeny performance and flowering data, while still leaving an acceptably broad genetic base for seed production (Eldridge, 1975b).

Although a final number of only 25 clones may be acceptable for producing seed for plantations, it is not enough for breeding purposes. Rigorous selection reduces genetic variability and therefore decreases the genetic gain which can be obtained by subsequent selection at the same time as it increases the risks of inbreeding. This inherent conflict between short-term and long-term gains can be partly overcome by keeping the seed-producing population separate from the breeding population. The breeding population should represent a compromise between maximum selection differential and full population size, and it should initially contain 200 or more unrelated select parents (Burdon and Shelbourne, 1978; Namkoong, 1978).

Eucalypt flowers are pollinated by insects, birds or other pollen vectors. Only a few cases of possible wind-pollination have been reported. The minimum safe distance between a seed orchard and another stand with which it could easily cross is therefore dependent on the distance that vectors travel to effect pollination. Although information on this aspect is not sufficient, it appears that 2 km is ample distance for isolation of a eucalypt seed orchard. An effective additional way of isolating seed-producing areas is to surround them with other, non-hybridizing eucalypt species (Pryor, 1961, 1978).

In order to achieve the gains expected from bulked eucalypt seed orchard seed, it is essential to minimize inbreeding in the orchard. In all cases studied, inbreeding effects have been found to be detrimental, leading to decreased seed set, deformities of leaves and stems, and greatly reduced vigour (Eldridge, 1978; Hodgson, 1976b; van Wyk, 1978; Venkatesh and Vakshasya, 1978). Big differences in flowering times between individual trees within the same population seem to be common. Although the possibilities of overlap in flowering are increased by the fact that flowering time in different parts of the crown of a tree and even within one floral cluster may vary, the bringing together of clones from differing environmental conditions may enhance the problem of poor flower synchronization. To avoid inbreeding and facilitate random mating it is therefore essential that seed orchards consist of clones with similar flowering times. As out-of-season flowering seems to be a feature occurring more frequently on certain sites than on others (e.g., on altitudes above 1 000 m in South Africa), such sites should be avoided as seed production areas (Ashton, 1975; Chaperon, 1978a; Eldridge, 1970, 1976; Hodgson, 1974, 1976a, 1977).

Some test of self-fertility should be done for each clone as it comes into production, as individuals within species may vary in their degree of self-compatibility. Hodgson (1976c) suggests that as a rough guide clones be compared according to the seed yields obtained by (*i*) self-pollination, and (*ii*) cross-pollination, both done at comparable stages of receptivity. Highly self-fertile clones should be rejected from seed orchards, which are based on the idea of panmixis.

The minute seed size of most eucalypt species (from about 10 000 in *E. calophylla* to many million seeds per kg in *E. deglupta*) means that only a relatively small weight of seed is required to satisfy the needs of large plantation programmes. Seed orchards may therefore be small as compared with those of many softwood species. Little published information is available on actual seed yields from eucalypt seed orchards. *E. grandis* is reported to have produced 0.67 kg of seed per ramet four years after the establishment of a clonal seed orchard in South Africa, and up to 1 kg of seed per ramet was collected from the same orchard at the age of 10 (van Wyk, 1978). When in full production, this 18-ha orchard is predicted to produce 50-100 kg of seed (Davidson, 1975-76). In Zambia, a clonal seed orchard of 3.6 ha, based on a limited number of clones of *E. grandis*, produced enough seed to provide plants for 450 ha of plantation seven years after establishment (Eldridge, 1975b). In northern New South Wales a heavily thinned *E. grandis* seedling seed orchard of 0.4 ha (estimated final crop, 30 trees) is predicted to yield about 7 kg of seed when the trees are felled for seed collection at ages 7-10 (Burgess, 1973a). Two grafted seed orchards of *E. globulus* in Portugal, based on 25 clones, are reported to have yielded 4 kg of seed at the age of 3 (Eldridge, 1975b).

Management methods used in eucalypt seed orchards do not generally differ from those of other tree species. Crown manipulation to facilitate seed collection has been widely tried to increase the productive life of the orchards (Eldridge, 1978; Hodgson, 1974, 1977). Especially when widely spaced as in seed orchard conditions (usually 8 × 8 or 9 × 9 m) growth of most eucalypts is very fast. Without bending or cutting back of the crowns, Davidson (1978a) estimates the production life of *E. deglupta* seed orchards to be some five years. Eldridge (1975b) envisages the management of seed orchards on a coppice rotation, collecting seed from felled trees; non-coppicing species would have to be felled and replanted. When using this method in grafted orchards, care would have to be taken to ensure that all coppice shoots used for the next generation seed orchard develop from the scion and not from the rootstock. Coppicing ability of grafted trees should also be studied before plans are made for rotational felling, as some observations have been made on poor coppicing powers of grafted plants (Hodgson, 1974).

Rogued seed orchards; second generation seed orchards

Because of the recent development of seed-orchard techniques adapted for eucalypts and because of the scarcity of information on genetic parameters, few if any genotypically rogued seed orchards, or second generation seed orchards are known to have been established to date. Some information does, however, exist on phenotypically rogued eucalypt seed orchards. Franklin and Meskimen (1973) report on the conversion of a large, 6-year-old provenance trial of *E. robusta* into a seed orchard by phenotypically roguing the trial, leaving only the best trees in each provenance to produce seed. Open-pollinated seedlings from this orchard were later planted together in a randomized design, and genetic parameters were estimated from the trial before thinning it for seed production, using a combination of individual and family selection based on the phenotypic performance of the trees. A grafted, genotypically rogued orchard based on progeny performance will be established in the near future.

STEP 5a: CONTROLLED CROSSING

Controlled crossing can be used (*i*) to estimate genetic parameters such as general and specific combining abilities in the parent trees, in order to determine the value of breeding alternatives; (*ii*) to augment natural cross-pollination in seed production areas or seed orchards, especially in clones which are known to be highly self-fertile; (*iii*) to build up a breeding population in which the identity of the clones is known; this will make it possible to avoid inbreeding in the seed-producing population; (*iv*) to create intra- and interspecific hybrids for selection and mass production by vegetative propagation.

Because of the bisexual flowers, emasculation is generally necessary for controlled crossing of eucalypts. On a large scale, crossing is therefore difficult and expensive; it also frequently leads to increased flower fall. The remoteness of the flowers from the ground and from the main trunk of the tree, coupled with the often small size of the flower buds, makes artificial crossing an almost impossible proposition on the original select tree, and emphasizes the need for vegetatively established clonal breeding orchards (Burgess, 1973a). Hodgson (1974) suggests that bagging and hand pollination on newly opened flowers might be done without emasculation as intra-flower selfing seems to be negligible at that stage owing to protandry. The fact that flowers in the same flower cluster open at different times would, however, mean sacrificing early and late flowering individuals within the cluster to avoid inter-floral selfing. Pryor (1978) suggests the possibility of building up self-incompatible clones of the female parent which, although rare, do exist; there would be no need to emasculate these individuals before controlled crossing, provided the flowers were bagged to prevent outside, competitive pollination.

Controlled crosses have to date been used mostly to create vigorous provenance hybrids (e.g., *E. deglupta* in Costa Rica), or F_1 species hybrids such as *E. tereticornis* × *E. camaldulensis*, and *E. tereticornis* × *E. grandis* (especially adapted to dry sites) in India (Venkatesh, 1978; Venkatesh and Sharma, 1978); *E. botryoides* × *E. camaldulensis* (= *E.* × *trabutii*) in the Mediterranean (Pryor, 1978); *E. urophylla* × *E. grandis* in Brazil (Martin, 1978); and *E. tereticornis* × *E. saligna*, and *E. urophylla* × *E. alba* in the Congo (Chaperon, 1978a). In addition to exhibiting vigorous growth, these crosses will sometimes bring together in a single individual desirable characters from both parent species.

The production of species hybrids can in some cases be done without artificial pollination. Pryor (1978) quotes the example of an experimental two-species seed production area of *E. tereticornis* and *E. grandis* in Zambia, used to produce species hybrids which can easily be distinguished from the pure species at the nursery stage. Part of the success of this experiment hinges upon a peculiarity which is almost confined to *E. tereticornis* in that this species is, at least in part, wind-pollinated; the probability of cross-pollination between the two species is therefore greater than with species fully dependent on pollen vectors.

STEP 5b: MASS PRODUCTION OF IMPROVED MATERIAL BY VEGETATIVE PROPAGATION

Recent advances in the production of eucalypt cuttings will facilitate the cloning of genetically improved or otherwise desirable individuals on a commercial scale. Intensive phenotypic selection is made either in plantations or in populations created by open or controlled pollination. The selected individuals are cloned and tested, and their rooting ability is noted. The mass production of cuttings is generally done from adventitious or epicormic shoots; the best results, both quantitatively and qualitatively, are achieved when plants from 3-5 years of age are used. With present technology it is possible to produce yearly up to 600 cuttings from one single individual and 100 cuttings per plant and year are produced as a routine operation in the multiplication orchards at Pointe-Noire in the Congo (Chaperon, 1978a, b; Chaperon and Quillet, 1978). Generally, a mixture of hybrids and a mixture of clones should be used for plantations. In the Congo, 200 clones per hybrid will be selected, and about 20 of these are likely to be mass-produced and planted out on a commercial scale. The mixture of clones, in combination with the very short rotations (around 5 years), is thought to ensure minimum risks from pests, diseases or adverse climatic conditions. In 1976, 300 ha of cuttings of *E. alba* × *E. urophylla* and *E. tereticornis* × *E. saligna* were planted in the Congo. This is the first time eucalypt cuttings have been planted on a semi-industrial scale (Chaperon, 1978a).

During recent years some basic research has been made into the possibilities of tissue culture. Techniques such as clonal culture from the meristem or from a single cell may open new ways both for conservation of genetic resources and for the multiplication of desirable individuals on a large scale. Work on this aspect has been published by Cresswell and Nitsch (1975); Durzan and Campbell (1974); Fossard *et al.* (1974); Fossard and Bourne (1978); and Konar and Nagmani (1974).

Predicted gains from tree-improvement programmes

Information on realized gains from eucalypt-improvement programmes is understandably still scarce. Cautious predictions have generally been made based on gains achieved or predicted for temperate species. One of the basic assumptions in most on-going eucalypt-improvement programmes is that eucalypts are randomly outbreeding. If selfing and non-random mating are common, estimates of additive genetic variance and consequently of predicted gains from mass selection will be over-optimistic (Namkoong, 1966). If the assumptions made prove correct, remarkable gains from traditional tree-improvement methods are likely to be achieved in a very short time-span with the eucalypts, thanks to their precocious flowering and short rotations.

The advances made in the techniques of vegetative propagation of eucalypts are revolutionary from a tree-breeding point of view; through a combination of traditional tree-breeding methods and vegetative propagation of improved material, volume production of some eucalypt species can in theory be more than doubled in less than ten years. The gains predicted from the breeding programme under way in the Congo are as follows (Chaperon 1978b): provenance selection, from 50 to 80 percent; hybridization, individual selection and vegetative propagation, from 100 to 150 percent.

8. Fire protection

The necessity of providing protection against fire has been recognized by all the major eucalypt-planting countries. Financing authorities supporting a substantial investment in plantations wish to be assured that protective measures are built into the design, that adequate warning systems have been erected and are manned in dangerous weather, and that field staff have been provided with adequate equipment to suppress accidental fires quickly. Companies insuring against fire loss will require that efficient fire-fighting equipment be available and functional.

Reporting countries have not stressed fire danger as a major factor in eucalypt plantations. Comment has been made, but perhaps less strongly than if coniferous plantations were under discussion. It may be that the short-rotation eucalypt coppice crop gives a greater feeling of security than the longer rotation of a coniferous crop. There is also a widespread belief that conifers are more susceptible to fire than broadleaved species, including eucalypts. Most species of *Eucalyptus* have some resistance to fire, and some (e.g., *E. robusta*) recover readily. Some, however, burn easily, and species with fibrous or semi-fibrous bark present special problems in fire control due to the movement of incandescent bark in the wind. *E. deglupta* is extremely sensitive to fire.

The threat of plantation fires demands the personal attention of all levels of management. Should they occur, they should be the subject of an early report by the staff in charge and an early inquiry by senior management.

Fire prevention

Roads as part of the firebreak system

Regular access to plantations is necessary at *all times*. It is necessary while the design is being laid out, while the land is being prepared for planting, whenever tending is required, whenever the crop is being harvested, and for fire protection both during the fire season and when firebreaks are being made ready.

It would be very convenient for owners if all the firebreaks between compartments were suitable for the use of vehicles all the time, but this is seldom the case. Active attack against a fire and indeed general good management require speed by heavy water-carrying equipment and other vehicles, and experience has increasingly shown that firebreaks which are not trafficable are of limited value. The tendency is to think in terms of a fireroad, rather than a firebreak system. Fireroads should be trafficable throughout the dry (fire) season and clear of inflammable material throughout their length. A reasonable road system in a plantation will require 1 kilometre of road to between 15 and 20 ha of plantation, or around 5 percent of the area. In flat country the same roads may be used both as logging roads and as fireroads, but in steep topography the fireroads follow the ridges, while the logging roads may follow the valleys; this may cause a decrease in the intensity of roading of each type and/or increase in the overall percentage of both together.

ROAD STANDARDS

An owner should recognize that the expense of an adequate road system is a necessary part of his investment in a plantation, for establishment, for treatment, for harvesting thinnings and final yields and for protection. Gradients should be kept as gentle as practicable and the maximum gradient should be kept close to 7 percent. All weather roads are necessary for day-to-day management purposes as well as fire protection. Wherever practicable, a gravel surface should be applied to main access roads.

The roads must service all the work of a plantation. Provision should be made for turning points and passing points at convenient places. The provision of water points to fill fire trucks may mean the difference between a small and a serious fire.

All access roads should be properly drained with adequate culverts to take away flood rains and to ensure that the roads are not badly eroded during the wet season.

THE FIREBREAK (FIREROAD) SYSTEM

The necessity to have firebreaks (fireroads) cleared around plantation units that are not too large is recognized in many reports. They should have a cleared width, sufficient to stop a surface fire with flames 1-2 m high in mild fire weather. It is convenient for management if they divide and outline compartments or subcompartments, that is, the units of management control. Conservative eucalypt planters keep the size of their management units down to about 20 ha.

A width of 20 m is suitable for perimeter firebreaks which separate the plantations from land under different ownership and management. The same width has also been used commonly in the past for internal fireroads (firebreaks), but the recent tendency has been to reduce this width to between 5 and 10 m. Wider firebreaks are more expensive to keep clean and they cause a break in the forest canopy, which can cause higher wind speeds at ground level, a more rapid growth of inflammable grass and weeds during the wet season and a more rapid drying out of this fuel material during the dry season.

Eucalypt plantations are established in the tropical and subtropical savanna zones of many countries, and it is in such areas that fire hazards are at a maximum. Grass must be eliminated from such areas. Clean weeding is essential before canopy closure, and canopy closure must be maintained thereafter. Firebreaks, unless continuously and expensively kept free of grass, will themselves increase the hazard. Narrow shaded grass-free roads are more effective in such areas. Fire security belts should be maintained around savanna plantations by early controlled burning.

The combined logging road and fireroad (firebreak) system makes up 5-10 percent of the total area available to the roots of the trees. The roots can penetrate below the roads and obtain water and minerals from them, so their area does not mean a full proportional loss of growing space to the owner. An owner can confidently design an efficient system without fearing that loss of productivity is threatened.

Attacking facilities

PREPARING ROADS AND FIREBREAKS

Preparing roads and firebreaks so that they are effective in stopping a fire or in being the most important facility in attacking a fire is an annual task in all forest stations in the fire belts of the world.

It is advisable that a width of at least 10 m along roads and firebreaks be made bare during the fire season. This may include a strip each side of the road under the canopy. There are different means of clearing this strip. It may be ploughed, disc-harrowed, graded or burned, or a combination of methods may be used. On a property of moderate size having a clay-loam soil, a road-grader may be employed for most of the year on the task of improving and maintaining roads and clearing the firebreaks. Well-handled road-graders can also be of great help in combating a grass fire.

A modern development of great help in maintaining firebreaks is the practice of accelerating desiccation of two narrow widths of the vegetation along each side of the firebreak before the vegetation has normally dried. These desiccated strips can then be burned before the normal vegetation will burn. This leaves two safe strips and the part of the firebreaks between them can be burned with reasonable safety as it cures. This desiccation is done with a chemical such as Tordon or Paraquat, which kills the above-ground parts of the plants without causing permanent injury to the soil. The desiccating agent must be carefully handled and applied in the manner advised by the manufacturers. Workmen must be properly protected. In South Africa, Paraquat is used at a concentration of 1 litre in 200 litres of clean water; this will kill a line 2.5 m wide in tall grass for 1.5 km, and 3 km in short grass. A gang of five men can handle about 1.5 km of 2.5-m line per hour, either by knapsack sprays or preferably by boom sprayers. Desiccation has proved a valuable tool, not only in firebreak preparation, but also in preparing for broadcast burns or other burning-off tasks.

Alternatives to clearing firebreaks

New Zealand Forest Products Limited grows lucerne and other fodder crops on firebreaks, and either harvests the crop of grazes it off, thereby maintaining effective breaks and offsetting the cost. Such practice might well be suitable in other countries with short danger seasons and moist climates.

Certain trees and shrubs can be planted in many areas to provide "green firebreaks". Examples are mango, *Mangifera indica, Acacia auriculiformis* and *Leucaena leucocephala.*

Detection and communication systems

While the road access system and the fireline system are the primary necessity for any plantation owner, other aids to communication and information are becoming more and more essential to modern fire-protection. These include fire-towers, which are a watching system, telephone connections, two-way radio communication, the use of fixed-wing aeroplanes or helicopters to spot fires, assistance from satellite photography to improve weather forecasting and perhaps in the not too distant future the use of infra-red equipment to detect "hot-spots".

Fire-towers, the watching system

In many parts of the world, fire-towers have been erected or set up in tall trees to enable observers to spot the start of a fire or to follow its progress. The towers are manned throughout daylight hours in the danger seasons and are equipped with maps and sighting instruments which enable the observer to line up the direction of a new fire from his fire-tower and to advise his head office of this line of sighting. If fire-towers are strategically sited, another observer in another tower can also line up the direction of the fire and advise the office of its direction from his sighting point. The control office should have maps on which threads can be withdrawn from holes at the location of various fire-towers, and a new fire should be located by the intersection of these lines. If directions from three towers can be obtained, so much the better.

If towers and control office are connected by phone, the location of a new fire may be determined within 10 minutes of it starting, or possibly less. Attack teams may be directed to the fire within 15 minutes. If they reach the fire within 30 minutes of its starting time, two attack teams have a good chance to control it. If the delay period is extended by half an hour, at least double the number of attack units may be necessary to control the fire.

A small plantation owner may not be able to establish a fire-tower or it may not appear to be of significance to him. If there are several owners in a district, it should be practicable to establish a collaborative series of fire-towers and a control centre to service a district.

Communications between fire-towers and control centres. It is highly desirable that telephone communication between fire-towers and head offices and control offices, and between fire-towers themselves, should be established, and it would appear that this is generally the case. It is also apparent that cooperation does exist between smaller and larger private owners and forest

38. Fire-tower on the "Gloucester tree," a 60-m-high *E. diversicolor*, at Pemberton, Western Australia (photo taken in about 1955)

Forests Department, Western Australia

39. The same tree about 20 years later, showing vigorous "reversion shoots"

Forests Department, Western Australia

services to improve the siting of fire-towers and rapid communication between this watching system and the attacking force. Moreover, more and more owners (and services) are realizing the general management advantage of two-way radio systems, as discussed in the next subsection.

In the modern period of reasonably efficient two-way radio equipment it may be of interest to recall that there are still some foresters serving who manned fire-towers with much less sophisticated equipment. The basic skill of the tower operator is perhaps still the best skill of all. He should know his district in relation to his map and have a very good idea if a fire has started near the intersection of certain roads, and so on. Local knowledge is still a vital skill. In earlier days he had to communicate this knowledge by the earlier means known to military or naval skills. Morse code messages transmitted by heliograph and even semaphore messages were used in the early days of eucalypt plantations. Semaphore messages soon became illegible in smoky conditions but heliograph messages were quite effective but slow. The most primitive phone line strung between trees was a godsend, but if other trees dropped on the line the heliograph could still assist.

Trees as watch-towers. In some areas of the world there is no better fixed observation point than the top of a tall tree. An example shown in the first edition of this book — a 60-m tower on an *E. diversicolor* tree in Manjimup, Western Australia, called the "Gloucester tree" — is still in perfect working order (see Figures 38 and 39).

Two-way radio

The development of two-way radio systems fitted to vehicles on high-frequency bands has been an important development of the last two decades in forest management and several other forms of management. In forestry they were sometimes forced on a suspicious management by the pressure of fire tragedies. The opportunity to communicate between fire-towers, control centres and field vehicles during fires soon assured management that they were a necessary tool in this field. There were sometimes problems of atmospheric conditions and topography interfering with reception.

The convenience of two-way radio in the day-to-day management of forest districts is now demanded rather than accepted by boards of management. A responsible station officer can communicate with the supervisors of his gangs for fire protection or any other management requirement. He can organize the work of his station while travelling from point to point within it. He can receive messages from higher authority and arrange for the preparation of suitable replies. It is a vital management tool.

Use of the local communication systems

In countries where fire is a recognized threat to the livelihood of many people in rural districts, excellent formal collaboration has been developed between forest services, police services, private owners and the telephone service. In these places several property owners may be connected on party lines. Fire calls are given preference by mutual agreement; all concerned help with the location of a fire; many rural owners will have an attack unit either ready to send to a fire or with its equipment ready to be loaded. Frequently, passing military or civil aircraft may help in locating a trouble spot.

Airborne inspection

Government forest services or substantial forest owners may have light planes or helicopters on standby to help locate fires or monitor their spread. These aids are particularly useful after a thunderstorm, particularly when a "dry storm" has passed along a mountain range. Sometimes a storm may make 20 or more lightning strikes. If the storm is accompanied by light rain, perhaps 15 of these may prove harmless, but the remainder may leave smouldering tree-butts which develop into "hot-spots", or may start a fire. Early air inspection after the storm is a very useful aid in detecting a new fire.

It would be wrong for authorities to assume that vandalistic or criminal arson has disappeared from society. Even in a pleasant countryside there are people who deliberately light fires or lines of fires in forest country. The mere presence of an aerial patrol is one of the best protections against this menace. If the aerial patrol has two-way radio contact with fire-towers and ground units, the fires may be stopped quickly and the police enabled to deal with the arsonist. One successful prosecution can be very helpful.

Light planes and helicopters are a wonderful aid in fire-spotting but not a replacement for fire-towers. They are grounded in a high wind. Then it may be necessary to rely on high-flying commercial aircraft or heavier military aircraft.

"Hot-spots": infra-red detection aids

There are several circumstances in natural forests or in plantations established on old forest land where a lightning strike or other fire source starts the underground part of an old tree burning. There may be no smoke, only a mass of red-hot coals underground. Sometimes an old root will glow on for weeks or a peaty swamp burn underground. Then if days of high wind occur, the underground fires surface and spread. All fire-prone countries have experienced this menace. The attacking force attending any fire should try to make sure even by hand contact on the ground that all "hot-spots" have been found and neutralized, but there are errors.

Infra-red detecting devices have been developed which can be attached to light planes to detect "hot-spots" after a fire has been brought under control. Hand-portable detectors are also available.

Fire suppression

ATTACKING EQUIPMENT

Every plantation station needs a supply of attacking equipment. Some essentials are listed below.

1. Knapsack water containers with spray pumps, filled and ready for use in the fire season. Each knapsack contains about 18 litres of water. There should be a knapsack spray for each gang member who can be

sent to a fire. Hand tools include slashers, shovels and combination rakes and hoes. Optimum weight is around 1.8 kg. Light-weight power saws are very useful.

2. There must be transport to a fire. If practicable, there should be a specially prepared powerful four-wheel truck with a tank containing 450 litres of water well fixed to the truck chassis. The tank should be baffled so that it does not overturn the truck at corners. The truck should also be able to carry the knapsack sprays of each member of the gang and his ancillary equipment such as hoes and axes. A small plantation owner may not be able to afford a special truck for fire protection. If not, it is recommended that a water tank which his truck could carry be suspended at a convenient height at headquarters so that it can be loaded quickly if a fire occurs.

Irrespective of the size of the plantation unit, the staff should be trained in fire-fighting procedures and allocated individual duties in case of an emergency.

Slash-burning and control-burning: pro and con

When eucalypt coppice crops are harvested, there is a large amount of slash left from the crowns. Should this be burned or left to decay and return to the soil? It is a question frequently asked in many places. Safe burning of the slash is quite an expensive operation; leaving it involves the danger of an accidental fire that might destroy half the stools that represent the owner's capital for the next coppice rotation.

It is recommended that, if possible, the slash be stacked in the centre of each second or third row of stools and left to decay. Its return to the soil will maintain much of its fertility and the presence of the slash reduces the danger of erosion between coppice crops. Nevertheless, this difficult question must be left to the judgement of the owner and forester in charge of a station. They must assess the local danger of fire, the danger of erosion, and the danger of loss of quality of site and make the best decision for their own situation.

The practice of prescribed burning or control-burning is carried out in parts of America, Africa and Australia where complete protection of parts of a forest is impossible because experience has shown that when it has been attempted, the build-up of fuel on the forest floor has led to catastrophic fires.

The eucalypt forests of Australia which are managed for sawlog production are usually fairly old stands and have had a long past history of burning. Control-burning has seemed to be the best way to prevent severe fires in many cases at the present time.

Plantation eucalypts grown on coppice rotations for pulpwood are not suitable forests to which the practice of prescribed burning should be applied. Difficult as the problem may become, they should be completely protected from fire. More research is needed on the possibilities of prescribed burning in older sawlog plantations, especially of rough-barked species.

9. Diseases, pests and disorders

Eucalypts, like other trees, provide nutrients and shelter for a wide range of plant and animal life ranging from higher animals and angiosperms to insects, fungi and lower life forms, some of which are parasitic and potentially harmful.

While many of these associates may reduce the value of their host to man, they seldom threaten its survival in its natural habitat. When this does occur, it is often through an exceptional environmental change which has led to a disturbance of the balance of the ecosystem, permitting a pest or pathogen to assume an enhanced aggressive role. Such attacks often decline with the resumption of more normal circumstances, and the outbreak may also succumb to a subsequent rise in the activity of one of the natural enemies of the pest or pathogen involved.

Man's activities in exploiting forest resources and altering their composition permanently for his own needs (including the creation of artificial stands of single forest species) may in some circumstances lead to increased risks of serious pests and diseases in these crops, where the natural constraints against them have been modified or removed altogether. In practice serious outbreaks can often be ascribed to the planting of a species in the wrong conditions or to the use of inappropriate techniques. Good silviculture and good management are the best safeguards against unhealthy plantations.

The risk of pests and diseases has been compounded by the advances that have taken place during the present century in the speed and efficiency of international transport, which has surmounted natural barriers to the spread of many pests and pathogens and increased the risk of their introduction to new natural and artificial plant communities.

The eucalypts have been widely adopted, as industrial and amenity crops, not only in the regions where they occur naturally, but as exotics in most parts of the tropics, subtropics and warm temperate zones. It might have been expected that these crops would encounter a range of important pest and disease problems in the course of their development, but this has not been the case. Although a number of pests and diseases of these crops are known, relatively few have had critical importance. This may be due to the

---

The introductory paragraphs of this chapter, and the sections on diseases and mycorrhiza, were kindly contributed by I.A.S. Gibson, of the Commonwealth Mycological Institute, Kew, England.

rich and varied genetic resource that is represented by a genus of over 700 species and subspecies, capable of providing combinations of heritable characters to meet the demands of a very wide range of growing conditions.

Another reason for the fast growth of eucalypts, when planted as exotics, is the absence generally of the leaf-eating insects which abound in their natural habitat and the fact that in most localities indigenous insects do not adapt themselves to species of the genus (Pryor, 1975, 1977). "Comparisons, under conditions as nearly comparable as possible, of growth rates inside and outside Australia show that commonly a loss of 20 percent of stemwood production is sustained under Australian conditions when the normal complement of indigenous insects is present and feeding on the leaves" (Pryor, 1977). However, when an Australian insect pest is introduced accidentally, exotic plantations may suffer very severe damage because the pest's natural Australian predators and parasites are absent (e.g., *Gonipterus* in Africa, *Paropsis* in New Zealand).

At present, our information on disease problems of *Eucalyptus* is sparse, largely because studies of the pests and diseases of the genus, as with other tree crops, has been limited by economic factors and the difficulties imposed on investigators by their size and longevity compared to annual crops. The extent to which we can hope to control diseases and pests depends directly on our knowledge of their cause, the damage that they do and the permissible margin of expenditure for special measures. In all these respects (especially the last) the forester is at a disadvantage compared to the managers of other perennial crops, who generally have more information on their problems and more money to deal with them. For the forester much depends on methods of prevention and avoidance to maintain adequate standards of forest health, rather than more sophisticated and expensive means.

The establishment of good plant import legislation (and the means for its enforcement) can go far to reduce the danger from introduced enemies of forest crops, but this is, of course, also subject to the information that we have on these risks. Nevertheless, adherence to sound basic principles, such as limiting the import of planting material to reputable sources, requiring reliable certification of these imports and ensuring their rigorous inspection in closed quarantine if necessary, can provide valuable safeguards. In principle, preference should always be given to the import of seeds, and vegetative propagating material should be avoided as far as possible. The import of rooted stock in soil should be completely prohibited and in all cases only the smallest practicable quantity of material should be involved in any importation.

The careful observation of trial crops during the initial stages of any forest development scheme can be of paramount importance in the identification of potentially important pests and diseases and the prescription of means for their control by correct choice of site, crop variety and cultural methods. Any suspected problems at this stage should be fully diagnosed with the help of local plant health specialists.

The use of chemical control methods is seldom practicable for forest crops beyond the nursery stage, for technical as well as economic reasons. However, they may represent the only quick means of control available in case of an emergency. Much has been written on the undesirable ecological side-effects that may arise from the use of pesticides, particularly where these are persistent and are used on a large scale. This possibility must always be considered if the use of these materials is contemplated, but it would be a mistake to assume that they are always harmful to the environment.

Biological control, by the introduction of the natural enemies of crop pests and pathogens, has sometimes provided excellent solutions to a problem, especially where insects are implicated. At least, this has the advantage of providing lasting results from a single operation, but the method can have disastrous side-effects if the control agent spreads from the pest that it was intended to control to attack more beneficial members of the ecosystem. The use of *Anaphoidea nitens* to control *Gonipterus scutellatus* on *Eucalyptus* spp. in South, Central and East Africa is a good example of the successful application of biological control.

In the following sections the more important diseases of *Eucalyptus* spp. caused by all pathogens are reviewed first, followed by an account of mycorrhiza, the insect pests, disorders due to other animals and finally problems with physical causes.

This account of the diseases of *Eucalyptus* spp. has drawn heavily on the recent compilation by Gibson (1975). The earlier work of Browne (1968) also provides a comprehensive review of all pests and pathogens of eucalypts. Information received in country statements on *Eucalyptus* pests and diseases has been incorporated in the text.

Diseases

Root and butt diseases

Diseases arising through primary invasion of the root system are usually caused by soil fungi which are facultative parasites, able to survive for part of their life cycle as competitive soil saprophytes, or as resting propagules (sclerotia, oospores or chlamydospores) by which they can survive periods adverse to active growth. Some of these fungi can utilize special substrates such as cellulose or lignin. Root pathogens spread slowly through the soil either by mycelial growth or contact between host roots. The distribution of infected plants in the crop is therefore often patchy. Some of these pathogens also produce airborne spores by which they can spread over long distances to new sites. Although most of these diseases have characteristic symptoms in their earlier stages, they usually result in the death of the host. Light chronic root infections often cause a reduction in increment.

In the nursery, damping off is a widespread disease complex that can cause appreciable pre- and post-emergence seed-bed losses. The post-emergence disease appears as a rot of the stem tissues at soil level, causing the seedling to fall and shrivel; it spreads rapidly leaving characteristic patches of dead plants. A wide range of fungi causes this condition including *Pythium* spp., *Phytophthora* spp., *Fusarium* spp. and *Thanatophorus cucumeris* (Frank) Donk (= *Rhizoctonia solani* Kühn). The conditions favouring attack vary with the pathogen but risk of loss can usually be reduced by avoidance of high sowing densities, of seed beds with high organic content and alkaline reaction, and of overwatering and overshading. In exceptional circumstances it may be necessary to sterilize seed beds and to treat seed with fungicide by pelleting or the use of a fungicide drench (Gibson, 1975).

Cylindrocladium scoparium Morgan has caused appreciable nursery losses to seed-bed and transplant stock in South America (Argentina, Brazil), India, Japan, New Zealand and elsewhere; a virulent form, *C. scoparium* var. *brasiliensis* [now *C. brasiliensis* (Batista & Ciferri) Peerally], is reported from Brazil (Batista, 1951; Peerally, 1974). Other *Cylindrocladium* spp. are recorded from nursery eucalypts in Brazil, including the new species *C. clavatum* Hodges & May. Diagnosis of these diseases is based on association of the pathogen with a root-rot condition; all these species form airborne conidia and sclerotia (Figueredo and Cruz, 1963; Figueredo and Namekata, 1967; Hodges and May, 1972).

Other soil-borne pathogens of nursery stock include special forms of *Fusarium oxysporum* Schlecht., *F. solani* (Mart.) Sacc., *Macrophomina phaseolina* (Tassi) Goid., *Phytophthora* spp. (including *P. cinnamomi* Rands). Root galls caused by *Agrobacterium tumefaciens* (E.F. Smith) Conn and nematodes are known; these should not be confused with the lignotubers normal to some *Eucalyptus* spp. (Gibson, 1975).

A number of damaging root diseases of eucalypts in the field are known, of which jarrah die-back is by far the most important. This is caused by *P. cinnamomi* in natural stands of *E. marginata* in Western Australia, and similar but less important outbreaks of disease have been recorded in Victoria and New South Wales (Podger and Ashton, 1970). The symptoms are a general decline, wilt and die-back of the host associated with necrosis of the root system, starting at the finer roots, from which *P. cinnamomi* can be isolated and shown to be pathogenic. Over the last two decades jarrah die-back has caused extensive losses and stimulated intensive research. *P. cinnamomi* is widely distributed and has numerous hosts; its ecology and role as a pathogen have been reviewed with particular reference to this disease by Newhook and Podger (1972) and Podger (1972). It is clear from field evidence in Western Australia that this disease is favoured by man's activities, as outbreaks are closely related to timber extraction tracks, power lines, roads and other forms of disturbance of the forest community. It has been concluded from this and other evidence that *P. cinnamomi* has been introduced to these forests on vehicles, tools and clothing of forest workers, and control measures are based on the cleaning and disinfection of all materials before they are brought into new forest areas. However, this evidence does not exclude the possibility that forest operations may also modify the environment to permit *P. cinnamomi* to assume an aggressive role, whether it is a member of the forest ecosystem or not. Other approaches to control have been sought through improved protection by mycorrhizal fungi and searches for resistant species and varieties. The possibility that biotypes of *P. cinnamomi* exist that vary in their pathogenicity is being investigated.

P. cinnamomi forms oospores by which it can survive soil conditions unfavourable to growth and it is spread in soil water and by movement of contaminated soil. It has no means of airborne spread.

Pseudophaeolus baudonii (Pat.) Ryv (+ *Phaeolus manihotis* Heim, *Polyporus baudonii* Pat.) has caused locally important losses in plantations of *Eucalyptus* spp., other hardwoods and pines in South Africa, Mozambique, Tanzania, the Congo, Madagascar, Ghana and other West African locations. It was first recorded as a forest pathogen by Luckhoff (1955b) in South African plantations which included *E. maculata* and *E. paniculata*, when it was misidentified as *Ganoderma colossum*. Later it was recorded on *E. citriodora*, *E. torelliana* and *E.* hybrid *cadambae* in Ghana and on other eucalypts elsewhere in West and Central Africa (Ofosu-Asiedu, 1975; Brunck, 1978; Gibson, 1967). The fungus is capable of decomposing wood and infections usually arise from infected woody debris in the soil. Diseased trees show a mycelial layer in their root surface, initially as a thin weft but later becoming a thick yellow mat with embedded soil and sand grains. Fruit bodies arise from infected trees with a thick short stipes, eccentric to the pileus, which is thick, orange to yellow above with an uneven surface, and a yellow poroid spore-bearing surface beneath; these darken with age and dry out. A full description is given by van der Westhuizen (1973). The function of the basidiospores liberated by the sporophore is not known but it is likely that they contribute to the long-distance spread of the fungus. Control at present rests largely in the avoidance of known contaminated sites for plantations.

Ganoderma lucidum [(W. Curtis) Fr.] Karst. is another basidiomycete wood-rotting fungus that is recorded as a lethal root pathogen of a wide range of *Eucalyptus* spp. in India (Bakshi *et al.*, 1973). As in other pathogens in this class, infections arise from infected woody debris in the soil. Roots become rotted and trees are lost from windthrow if they are not killed at an earlier stage. The fungus forms stipitate thick brackets with a shiny brown upper surface, white flesh and a white poroid undersurface. The role of basidiospores is not known but may contribute to the long-distance spread of the fungus. Within the plantation, infection is transmitted by root contact. Control measures include the removal of stumps and other root debris from the site before planting, or the avoidance of forest sites likely to carry infection for the planting of susceptible species. Planting *Eucalyptus* spp. in mixture with resistant tree species is also recommended.

A second, unidentified, *Ganoderma* sp. has been associated with root disease of *Eucalyptus* spp. in India, causing losses of 10-15 percent of the stand (Bakshi, 1967).

Armillariella mellea (Vahl. ex Fr.) Karst [= *Armillaria mellea* (Vahl. ex Fr.) Kummer] has been recorded from *Eucalyptus* spp. in Australia, South Africa, East Africa, the United States, Spain, Cyprus, New Zealand, Portugal, Tunisia, and probably elsewhere (Gibson, 1975) but it has rarely caused damage

40. Basal stem canker of *E. saligna* in Brazil caused by *Diaporthe cubensis.* Bark is covering the affected area
C.S. Hodges

41. The same tree as in Figure 40, with bark removed to show callus formation on lower part of canker
C.S. Hodges

of importance. The symptoms include thick, white fan-like mycelial sheets under the bark of the roots and stem bases of infected trees, the formation of black or dark brown bootlace-like rhizomorphs under the bark or growing into the soil from infected roots and, later in the development of the disease, a white rot of the wood of the host with characteristic black zone lines. The fungus forms toadstools sometimes at the base of infected trees. These have a honey-coloured cap, white gills and a ring around the stipes beneath the cap. A closely related species, *A. luteobubalina*, has been described recently as the probable cause of losses to eucalypts in Tasmania (Podger *et al.*, 1978).

A number of other root pathogens of limited importance have been reported on *Eucalyptus* spp., including *Helicobasidium compactum* Boedijn in Nigeria, *Dematophora* and *Rosellinia* spp. from New Zealand and Portugal, *Verticillium albo-atrum* Reinke & Berth., the cause of vascular wilt in young plants in Australia, and *Peniophora sacrata* G.H. Cunn. on *E. saligna* in New Zealand (Gibson, 1975). A root disease of *E. globulus* associated with *Ptychogaster rubescens* Boudier has been recorded recently in Ecuador.

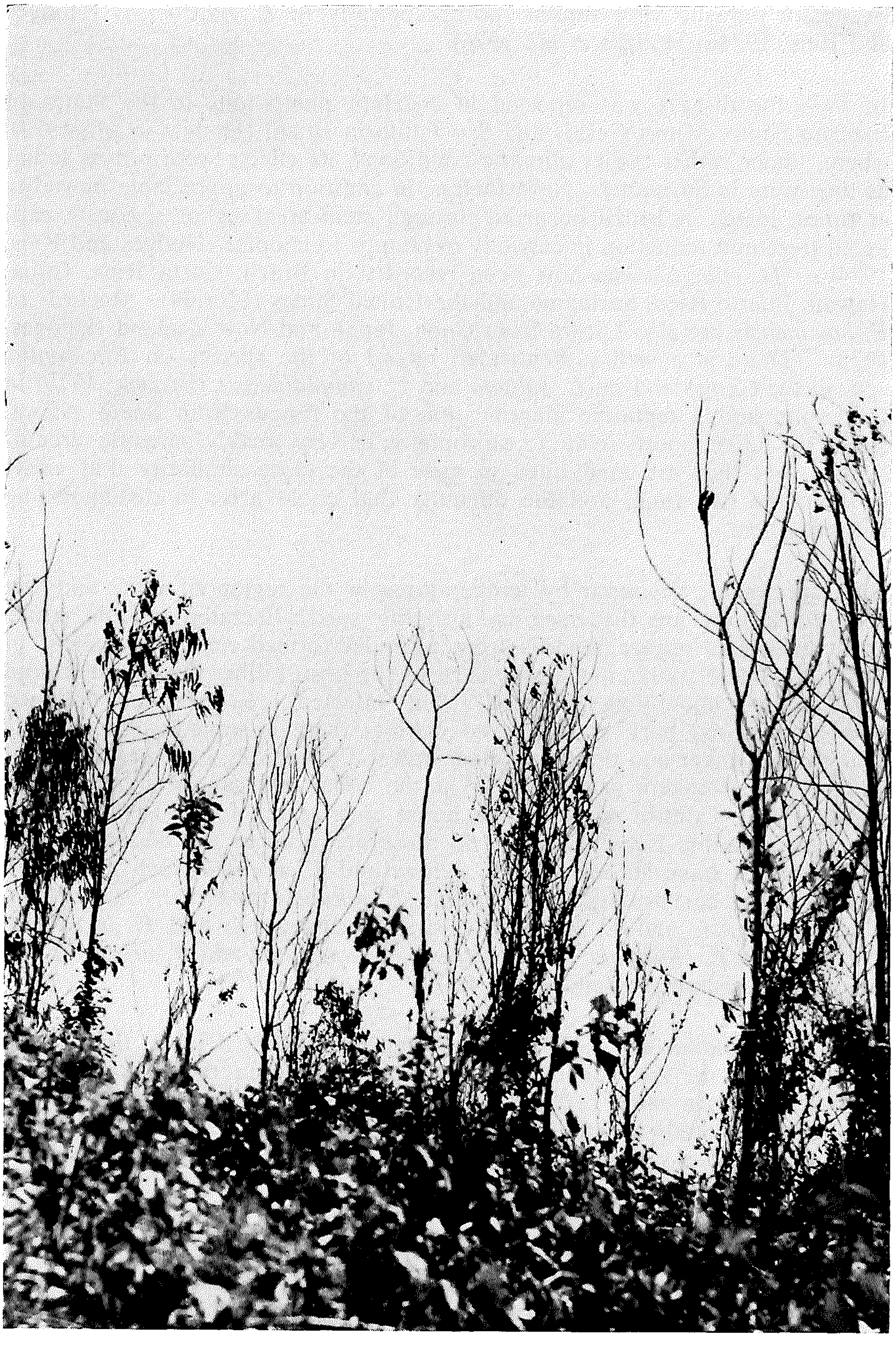
Two parasitic higher plants have been reported colonizing the roots of *Eucalyptus* spp., *Exocarpus cupressiformis* Labill on *E. dives* in Victoria, Australia (Jehne, 1972) and *Santalum album* L. on other *Eucalyptus* spp. in India. In the latter case the essential oils of the eucalypt act as a repellent to the leaf-hopper vector of the mycoplasma causing sandal spike disease, so the association promises to be a beneficial one to the sandal crop.

Stem diseases, including systemic infections

These are largely confined to field crops and include cankers, galls, wilts, die-backs and other conditions resulting from primary parasitism of the cambium and sapwood. These pathogens are rather more specialized than those causing root diseases, being more dependent on the parasitic habit for completion of the life cycle and having a narrower host range. The losses due to these diseases arise through death of trees, distortions, reduction in capacity for vegetative reproduction and, to a small extent, loss of increment to the growing trees. Most stem diseases are spread by airborne spores or other propagules and have a distribution in the crop that is more random than in root diseases.

A number of stem pathogens have been recorded from *Eucalyptus* spp. of which two, at least, have caused serious losses. These are *Diaporthe cubensis* Bruner (referred to in early records as *Endothia havanensis* Bruner) and *Corticium salmonicolor* Berk. & Br.

Diaporthe canker was first reported from trial plantations of *Eucalyptus saligna* and *E. grandis* aged up to about 3 years in Suriname. Deaths of up to 90 percent of infected stands occurred and led to the suspension of further planting of the species. The cause was shown to be a fungus, identified at the time as *Endothia havanensis* Bruner (Boerboom and Maas, 1970). Later, it was shown that *E. havanensis* was more properly regarded as a saprophytic species and that the causal agent of the disease was *Diaporthe cubensis*



42. Large-scale dying of *E. tereticornis* in a plantation in Kerala, India, caused by the fungus *Corticium salmonicolor*. Rainfall, 2 500 mm; temperature range, 27-38°C
Sujan Singh

Bruner, a parasite very similar morphologically to *E. havanensis* (Hodges and Reis, 1974a; Hodges *et al.*, 1976).

In 1973 the disease was reported in eucalypt plantations in the States of Espírito Santo, Minas Gerais and São Paulo in Brazil (Hodges *et al.*, 1973), where, under rather cooler climatic conditions, its effects were not as lethal as they were in Suriname. Nevertheless, in addition to appreciable mortality at times, losses in Brazil occurred through stem-breaking of seriously cankered trees and reduction in capacity of stumps to coppice (Hodges and Reis, 1974b). *D. cubensis* has now been recorded in Brazil, Costa Rica, Cuba, Hawaii, Puerto Rico, Suriname and the United States (Florida). Records of *E. havanensis* are also known from Cuba, Japan and New Zealand (Hodges, 1978). There is a well-authenticated record of the species on *Eucalyptus* spp. in the Congo and on *E. saligna* and *E. camaldulensis* (Brunck, 1978) in Cameroon and a tentative identification of the fungus from South Africa. All of the latter reports relate to saprophytic or very weakly parasitic circumstances, but they are mentioned in view of the close similarity that exists between the two fungi and the difficulty that could arise in distinguishing between them.

Both species are favoured by temperatures in the region of 30°C and wet conditions; they are dispersed by airborne splash-liberated conidia which are extruded as orange tendrils from pycnidia formed on the periphery of cankers. These spores invade the bark of the host, killing the cambium and invading the underlying sapwood. The infected area becomes flattened with longitudinal bark cracking and flaking; there is some swelling at the edge of the canker and the underlying sapwood eventually becomes darkened and brown. Cankers usually occur at the collar but can be found higher up the stem. Control measures are based on a search for resistance within the more valuable *Eucalyptus* spp. in those areas where the disease occurs. Investigations have shown that *E. saligna* and *E. grandis* (each as two or three provenances) are highly susceptible, *E. pilularis* moderately susceptible, *E. camaldulensis* and *E. tereticornis* slightly susceptible and *E. brassiana, E. citriodora, E. cloeziana, E. phaeotricha, E. torelliana* and *E. urophylla* are effectively resistant (Ferreira *et. al.*, 1977).

Corticium salmonicolor is a stem pathogen of wide host range that occurs in most areas of the humid tropics and subtropics in the Old and New Worlds. It is the cause of "pink disease" of rubber and in this crop it has received most study (Hilton, 1958). This disease may cause the death of branches or large parts of the crown of the host by girdling, but it rarely kills the whole tree.

The first symptoms of infection usually appear as an exudation of gum or resin from areas of stem with young, thin bark. This is followed by a growth of silky shining mycelial threads which become denser and assume a pinkish colour with time. As the bark dies this mycelial sheet dries up to form pink pustules (often in bark cracks) and crusts, which are usually on the lower side of the branch. Basidiospores, which are liberated directly into the air, and conidia, which are splash-dispersed, then arise on the infected tissues. These are regarded as the means of dispersal of the fungus, but the conditions favouring infection are still not fully understood. In India the conidial stage is not found on *Eucalyptus* spp. (Bakshi *et al.*, 1970, 1972). Trees of all ages are susceptible but young ones sustain the most severe damage; host vigour may modify the extent of attack. Infections sometimes die out, while others may remain dormant for a period and then become active once more with the return of more favourable conditions.

The disease has been recorded on *Eucalyptus* spp. in West and Central Africa (the Congo, Cameroon, Nigeria, Mauritius), South and Central America (Brazil, Costa Rica) and Asia (India) on *E. saligna, E. grandis, E. urophylla, E. tereticornis, E. globulus, E. citriodora* and other species (Bakshi *et al.*, 1970, 1972; Segura, 1970a; Brunck, 1978; Ferreira and Alfenas, 1977). In India the disease has caused very severe losses in plantations of *E. tereticornis* (Mysore hybrid), *E. grandis* and *E. globulus* in Karnataka, Kerala and Goa, under conditions of high rainfall and temperature. Inoculum builds up in young plantations until it reaches epidemic levels in crops between the ages of 2 and 5 years. Trees suffer severe damage from repeated die-back (which may lead to the death of the whole tree) during these years. Later, trees which escape may form a satisfactory crown but canker incidence will continue. At this stage the stems and branches are bigger and the risk of lethal girdling becomes less. In India, control of pink disease of eucalypts is being sought by selection for resistance within useful species. *E. torelliana* is reported to show a degree of immunity to the disease and surviving individuals from severely infected plantations of *E. tereticornis* and *E. grandis* are being tested for inherent resistance. In Brazil, provenances of *E. urophylla* derived from high altitude sites have been found to be more susceptible (Ferreira and Alfenas, 1977). *C. salmonicolor* appears to be a potentially important pathogen of *Eucalyptus* plantations in the Philippines (de Guzman, 1977) but is not known in this role in Indonesia (Hadi, 1977). In other crops the impact of pink disease has been reduced by the application of copper and dithiocarbamate fungicides to diseased branches and stems, and by the excision and destruction of diseased trees or parts of trees.

There are a number of other stem pathogens of eucalypts on record but none have had the impact of the two pathogens described above. *Cytospora eucalyptina* Speg., *C. australis* Speg. and *C. eucalypticola* van der Westhuizen have all attracted attention at various times. *C. eucalyptina* occurs in Australia while *C. australis* is known in Australia and Portugal; *E. ficifolia, E. globulus* and other species are reported as hosts. Both produce cankers originating at branch crotches which lead to strips of dead bark down the tree to ground level. The fungi fruit on the diseased tissues produce splash-dispersed spores by which the diseases are spread (Gibson, 1975). *C. eucalypticola* is rather more important and has been reported as damaging to *Eucalyptus* spp. growing under marginal conditions in Africa. Cankers are usually near the base of the tree and may be associated with longitudinal bark-cracking; young trees may be girdled and killed (van der Westhuizen, 1959a, b). The disease has been recorded in South Africa, Malawi, Kenya, Uganda, Pakistan and Western Australia. Other *Cytospora* spp., either undescribed or not fully identified, are also known from cankers of eucalypts.

Botryodiplodia theobromae Pat. was associated with cankers caused by *C. eucalypticola* in Kenya. It has also been named as the cause of cankers and staining of sapwood of eucalypts in Nigeria and the United States. *Botryosphaeria* spp., generally weak facultative pathogens, have been reported from numerous sources including Portugal, the United States, Australia, India and Hawaii as the cause of stem cankers of *Eucalyptus* spp. These are characterized by necrosis and darkening of the bark and cambium with clusters of minute spherical black pycnidia on the lesion. *Botryosphaeria ribis* (Tode ex Fr.) Gross & Dugg. and its more virulent form *B. ribis* var. *chromogena* Shear & N.F. Stev. are possibly the most important members of this group.

Hypoxylon mediterraneum (de Not.) Ces. & de Not., the cause of "charcoal disease" of cork oak, has been recorded on the stem bark of several *Eucalyptus* spp. in the Mediterranean region and Portugal. *H. annulatum* (Schw.) Mont. and *H. howeianum* Petch have caused similar damage in Australia.

The important tea pathogen *Calonectria theae* Loos (imperfect state *Cercosporella theae* Petch) has caused leaf spot and sunken twig-cankers on *E. robusta.*

Phytophthora nicotiniae B. de Haan var. *nicotiniae* (Dastur) Waterh. causes basal stem cankers of *E. citriodora* in Brazil and *E. viminalis* in Argentina. These are probably incurred by inoculum splashed from the soil; the symptoms include bark-cracking, discoloration of wood under the bark and exudation of gum from the infected area. *P. cactorum* (Leb. & Cohn.) Schrenk causes similar disease in the United States.

In New South Wales, Australia, *Ramularia pitareka* Walker & Bertus has caused deaths in nursery stock of *E. maculata, E. eximia* and *E. ficifolia* by attack of stem and leaves where it produces characteristic profuse superficial white mycelium and conidia. Another widespread cause of stem disease in *Eucalyptus* nursery stock is *Sclerotinia fuckeliana* (de Barry) Fuckel (imperfect state *Botrytis cinerea* Pers.). The fungus invades young stem tissue, producing wilt and a water-soaked condition followed by death. A mass of grey sporophores is borne on dead, shrivelled tissues which liberate airborne conidia. The disease is favoured by crowded humid growing conditions.

Septobasidium curtisii (B. & D.) Boed & Stein., a symbiont of a parasitic scale insect, is recorded on eucalypts in Puerto Rico. The fungus itself is not harmful.

Bacterial stem galls caused by *Agrobacterium tumefaciens* (E.F. Smith) Conn. are known on *Eucalyptus* spp. in the United States and are sometimes regarded as serious. A die-back of *E. citriodora* caused by the bacterium *Xanthomonas eucalypti* Truman has been described recently from New South Wales, Australia (Truman, 1974); *E. maculata* is also mildly susceptible.

Several virus diseases of *Eucalyptus* spp. have been reported and there are accounts of other conditions that may be due to viruses or virus-like agencies (i.e., mycoplasmas). The first of these was described by Fawcett (1940) from Argentina as a graft-transmissible chlorosis and stunting of young plants;

the natural means of spread was not known. *E. propinqua* was susceptible, *E. citriodora, E. saligna* and *E. maculata* were less so, while *E. punctata, E. tereticornis* and *E. rudis* were resistant. Foddai and Marras (1963) described a graft-transmissible mosaic of *E. camaldulensis* in Sardinia which could lead to witches' broom, leaf malformation and necrosis. Here, also, the natural vector was not known and symptoms appeared to be most severe at the start of the growing season.

Sastry *et al.* (1971) have described three virus diseases in India which reduce the quality and quantity of oil in the leaves of *E. citriodora.* These include tobacco mosaic, which produces an intense red coloration of the growing points, leaf distortion and bushy growth in 1- and 2-year-old plants, and mosaic symptoms in older leaves. The symptoms disappear as the plant grows older. Sap transmission is possible but the natural means of spread is not known. Rather similar symptoms are known in *Eucalyptus* spp. in Zambia. The second disease is known as "little leaf," which occurs on 4- and 5-year-old plants, is graft transmissible and causes stunted plants with greatly reduced leaves with thin pale narrow laminae; axillary buds are stimulated to give a bushy form. "Leaf crinkle" is the third disease, causing an upward curling of leaves with a wavy margin and some vein banding.

A stunting disorder of *E. camaldulensis, E. citriodora, E. grandis, E. maculata, E. propinqua* and *E. saligna* believed to be due to a virus is reported from South Africa.

Mistletoes have been recorded on a range of *Eucalyptus* spp. where they can cause serious die-back and stunting by girdling and replacement of the crown of the host by their own foliage. Greenham and Hawksworth (1964) quote Nicholson (1955) to show that crown replacement in *E. polyanthemos* by *Amyema pendula* is closely related to loss in basal area. Most records derive from Australia (*Amyema, Dendrophthoe, Muellerina, Diplatia* spp.) but infestations of eucalypts have been recorded also in India and Sri Lanka (*Dendrophthoe falcata* (L.f.) Ettingsh., *D. neelgherrensis* (W. & A.) Tiegh., *Scurrula parasitica* L., Belgium (*Viscum album* L.), Costa Rica [*Struthanthus polystachyus* (Ruiz. & Pav.) Blume], Zaire [*Tapinanthus erianthus* (Sprague) Dans.] (Hawksworth, 1974). Control depends on early detection and excision. Chemical control has been tried with varying results; it is liable to be expensive. All mistletoes produce sticky edible seeds that are distributed by animals and birds.

There are a number of undiagnosed stem disorders that may be due to biotic agencies. Gum pockets in the wood of *Eucalyptus* spp., known as "kino," are now thought to be physiogenic in origin and there are other conditions, such as a witches' broom, caused by eriophyd mites, that may be confused with stem disease in the strict sense. Gibson (1975) notes a number of fungi associated with stem diseases of *Eucalyptus* spp. which have minor importance and which may be doubtfully pathogenic.

De Guzman (1977) reports two stem diseases from the Philippines that have caused serious damage to eucalypt plantations, "*Eucalyptus* blight" causing bark and sapwood necrosis with premature leaf cast and witches' broom in *E. grandis* and *E. saligna*, and "tip blight" which is characterized by a serious die-back, reduction in increment and deaths in *E. deglupta*. The first disease (Eucalyptus blight) is thought to be due to a basidiomycete, possibly a *Stereum* sp., which forms whitish flat fruit bodies on diseased tissues.

Leaf diseases

Although a number of leaf diseases of *Eucalyptus* spp. are caused by facultative parasites with some ability to survive for part of their life cycles as competitive saprophytes, most of these pathogens are obligate (or effectively so, under natural conditions) with a limited host range which may be confined to a small number of species within the genus. Nearly all the organisms considered in this section have airborne spores for spread which, under suitable conditions, germinate on the host leaf and penetrate these tissues directly. The symptoms are nearly always expressed as a partial necrosis of the foliage (leaf spot, anthracnose, etc.) which in severe cases may lead to premature leaf cast. The effects of this type of disease on the host are mainly through damage to photosynthetic tissues, leading to reduction in increment. The severity of the impact will depend on the age of the foliage that is attacked and the persistence of the condition. Disease of young, photosynthetically active leaves is therefore much more important than that of older foliage which is less productive. Leaf diseases may lead to such chronic depletion of foliage that the tree itself dies, but this is exceptional.

Wounding and other factors leading to host debility do not necessarily predispose the tree to attack by leaf pathogens. Indeed, this applies mainly to facultative organisms and, where the pathogen is completely obligate, the healthiest tree may prove to be the most susceptible.

By their nature, diseases of this kind provide a contrast to those arising through root infections. In exotic plantations, root diseases of *Eucalyptus* spp. may be expected to arise from pathogens that are members of the local microflora, as these usually have a wide host range, a facultative habit and limited radius of dispersal. Leaf pathogens, on the other hand, are often obligate with specialized requirements, including a limited host range, and a capacity to spread over long distances. They are thus more likely to be introduced from native stands of eucalypts and to have an exotic origin like their host.

Although a wide range of pathogens is known to infect the foliage of *Eucalyptus* spp., and their symptoms are often striking, the impact of these diseases, particularly in plantations, is much smaller than root or stem infections. The symptoms, which have been described in detail for many of these diseases, are useful for diagnosis but tend to vary with host species and environment as well as the pathogen.

The two most specialized groups of fungal leaf pathogens, the rusts and powdery mildews, are represented in this group. While there are no known rusts of eucalypts in their native state, *Puccinia psidii* Wint. has been recorded in Brazil, where it can cause loss to nursery stock of *E. citriodora* and other species. *P. psidii*, as its name infers, normally attacks *Psidium* spp. and other Myrtaceous hosts in the New World (Joffily, 1944). It is clearly important to ensure that this fungus is not introduced to Australasia, where eucalypts are native.

Powdery mildews of eucalypts have been described from Europe, Argentina, Brazil, Australia, Burundi, South Africa and the United States. The symptoms appear as whitish, powdery patches on the leaves which spread, cause leaf distortion, necrosis and leaf cast. The causal agent has been identified as *Erysiphe cichoracearum* DC ex Merat in the United States. This is a species of wide host range which spreads by airborne conidia and ascospores. Elsewhere only the imperfect, conidial stages of powdery mildews have been found, identified either as *Oidium eucalypti* Rostr. or other unidentified *Oidium* spp. Attack generally takes place in young plants under crowded conditions and can be controlled by fungicides such as benlate, karathane or sulphur dust. *E. camaldulensis, E. globulus*, incl. ssp. *maidenii*, and *E. viminalis* are included in susceptible host species. It is possible that more than one *Oidium* sp. may exist capable of attacking eucalypts and that each of these fungi has a different host range.

The *Cylindrocladium* spp., particularly *C. scoparium* Morgan and *C. quinqueseptatum* Figueredo & Namekata, can cause appreciable damage to foliage and young shoots of *Eucalyptus* spp., as well as by root attack. These pathogens are particularly important in Brazil and India, while *C. scoparium* has also caused damage in Costa Rica (Figueredo and Namekata, 1967; Segura 1970b). A third species, *C. ilicicola*, is also recorded from Brazil, India, Malaysia and Kenya (Figueredo and Cruz, 1963; Gibson, 1975).

The symptoms of attack by these fungi appear initially as greyish brown spots starting often from the edge of the leaf and causing leaf cast in severe cases. Spread is by splash-dispersed conidia and infection is favoured by wet conditions. Fungicidal control of these pathogens is possible in the nursery using copper preparations and captan. Segura (1970b) found *Eucalyptus* 'Bangalore Hybrid' very susceptible to *C. scoparium* in Costa Rica, with *E. saligna* and *E. maculata* moderately so and *E. deglupta* resistant. In Brazil *E. tereticornis, E. alba* and *E. citriodora* proved susceptible, with *E. saligna* resistant, to *C. scoparium* var. *braziliensis* (*C. braziliensis* Peerally) (Batista, 1951).

Other fungi, mainly ascomycetes and fungi imperfecti, known to cause spots and other symptoms on eucalypt foliage, include species of *Cercospora, Mycosphaerella, Harknessia, Hendersonia, Phyllosticta* and *Septoria* and are listed with brief notes in Gibson (1975).

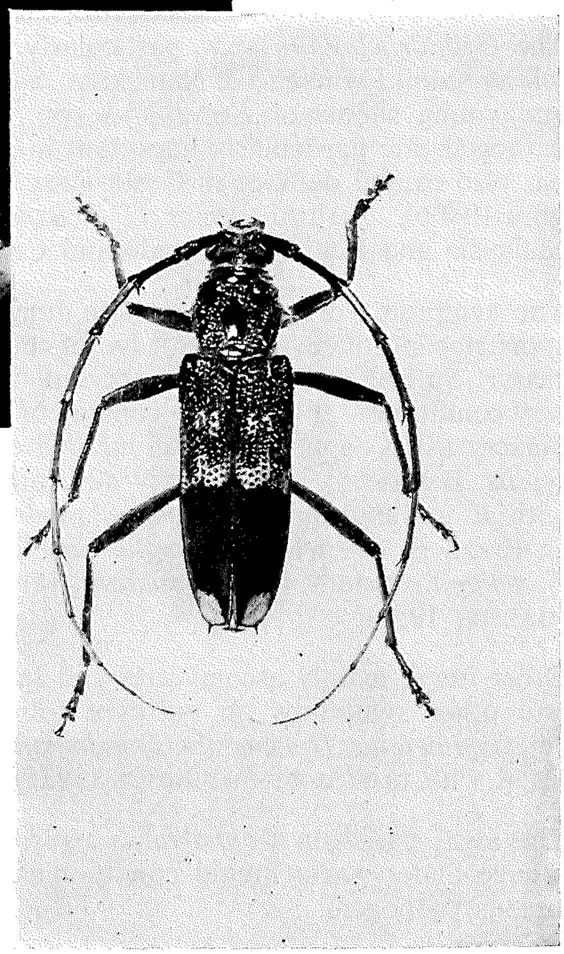
The algal pathogen *Cephaleuros virescens* Kuntze is recorded on eucalypt foliage under warm humid conditions in Africa (Brunck, 1978); it is not a serious pathogen.

Heart and butt rots

These diseases are caused by fungi capable of destroying the dead heartwood of trees, either by invasion through stem wounds (pruning scars, game

43. Larval galleries of *Phoracantha semipunctata* (adult form shown below)

Centro di sperimentazione agricola e forestale, Rome, Italy



damage, storm breaks) to cause heart rots, or through the roots for butt rots. A wide range of basidiomycetes cause these conditions, which can be divided into brown cubical rots, caused by fungi that can digest cellulose only, and white fibrous rots due to those that can digest both lignin and cellulose to some extent.

These fungi generally produce prominent sporophores (toadstools, brackets or other forms) which liberate quantities of airborne spores and spread infection. They may also be spread by mycelial growth through the soil and root contact with infected debris.

Heart and butt rots are characteristically diseases of the over-mature tree and are responsible for considerable loss of timber in natural eucalypt stands in Australasia. However, in even-aged plantations, trees are seldom allowed to reach an age where losses from rots are likely to become important and they are seldom significant under these conditions.

Nevertheless, special conditions have arisen which have favoured rot invasion of very young *Eucalyptus* spp. in plantations. In Zambia, for instance, damage to the roots and stem bases of young trees by mechanized clearing and weeding operations led to a severe but localized invasion of *E. grandis* and *E. saligna* by *Poria epimiltina* (Berk & Br.) Bres. and other rot fungi (Ivory, 1975).

A wide range of rot fungi has been recorded from *Eucalyptus* spp. throughout the world and is listed with hosts and geographical distribution by Gibson (1975). However, of these records only *Coriolus zonatus* (Fr.) Quel. and *Piptoporus portentosus* (Berk.) G.H. Cunn. in Australia, *Laetoporus sulphureus* (Fr.) Murrill in Brazil and *Phaeolus schweinitzii* (Fr.) Pat. in South Africa appear to have achieved any importance in plantations. Many of the basidiomycete root pathogens, such as *Ganoderma lucidum* [(W. Curtis.) Fr.] Karst. may cause butt rots under different environmental conditions. Few of the rot fungi are specialized to a narrow host range. Control of loss from heart rots depends on a knowledge of predisposing conditions to infection and their avoidance.

Mycorrhiza

Like many trees, eucalypts form symbiotic mycorrhizal associations between the roots and a fungus. The formation of correct mycorrhizal relationships is often essential to the establishment and healthy growth of the tree host. This is the case with most pines, and their successful introduction into new regions is usually only possible after the soil has been inoculated with the correct mycorrhizal fungus.

However, this problem has seldom arisen when *Eucalyptus* spp. have been grown outside their natural range, although there is some evidence that inoculation of *E. camaldulensis* with *Pisolithus tinctorius* (Mich. ex Pers.) Coker & Couch can be beneficial to plants grown in Israel (Neumann, 1959). In Australia also (Pryor, 1956a, b), *E. dives, E. pauciflora* and *E. macrorhyncha* have been found to benefit from inoculation with *Scleroderma verru-*

cosum (Vaill.) Pers., without which young plants become chlorotic and lack vigour. *E. bicostata* was not found to depend on correct mycorrhizal inoculum for healthy growth in these experiments.

In South Africa, however, no improvement was observed in growth of *E. grandis* after inoculation with *P. tinctorius* (Anon., 1964) and Uhlig (1968) found that *E. rudis, E. camaldulensis* and *E. tereticornis* grew without mycorrhiza in the Sudan and the same applied to *E. exserta* in Germany (FR).

Various surveys have been made of the occurrence of mycorrhiza in eucalypts grown outside their natural range (Bakshi, 1966; Levisohn, 1958; Singh and Kumar, 1966) and the morphology of these associations has been studied in Australia (Chilvers and Pryor, 1965; Chilvers, 1968).

Damage by weeds and strangling vines

The necessity to remove competitive weed growth from young eucalypt plantations has been stressed in Chapter 5. Clean tending is almost as necessary as regular fertilizing to ensure a rapid closure of the canopy, after which competitive weed growth should not be a problem. Certain aggressive weeds, which have become more or less international, are likely to take charge of any accidental opening in the canopy of plantations in many countries. The Mexican garden plant, *Lantana camara*, develops dense clumps which are difficult to remove throughout subtropical forests in Australia, Africa and India. An aggressive weed from Mauritius, *Solanum mauritianum*, is a particularly troublesome plant in southern Africa. The American brambles, *Rubus* spp., are troublesome in many countries. The problem with many of these aggressive weeds is that they can spread or reproduce themselves by seeds, layering or root-suckers. Control may be by repeated cutting, by 2,4,5-T sprays or by desiccant sprays, but great care must be taken that the sprays do not touch the eucalypts.

Vines climbing up into the canopy of plantations are a nuisance, as are a number of twining vines that repeatedly encircle the trunks of plantation trees. Sometimes the stems of these vines are very strong and can literally girdle and kill the stems. The genera *Merremia* and *Mikania* especially can be a menace in moist tropical conditions. A fairly quick control is to cut the encircling vine stems in several places.

Insect pests

A very large number of insects have been recorded as attacking the living or dead parts of eucalypts grown in plantations, windbreaks and ornamental plantings. In Brazil alone some 177 different species of insects were recorded as feeding on eucalypts up to 1967 (d'Araujo e Silva *et al.*, 1967-68; Clark, 1973). Detailed information is available from various sources (e.g., Browne, 1968; Wattle Research Institute, 1972; Sujan Singh and Pratap Singh, 1975). The present account concentrates on the pests of most potential danger. These include indigenous pests of catholic taste which attack introduced genera as well as native vegetation (e.g., termites and leaf-cutting ants) and pests introduced from Australasia (e.g., *Gonipterus, Phoracantha*, which can cause serious epidemics when they are free from control by their natural predators and parasites).

Seed-attacking insects

Several insects are known to attack seeds within the capsules in Australia. Greece has reported that a hymenopterous insect attacks the seed of *E. camaldulensis.*

Nursery pests

White grubs, the larvae of chafer beetles of the family Scarabaeidae, are pests of nurseries throughout the world and attack *Eucalyptus* as well as many other genera. The female beetles lay their eggs in the soil and the larvae feed on the fine roots of young seedlings, often causing their death. Some control can be obtained by sieving nursery soil or fumigating it with methyl bromide before use. Treatment of the beds or pots with insecticide is also effective, for example, gamma BHC dust (0.6 percent active ingredient) at 30 g/m^2 watered in (Barrett, 1978).

Other common pests are cutworms, the larvae of various species of the Noctuid moth. The female moth lays its eggs on the ground or on plants. The larvae remain in the soil by day and emerge at night to cut through young seedlings at soil level. Damage can be reduced by keeping the nursery and its surrounds free of weeds. If necessary, beds or pots can be sprayed with a mixture of 50 ml dieldrin emulsifiable concentrate (15 percent active ingredient) in 200 litres of water, at a rate of 1 litre per m^2 (Barrett, 1978).

The special problems of dealing with termites and true ants are discussed later. Both may attack seedlings in the nursery as well as young trees in the plantation. Catastrophic nursery losses occur occasionally as a result of invasion by locusts. Less serious damage sometimes results from grasshoppers, crickets and mole-crickets which chew leaves or cut through seedlings at ground level. Defoliation by grasshoppers is reported as a nuisance in Ghana. Defoliation by common mole-crickets is reported by Burundi, Nepal and Turkey, while the giant cricket, *Brachytrypes membranaceus* Drury, has attacked nursery plants in Kenya, Malawi, Zimbabwe, Uganda, Gabon, Guinea and the Congo (Sujan and Pratap Singh, 1975). In Burundi lindane is used to control crickets but is effective for six months only. In South Africa grasshoppers are controlled by applying 0.6 percent active ingredient gamma BHC at 1.5 to 2.5 g/m^2 (Barrett, 1978).

Defoliating insects

Gonipterus scutellatus Gyll., the *Eucalyptus* snout beetle, is a native Australian weevil (Curculionidae), introduced into New Zealand, Mauritius, Madagascar, St. Helena, and countries in southern and eastern Africa, where in the past it has been proved to be a major eucalypt defoliator. Both the adults and the larvae feed on the leaves and fresh shoots of susceptible species; the larvae do the worst damage by destroying the leaf epidermis. Eggs are laid on young leaves and there are usually two generations during a year.

Species of eucalypt vary greatly in susceptibility to the pest. Among the most susceptible are all subspecies of *E. globulus.* The resistance rating of some species in South Africa is shown in Appendix 4 but, as pointed out by Browne (1968), resistance may vary from country to country; for example, *E. macarthurii* was infested in New Zealand and Uganda, but not in South Africa.

Although the snout beetle did spectacular damage in several countries soon after its introduction, the subsequent introduction of the Myrmarid wasp *Anophoidea nitens* Gir., an Australian parasite of *Gonipterus* eggs, has usually effected satisfactory control of the pest even among the more susceptible species. There is some evidence that the parasite may be less effective at colder temperatures, hence at high altitudes or latitudes it is advisable to plant only resistant species.

A related Australian species, *G. gibberus* Boisd., was established in Argentina by 1925 (Santoro, 1964) and has caused severe damage in the southern States of Brazil (Reis and Hodges, 1975). A third species, *G. platensis* Mar., was recorded attacking eucalypts in Argentina in 1955.

Paropsis obsoleta Olivier (syn. *P. charybdis* Stal.), a Chrysomelid beetle, is another Australian species which has become an introduced pest. Both the adults and the larvae feed on the edges of leaves and have caused serious defoliation of eucalypts in New Zealand. There are not less than two generations in a year (Browne, 1968). Species vary in their susceptibility to the pest. The two main species now planted, *E. regnans* and *E. delegatensis*, are relatively resistant, while planting of other species, e.g., *E. globulus*, *E. viminalis*, *E. macarthurii*, *E. nitens*, has been severely restricted by their susceptibility. Some control was effected by aerial spraying of DDT. Attempts are being made to introduce a Tachinid parasite.

Adults of the indigenous weevil, *Achradidius creticus* Kies., have injured young plantations of *E. camaldulensis* and *E. gomphocephala* in Israel. In heavily infested plots mortality was up to 16 percent. Spraying with an 0.4% water solution of dieldrex 15 gave satisfactory control (Halperin, 1963). In the Coff's Harbour area of New South Wales, Australia, defoliation of eucalypt plantations has been caused by adults of the Scarabaeid *Anoplognathus chloropyrus* (Drapiez) and related species. *E. dunnii* was the most susceptible species, followed by *E. grandis*, while *E. pilularis* and *E. saligna* were more or less resistant (Carne *et al.*, 1974).

Among indigenous defoliators in Latin America, serious damage may be caused by the larvae of the Lymantrid moth *Sarsina violascens* H.-S. This was first identified in Brazil in 1949 and has been reported from most of the Brazil States as well as from Misiones in Argentina. Some outbreaks are well controlled by parasites, *Lespesia* sp., *Copidosoma koehleri* and *Apanteles gaytotini* Blanchard, or by a Pentatomid predator. Mechanized dusting with BHC (3 percent) or Malatol-LVC has also proved effective (Cola Zanuncio and Gomes de Lima, 1975). Other lepidopterous larval defoliators in Brazil are *Thyrinteina arnobia* Stoll., *Eupseudosoma involuta* Sepp., and *Euselasia eucerus* Hewitson. The last was controlled by aerial application of a mixture of 25 percent DDT, 25 percent malathion, 50 percent oil base (Malatol 2 LVC) but cost about US$ 9.00/ha at that time (Clark, 1973). In Argentina

Caphisus siccifolius Walk. has caused defoliation of eucalypts (Sujan and Pratap Singh, 1975).

In Zambia spasmodic outbreaks of defoliation have occurred on *E. cloeziana* caused by larvae of the indigenous moths *Taragama* sp., and *Narosa viridana* (Ivory, 1977). Looper caterpillars of the genera *Buzura* and *Neocleora* have damaged eucalypt plantations in several countries in southern Africa.

Ghana has suffered damage from the larvae of the lepidopterous *Strepsicrates rothia.* Other lepidopterous pests reported include *Madasia amblycalyma* and *Eumeta cervina* Druce in Nigeria, *Nudaurelia diona* Fabr. in the Congo and *Sauna concolor* in India (Sujan and Pratap Singh, 1975). In normal years adequate control of these indigenous pests is exercised by local parasites and predators.

SAP-SUCKERS

There are several insects which cause severe debilitation in trees by sucking the sap from them. Some of these, in the absence of their natural Australian predators, have caused great damage.

An Australian psyllid sap-sucker, *Ctenarytaina eucalypti* Mask., is reported as doing considerable damage to plantations of *E. globulus* in both Spain and Portugal, and has also been introduced into New Zealand. In Portugal it was first identified in 1971 but is already considered the most serious insect pest in that country. In Spain malathion-based insecticides have been used with some success.

The scale insect, *Icerya purchasi* Mask., is another Australian species, which has attacked eucalypt plantations in Angola, Malawi and India, but does more severe damage on *Acacia* spp. such as *A. mearnsii.* It can be controlled by introducing the predator *Rodolia cardinalis* Mulsant.

Another scale insect, *Eriococcus coriaceus* Mask., caused severe damage in New Zealand in plantations of *E. globulus, E. viminalis, E. gunnii* and *E. macarthurii* early in the twentieth century. Partial control has been obtained by biological means through the introductions to New Zealand of a predatory Coccinellid beetle *Rhizobius ventralis*, a fly *Pseudoleucopis benefica*, and a moth *Stathmopoda melanchra.*

An armoured scale, *Hemiberlesia rapax* Com., sucks sap from *E. cornuta* and a shield bug, *Agnoscelis versicolor* Fabr., from *E. viminalis,* in South Africa.

Cicadas have lived together with many different eucalypts in Australia for a long time. They usually flit noisily around the taller trees rather than the smaller ones. They inflict many thousands of punctures through the bark of the smaller branches. What effect this has on growth is not known. There are cicadas in many countries where eucalypts are grown but damage from them has not been reported.

Indigenous species of thrips sometimes attack young trees and cause loss of increment but are not a serious hazard.

In the British Solomon Islands tip die-back of newly planted *E. deglupta* is caused by a Coreid bug, *Ambleypelta cocophaga.* The ant, *Oecophylla smaragadina,* has proved a successful predator. The movement of the ant is facilitated by clean weeding. In Papua New Guinea *E. deglupta* has been defoliated during the dry season by a combination of the Coreid *Leptoglossus australis* Fabr., the Pentatomid *Austromalaya* sp. and the Flatid *Paratella errudita* Mel. None of the three sap-suckers caused extensive damage alone, but the joint attack caused a serious growth setback. The outbreak was apparently controlled by the parasite *Graptoclopius pallescens.*

BARK BEETLES AND WOOD-BORERS

These pests cause some trouble in unthrifty trees and in logs which have been felled but not barked and in which the wood is in an unseasoned condition. Easily the most important pest in this category is the Australian Cerambycid (longhorn) beetle *Phoracantha semipunctata* Fabr. It was reported as being accidentally introduced into South Africa in 1906, Argentina in 1917, Israel and Uruguay by about 1945, Egypt in 1950, Turkey in 1959, Tunisia in 1962, Peru in 1967, Italy (Sardinia by 1971, Sicily by 1975, Calabria by 1978) and Algeria by 1976. It has also spread to New Zealand, Cyprus, Mauritius, Angola, Zimbabwe, Zambia, Chile and Bolivia. Recent summaries of information are available in Ivory (1977) and Cavalcaselle (1971) and more detailed accounts of biological research have been published by Chararas (1969, 1971).

The species attacks freshly felled trees or live trees which have been weakened by drought stress or other causes. Eggs are laid in crevices of the bark, often near the junction of stem and branches. The larvae tunnel first in the bark and cambial area and later in the wood, where they pupate. Adult activity is regulated by temperature, the optimum being 26-28°C and the minimum for flight 15-16°C. In warm conditions there may be two generations in a year. In a heavy attack by Australian Cerambycids the tree is killed by the interruption of sap flow.

Many species of eucalypt are attacked, but resistance to attack appears to be related to the drought resistance of the species, which results from its relative ability to maintain a high osmotic pressure without damage in the dry season (Chararas, 1971). In Zambia mortality in 1973/74 was greatest in 5-year-old *E. grandis* and 6-year-old *E. cloeziana,* at 34 and 29 percent respectively. Younger crops were virtually unaffected, and there was evidence that severity of attack was related to soil depth and type. Many other species were attacked, but not *E. tereticornis, E. camaldulensis, E. raveretiana* and *E. obliqua* (Ivory, 1977). In North Africa, on the other hand, *E. camaldulensis,* together with *E. globulus, E. gomphocephala* and *E. viminalis,* is among the more susceptible species, while *E. astringens, E. cladocalyx, E. sargentii, E. stoatei, E. flocktoniae* and *E. oleosa* are relatively resistant (Chararas, 1969). They are also slower-growing.

The best prevention against attack is to plant a species which will not suffer excessive drought-stress. However, control measures may still need to be taken, for example, when planting a fast-growing species in conditions where it remains healthy in most years but suffers attack in an exceptionally dry year. In Tunisia the problem has been brought under some control by the use of "trap trees." In places where the infestations were particularly heavy, up to 50 trap trees per hectare were used, but later it proved possible to reduce the trap trees to 10 per hectare. These were cut and sliced in a few places by a machete and leaned into the crowns of the remaining trees. After three weeks the trap trees were extracted and the bark (with larvae) was removed and burned. The wood could be used for poles. Sex attractants were also used. As many as 900-1 500 larvae were collected per trap tree.

Attack on felled trees can be prevented by felling them in the cold season when adults are inactive, or by immediate de-barking. If neither of these measures is possible, chemical spraying with an 0.5 percent solution of lindane in cracked gas oil has proved effective and cheap in Israel (Spetter, 1963).

A second species of *Phoracantha, P. recurva* New., has also been introduced into southern Africa, where it does similar damage. Both species were present in the Zambian infestation mentioned above. *P. recurva* has not been identified yet in the Mediterranean area. In Zambia occasional parasitism of the larvae by a species of *Iphiaulax* has been reported.

A number of indigenous borers are reported as doing damage to eucalypt plantations from time to time. Many of these are primarily pests of freshly felled trees, but can also attack living trees through wounds, or trees that are unhealthy for other reasons. Examples are the fungus-rearing ambrosia beetles of the Platypodid and Scolytid families. Damage has been reported by *Platypus sulcatus* Chap. in Argentina and Uruguay, *Xyleborus fijianus* in Fiji and by *Crossotarsus externedentatus* in Western Samoa (on *E. grandis*) and South Africa (on *E. citriodora, E. maculata* and *E. paniculata*). The ecology of the ambrosia beetles is sometimes complex. In Minas Gerais, Brazil, eucalypts from 5 to 8 years old suffered 1 percent mortality as a result of the snapping of the trees some 2 metres from the ground. A complex of six to ten species of Scolytids, Platypodids and Bostrychids was associated with the damage, but it was not clear which were primary and which secondary pests (Clark, 1973).

Adult beetles of the Bostrychid genus *Apate* sometimes damage eucalypt trees by tunnelling in the branches or smaller stems, causing die-back or breakage. *Apate monachus* Fabr. has injured several species in Israel (Halperin, 1961), but trees rich in kino are resistant to attack. In Nigeria *E. torelliana* has suffered damage, and in Zambia *E. camaldulensis* and *E. tereticornis* (Browne, 1968). *Apate terebrans* Pall. is another species which does some damage in Africa south of the Sahara.

Larvae of the Buprestid beetle *Agrilus opulentus* make long winding tunnels at the cambium-sapwood interface of affected trees of *E. deglupta* in Papua New Guinea. In vigorous trees the tunnels are usually callused over and growth is not affected, but suppressed trees may be killed by girdling. In India the Cerambycid *Celosterna scabrator* Fabr., an indigenous pest of *Acacia nilotica* and other species, has killed 1- to 3-year-old eucalypts through girdling of shoots by the adults and boring through stem and roots by the larvae (Sujan and Pratap Singh, 1975). Girdling of young *E. torelliana* stems up to 8 cm in diameter by the Lamiid, *Analeptes trifasciata* Fabr., has occurred in the Guinea Zone of Nigeria and similar damage in Uganda (Roberts, 1964).

Indigenous moth larvae also cause damage. The Hepialid moth, *Sahyadrassus malabaricus* Moore, caused cankers on young plants of *E. globulus* in South India. Affected saplings snapped at the cankered region. In Papua New Guinea the Cossid *Zeuzera coffeae* Nietner bores into the cambium and sapwood of *E. deglupta* and can partially girdle the tree, making it very prone to wind damage. Three percent of trees were affected in one young plantation.

Pests of seasoned and converted timber, such as the widespread *Lyctus brunneus* Steph., attack eucalypt timber, but are outside the scope of this book.

TERMITES AND ANT COLONIES

Termites

Termites of different types are spread over the lower altitudes of the tropical and subtropical parts of most land masses. There are many species in the drier parts of Australia and some over most of the continent. They all live in well-organized colonies, some living in or closely connected with the soil, some largely in tree trunks and some small colonies in tree branches. In the better native woodland of Australia they tend to eat out the old heartwood of the larger eucalypts and in the hotter northern part of the continent they may eat out the central part of most eucalypts of moderate size. The cross-cut logs shown in Figure 44 show how much of the central part of large eucalypt logs goes to feed and house termites. In the better eucalypt woodland of Australia termites are not a problem in regenerating eucalypts, but they may destroy regeneration in the hot northern woodlands.

In Australia termites search for and find entry points into living and dead trees and frequently make large colonies in the central parts of the trees where the wood has been crushed by the growth stresses discussed in Chapter 2. Perhaps as much as one third of the volume of the lower trunks of old very large eucalypts is eaten by termites. The colonies inside the trees are made up of huge numbers of living organisms, which raises the temperature of the inside of the trees considerably. What influence this increased temperature has on growth near the nests is not certain. The trees tend to belly out somewhat in the region of the nest but part of this is due to the release of the tangential compression of the outer layers of wood, once the restraining inner wood has been destroyed.

When eucalypts are planted at low altitudes in subtropical and tropical areas outside Australia, termites may be a serious hazard to plantations. In the

44. Squared hollow logs of old natural eucalypts in Australia, showing the amount of central heartwood lost to termites
Associated Country Sawmillers of New South Wales

land frequently allocated to forestry there may be many colonies of semi-subterranean termites on each hectare. These can be exterminated by a combination of mechanical cultivation and fumigation, but the termites are likely to re-invade the site. If a complete canopy of vegetation can be established and maintained, eucalypt plantations can be successful, but this is difficult to achieve below an altitude of 1 000 m in the lower latitudes, unless insecticides are used at the time of planting.

Difficulties with termites in plantations in low altitudes have been reported by Burundi, Sri Lanka, Ghana, Indonesia, Israel, Kenya, Malawi, Malaysia, Mozambique, Pakistan, Papua New Guinea, Nigeria, Tanzania and Zambia. In most cases casualties due to termites in the initial first year or two after planting can be eliminated or greatly reduced by the use of insecticides as described in Chapter 5. Deaths of trees, apparently caused by termites, sometimes occur in older plantations. However, most of these are due to unfavourable climatic or site conditions, e.g., an excessively severe dry season or a shallow soil, and the termites attack the tree only after it is already weakened or dying.

In Africa *Macrotermes bellicosus* Sme., *M. natalensis* Hav., and several species of *Microtermes* are the most injurious. In Israel damage by *Reticulitermes lucifugus* Rossi. and *Microtermes diversus* Silv., and in Papua New Guinea by *Nasutitermes novarumhebridarum* (N. & K. Holmgren) has been reported.

Highly organized colonies of true ants

The termites and the true ants are not closely related, but both have the common feature of having highly organized communities in which there are different castes with functions of defence, food gathering or food culture.

From the point of view of eucalypt plantations the true ants which present the greatest dangers are the leaf-cutting ants of the genera *Atta* and *Acromyrmex.* They occupy South America from central Argentina northward and some species extend northward into Texas and eastward to the islands of the Caribbean.

Characteristically, these ants have castes which cut leaves into pieces about the size of the nail of a little finger and transport them back to their underground "cities." In tunnels or cavities in these cities the leaf pieces are stacked by other castes and fungi are cultivated on them. The ants use the fungi as food. The ants can use almost any leaf for the cultivation of fungi, but eucalypt leaves are highly favoured even though they are recent introductions into Latin America.

There are many ant "cities" on a hectare of plantable land in Latin America and all must be destroyed by digging, fumigation with methyl bromide or by the use of other powerful formicides, such as mirex or aldrin. It is an expensive operation, estimated at 5 percent of the total cost for the first three years of establishment (Clark, 1973), but without it Brazilian plantations would not be productive. Moreover, the population of the leaf-cutting ants must be prevented from building up and this is not easy. Like most of their relatives the leaf-cutting ants have a flight season at least once a year, and thousands of gravid females must fall on each square kilometre every flight season. Each could start a colony.

Should eucalypt plantations be abandoned as production units in north central Brazil, it is quite likely that large sections of them would disappear as eucalypt stands because the *Atta* ants would destroy all the regeneration.

Other animal pests

LOWER FORMS OF ANIMAL LIFE

Nematodes cause problems in nurseries in several countries. The correction is to sterilize the soil. Slugs and snails are reported as requiring control in nurseries in Lesotho and Malta. Commercial snail baits are used to combat the pests.

BROWSING MAMMALS AND PALATABILITY

The palatability of a plant affects its chance of success when it is growing in competition with other plants and is subject to attack by animals which have a variety of foods to choose from. Some animals will only eat certain plant species; others, such as the locust, attack any green vegetation.

The varying palatability of different eucalypts is of interest both in Australia and in overseas countries where they have been planted. For example, in Tasmania, *E. regnans* is more palatable than *E. obliqua* in their younger stages both to native marsupials and to European cattle and sheep. *E. globulus* is much less palatable than both the other species while it is producing its very glaucous juvenile leaves. In the native forests of Tasmania *E. globulus* is favoured in mixed regeneration against the more vigorous *E. regnans* and *E. obliqua* because it is unpalatable. In countries like Ethiopia *E. globulus* can be grown without fencing because cattle, sheep and even goats do not like the glaucous juvenile foliage. This has made the species of great importance as a plantation tree which produces most of the fuelwood and poles for the highland city of Addis Ababa. It is also probably the reason why *E. globulus* became such a popular species in Mediterranean lands early in the 19th century. It could be planted without fencing — an important economic advantage.

Another instance of varying palatability is seen in mixed plantations of *E. regnans* and *E. delegatensis*. If cattle are allowed to graze in the young plantations they chew the fibrous bark of *E. regnans,* but rarely *E. delegatensis.*

The varying palatability of leaves and bark of plantation eucalypts should be carefully checked by trials before grazing is permitted in a plantation.

CROWN-FEEDING MAMMALS

Several Australian marsupial mammals feed on leaves in the crowns of eucalypts. They do not do serious damage in Australia, where their numbers appear to be controlled by internal parasites. There is a very limited natural carnivorous fauna in Australia and very little of it is arboreal in habit. One Australian possum (*Trichosurus vulpecula*) was introduced into New Zealand where it is causing serious damage to native rain forest and introduced eucalypt plantations. The possum is a carrier of bovine tuberculosis in New Zealand, and, as it has multiplied to plague proportions, strong efforts are being made at control. Countries are warned against introducing these rather attractive arboreal marsupials, not only as a precaution in relation to their eucalypt plantations, but also to protect a wide spectrum of their native trees or commercial animals.

In Australia the arboreal marsupials usually feed at night, when they come down from the crowns of the trees and nibble regeneration. This does not kill much regeneration but it does restrict height growth and thereby the rate at which the regeneration can regain control of the site.

Many countries have expressed an interest in introducing the Australian koala bear to their eucalypt forests. These harmless and charming little animals have a very restricted diet of eucalypt leaves and shoots of species close to *E. viminalis*. They have been introduced to various zoological gardens but it is doubtful if they could survive in the wild against the carnivorous animals of Asia, Africa and the Americas.

North American squirrels have found the seed of *E. globulus* attractive food. The well-known plot of large trees of *E. globulus* on the campus at the University of California at Berkeley now supports hundreds of squirrels, which eat most of the seed.

Disorders from inorganic causes

MINERAL DEFICIENCIES

In the localities of their natural occurrence trees do not usually manifest indications of deficiencies of the major or minor elements necessary for tree growth. They may be vigorous or thrifty according to the nutritional status of the site, but in the course of evolution they have either become accommodated to the quantities of specific elements available to plants on the site they occupy, or they may have been pressed to occupy a deficient site to which they may be better suited than other species in the vicinity.

Species that are planted in a different locality or country may manifest special colourings in their foliage, which demonstrate that the locality is deficient in certain elements necessary for healthy growth. This is valuable information for the grower, who may be able to correct the deficiency. Where deficiencies are slight, they may cause reduction in growth rate without producing any visible symptoms.

Mineral deficiency symptoms may occur even where there is no shortage of the element in the soil. Poor aeration of the soil in swampy conditions may prevent the absorption of mineral nutrients by the roots. In Uganda eucalypt plantations on swamp sites exhibited mineral deficiency symptoms (Kingston, 1977). In such cases the cure is drainage rather than fertilization. Table 9.1 summarizes the symptoms of mineral deficiencies in eucalypts and is reproduced from Malavolta *et al.*, 1962, and Wattle Research Institute 1972, by courtesy of the International Potash Institute, Berne, and the Wattle Research Institute, Pietermaritzburg.

In tropical Africa boron deficiency may be so serious that deficiency symptoms are more extreme than those described below. In Zambia Savory (1962) described the symptoms as follows:

> "Typically, the first symptom is the crinkling and discoloration of the unfolding leaves of the apical bud; this is then repeated in the other buds on the upper part of the crown. The buds become brittle and die. The mature leaves of the upper crown then become discoloured and later drop off. Following this, the bark of the main stem and the upper laterals become dark brown and necrotic, the necrosis beginning at the buds and progressing down the stems.
>
> "The discoloration of the mature leaves takes different forms: in *E. grandis* ... the diseased leaves typically become a reddish purple, but may first show yellow patches on the broad part of the leaf. Species such as *E. citriodora* and *E. torelliana,* whose healthy young leaves are reddish in colour, show a yellowing but no purpling."

In extreme cases, die-back of the leading shoot, which occurs during the dry season each year, may extend to 2-3 m. It may be repeated for several years until all that is left is a densely branching bush (Jackson, 1977b). Remedial treatment is described in Chapter 5.

Mineral excesses

Physiological disorders in eucalypts may be caused by excess of certain elements. In extreme cases, such as afforestation of mining residues, the element may be so concentrated as to be toxic to the trees. In others it may interfere with the uptake or internal use of other essential elements. Lime-induced chlorosis, which affects many species growing on strongly calcareous soils, is often ascribed to non-availability of iron in a form which can be used in the metabolism of the plant. In these conditions iron deficiency symptoms can appear even though chemical analysis shows as high an iron content in soil and plant as that in healthy trees on other sites. Addition of iron sulphate or iron chelate, or reduction of pH by acidification with aluminium sulphate, sulphur or sulphuric acid may be effective in the nursery but is not practicable on a plantation scale. Selection of a species or provenance adapted to the local soil conditions is the best solution.

In highly acid soils toxic concentrations of soluble aluminium may occur. Addition of lime will reduce the solubility of the aluminium and hence the danger of its absorption by tree roots in toxic concentration.

In arid areas the excess of evaporation over precipitation often results in the accumulation of salts of sodium, potassium and magnesium in the surface layers of the soil in sufficient quantity to be toxic to many species of eucalypt. Selection of salt-tolerant species, e.g., *E. sargentii,* and planting on raised mounds can mitigate the effects of salinity.

Table 9.1 Symptoms of mineral deficiencies in eucalypts

Deficiency of:	**I. Symptoms first localized in older leaves**
Nitrogen	A. Yellowing first, spotting later Slight yellowing of older leaves at first, then younger leaves. As the deficiency becomes more acute, the leaf blades show a lemon-yellow colour, after which small reddish spots develop, and cover the entire leaf. In seedlings, stems and leaf stalks are redder than normal, and branching is restricted, resulting in tall spindly seedlings with few or no side branches.
	B. Spotting first, yellowing later
Phosphorus	1. Numerous dark spots appear on the green leaf. These subsequently increase in size and the background develops an orange-yellow tint. Leaves of seedlings have bluish purple blotches and the surrounding green is darker than normal. Branching is restricted as in nitrogen deficiency.
Calcium	2. Reddish spots appear on a pale green background. As the deficiency becomes more acute, the tissues in the reddish areas die, and the leaves wither and fall.
Magnesium	C. Yellowing between the main lateral veins Older leaves yellow along the midrib. Green colour gradually changes to brown with dying off of tissues. The affected regions are separated from the main lateral veins by areas of green tissue. The lower leaves of seedlings become pale green and are often shed prematurely, leaving a bare stem with a tuft of leaves at the top. The seedlings of *E. grandis, E. saligna*, and *E. botryoides*, in particular, produce larger than normal leaves similar to leaves which have developed in the shade.
	II. Symptoms first localized in younger leaves
Sulphur	A. Uniform yellowing. Younger leaves show a uniform yellowing, later changing to a bronzelike colour. Branches show a purplish tinge.
	B. Mottling
Iron	1. Yellow mottling appears on the leaf blades, with the areas along the veins retaining their green colour.
Manganese	2. Yellowing appears between the veins, but tissues near the veins remain green. As the deficiency becomes more acute, the tips and margins of the leaves begin to wither and show a sandy colour, which spreads throughout the blade.
	C. Yellowing between the veins
	1. Leaves normal in size and shape
Boron	(*a*) Yellowing of younger leaves occurs between the lateral veins, starting at the leaf margins and proceeding toward the midrib. Alongside the lateral veins the tissue remains green but later takes on a purplish tint. The lower surfaces of the leaves become light green.

Table 9.1 Symptoms of mineral deficiencies in eucalypts *(concluded)*

Molybdenum	(*b*) Yellowish spots occur between the lateral veins of mature leaves. Narrow bands along the veins remain green, with a purplish colour along the leaf margins.
Copper	2. Leaves normal in size, abnormal in shape Younger leaves become yellow between the lateral veins, accompanied by deformation of the blade, with leaf margins irregular.
Zinc	3. Leaves abnormally small in size, narrower in shape Shortening of stem length between younger leaves, forming a rosette of small, narrow, yellowish leaves showing purplish areas between numerous discoloured patches. Small circular areas of lighter discoloured tissue with brownish edges occur near the leaf margins away from the midrib. The whole leaf becomes pale green, the veins being darker in colour.
Potash	D. Leaves not abnormally discoloured, but margins and veins dying off Leaves of seedlings are smaller than normal, often with crinkled surfaces and margins. Branching is pronounced, giving a bushy, round-topped appearance.

Other soil defects

Soil depth and texture interact with climate. A shallow soil will increase the risk of casualties or die-back during a drought, the reduction of growth during seasonal waterlogging and the incidence of windblow from cyclones. Light sandy soils dry out more quickly in the dry season and are more subject to windblow than well-drained clay soils; the latter are more subject to waterlogging. Groups of dead or sickly trees in a plantation can often be explained by the occurrence of patches of abnormally shallow or poor-textured soils. Texture can be improved by ploughing and, in the case of soils with a hardpan, effective rooting depth can be increased by deep ripping.

Disorders caused by climate

Damage to eucalypt plantations can result from a number of climatic causes, e.g., drought, cold and wind. Often climate interacts with other factors, for example, boron deficiency symptoms always appear in the dry season and trees recover during the rains, while there is some evidence that boron application increases resistance to frost (Cooling and Jones, 1970). Deficiences in climate are compounded by deficiencies in soil.

In eucalypts affected by drought in Zambia the leaves become pale green, then bleached grey and are later shed, the lower branches being affected first (Allan and Endean, 1966). Patches of affected trees become progressively larger as the dry season progresses. With a coppicing species early action should be taken to coppice the crop in order to preserve the rootstocks.

Similar action may be necessary if severe die-back has been caused by frost or hail, but most species of eucalypt recover well from lesser damage.

Damage from wind may take the form of branch or stem break or of uprooting (Jacobs, 1955). The danger of uprooting is increased by planting on wet sites, which restricts roots to the surface layers; by "root-binding," which can be caused by planting container nursery stock without removing the containers; or by too sudden opening of the crop in thinning.

Species of eucalypt vary in resistance to winds. In Mauritius *E. tereticornis* usually stands up to winds of 160 km per hour at all stages of its development but *E. robusta* is often seriously damaged or virtually annihilated, particularly during the pole stage, at less strong wind speeds (Brouard, 1967). *E. botryoides* is also resistant to wind, including salt-bearing coastal winds.

The bark of some eucalypts is very susceptible to sunscorch. Newly planted transplants may be killed on hot aspects, especially if the soil is very light in colour (Wattle Research Institute, 1972). Temporary shading or earthing up of the base of the stem to protect the root collar may be necessary in areas where this form of damage is known to occur.

In general, little can be done to control climate. The choice of species well adapted to the local climate, together with the avoidance of the most unsuitable sites (frost hollows, shallow soils, exposed ridge-tops), should reduce damage to an acceptable degree.

Air pollution

Eucalypts may suffer from pollution if planted close to industrial centres. Marginal leaf necrosis and necrosis with intervenal browning of *E. camaldulensis*, caused by sulphur dioxide from crude oil fumes, have been described by Karschon (1970).

Gum veins: gummosis

Exudation of gum ("kino"), either externally on the outside of the stem (gummosis) or internally in the wood (gum veins), is a common defect in eucalypts which has been reported by many countries. It is described by Jacobs (1955) and is caused by any injury to the cambium, such as fire, fungal, termite or borer attack, and mechanical injury from wind damage. It is therefore the reaction of the tree to previous injury and not itself a disease.

10. Utilization

By 1974 there were about 4 million hectares of eucalypt plantations producing an average of some 60 million m^3 of wood per year. The wood produced is mainly smallwood, of great importance to the countries growing it and representing a massive financial investment for them.

The yield from the plantations is divided roughly into: fuelwood or pulpwood, 85 percent; poles and roundwood products of higher quality, 10 percent; and sawnwood, 5 percent.

Most of the yield from short-rotation eucalypt forests is fuelwood, the product of lowest market value per unit of volume in spite of the fact that it may be the commodity of greatest social value to communities growing the plantations.

The best means of improving the value of eucalypt plantation smallwood are to convert it into the highest unit value wood product — paper. However, constraints on the minimum size of an economically viable mill mean that this is most likely to benefit nations which have large areas of eucalypt plantations, such as Brazil, India, Portugal, South Africa and Spain. In countries having a modest but substantial eucalypt-planting programme the best avenue to improve the unit value of the raw material from their eucalypt plantations is to invest more and improve the unit value of the 15 percent of material that can go into better poles and sawnwood. Obviously, the invention of viable smaller paper-processing plants would be of great benefit.

Some African countries are already making a great number of uses of eucalypt wood, thereby considerably increasing the value added. A list of these products is given in Tables 10.5 and 10.6, which appear on page 276, showing the most important species utilized.

This chapter considers the many possible forms of utilization of the various species and includes a discussion of harvesting operations, methods of treatment and preservation of the wood for various purposes.

Harvesting: planning

Harvesting operations in eucalypt plantations have much in common with those in other forest plantations. However, there are some important differences. One of these is the coppice crop management, which represents today the most extended form of management in eucalypt plantations.

45. Plantation in the Mangoro Valley, Madagascar, probably of the local provenance 12ABL, 10 to 15 years old, with stacked fuelwood from thinnings
E. Maudoux

Suitable felling techniques have to be applied in order to obtain full stocking from coppice after clearcutting, without incurring the extra cost of replanting. Other differences are the characteristics of the bark and the weight of the wood as compared with coniferous species.

In most operations a high level of mechanization has not yet been introduced, and there are no data available on the performance of multi-purpose logging machines.

Before describing the different harvesting operations, some general guidelines will be briefly reviewed. These must be considered during the planning of harvesting operations as they influence individual and overall operations.

WORKING CONDITIONS

An evaluation of the working conditions is needed for the choice of the methods that will best suit these conditions. This evaluation should consider the following aspects: stand, tree and log characteristics; topography and terrain conditions; climate, annual distribution and amount of rainfall; accessibility.

Economic parameters

Cost of equipment and availability of capital are important considerations if a certain degree of mechanization is to be considered. Careful costing calculations have to be made to evaluate the different alternatives.

Employment questions

In some areas, employment in forestry may be the only means of earning an income. The local situation must be carefully considered in the selection of manual or mechanized methods. If unemployment exists, the first alternative should frequently be the preferred one.

Proper training programmes must be implemented early, to allow higher productivity and income levels. Work security and health measures should be given importance and proper clothing made available for the workers.

Time planning

Equipment to be purchased must be ordered well in advance, as delivery periods may be very long and sometimes overlap the planned starting of the harvesting operations. The road network for at least the first operating year must be completed in advance. Time planning may also be needed for individual operations. The felling season can have an effect on coppice regrowth if intense frost occurs in winter and loosens the bark from the stumps. Ease of debarking is also influenced by the period for which logs are left to season.

Harvesting: operations

Felling

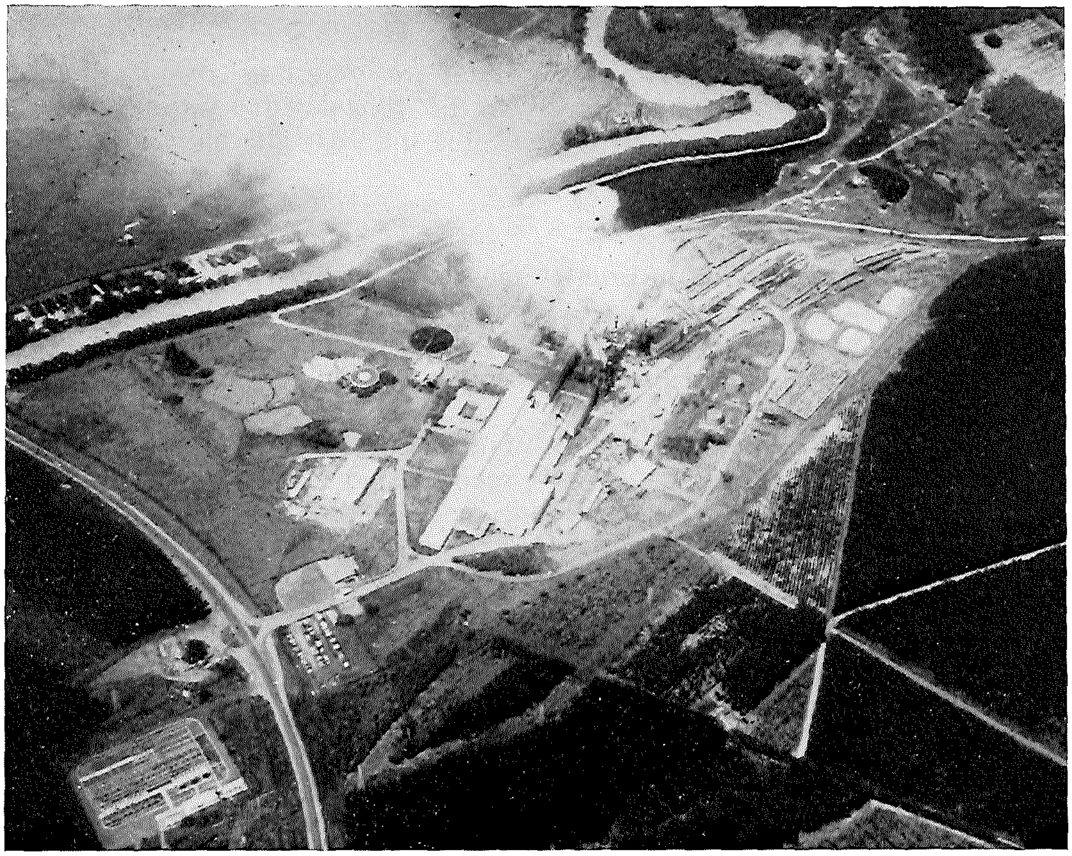
Eucalypt wood is harder than pine, so for felling and crosscutting it is recommended that the chain-saw selected should be more powerful. The following values can be used as a guide:

DBH (cm)	Engine capacity (cm^3)
10-30	50- 70
70-30	70- 90
70	90-125

Felling is the first link in the transport chain, so directional felling should be used to facilitate extraction. Bunching will increase efficiency of the extraction methods used. Directional felling will also mean less effort where manual skidding or forwarding[1] is practised, as the trees will be placed closer to the landings at roadside.

---

[1] "Forwarding" is used here for a method of moving logs from stump to roadside which involves carrying them clear of contact with the ground, as opposed to "skidding", in which at least one end of the log is in contact with the ground. It is not considered as including cable systems. "Forwarders" are machines specially designed for this purpose which incorporate a self-loading mechanism.



46. Industrial complex in north central São Paulo, Brazil, surrounded by plantations of *E. grandis*
L.D. Pryor

The felling can be organized by giving each crew parallel strips of 20 m. The felling can be done toward the centre of the strip where tops and branches can be piled up for burning or to avoid interference with the logging operations and coppice development. If the load-bearing capacity of the soil is low, the slash can be placed in the skidding trails. If possible, the crews should begin at opposite ends of the strips so as to reduce interference between them.

In well-managed stands of eucalypts, undergrowth rarely occurs. This condition, and the fact that hangups are rare allow a high productivity in felling. With diameters in the DBH range of 10-30 cm the production of a two-man chain-saw crew can vary between 500 and 300 trees per day. If the trees or logs are to be debarked, advantage should be taken of the fact that bark can be loosened in strips while the tree is standing. Cuts should be made around the tree above the final cutting level, and the bark pulled upward so as not to harm the stump bark. The silviculture and management aspects of felling are set out in Chapter 5.

TRIMMING AND TOPPING

Trimming does not involve a lot of working time as there are usually few thin branches on the commercial bole. Data obtained from Portugal indicate that, in stands with 1 100 trees per hectare, branches occur on 40-50 percent of the commercial bole. With 2 300 trees per hectare, branches occur on

10 percent of the commercial bole. Topping can easily be done with an axe or with a light chain-saw. As the axe is commonly used for trimming, these two operations can be combined.

Debarking

Bark removal will depend on the final industrial use of the wood. Some processes reject wood with bark still attached and, in these cases, debarking must be done before or after crosscutting, depending on the dimensions of the trees, and the suitability of the bark to be detached in strips. Posts have to be debarked before preservation. As mentioned above, debarking can be done in some cases while the tree is standing, by pulling the bark upward. Productivity in debarking by hand is influenced principally by felling season; species; age of trees; seasoning of the felled trees or logs. Sap-flow periods facilitate bark stripping; bark characteristics vary from species to species; age increases bark thickness and debarking difficulty; increase in time between felling and debarking causes the bark to adhere to the wood and stripping becomes more difficult.

Mechanical ring debarkers are difficult to use on account of the fibrous characteristic of the bark which delays the operation, as the bark must be removed by hand when it chokes the machine. Apart from the axe, other more specific hand tools can be used, such as the debarking spud and similar tools which can be locally manufactured. If the axe is used, debarking is combined with trimming. The production per man-day in trimming and debarking by axe ranges from 20-50 trees with a DBH of 20 cm to 60-100 trees with a DBH of 10 cm.

Crosscutting

Before crosscutting, the position of the cuts should be marked so as to obtain the best utilization of the tree length for production of different items, such as poles, different sawlog lengths and pulpwood. If only one type of product is required, the marking will be at constant lengths, as specified by the industry. Crosscutting can be performed before or after skidding, depending whether the short-wood or whole-stem logging system is used. Chain-saws, bow-saws or cross-cut saws are used.

Productivity is affected by the degree of seasoning of the wood. It can be 40 percent higher when logs are crosscut immediately after felling than when they have dried. Chain-saw production values for 2.4 m pulpwood logs with DBH from 10 to 20 cm range between 450 and 200 trees per man-day.

Skidding and forwarding

Transport from stump to roadside can be done by various methods, depending on the dimensions of the wood, employment situation, size of operations, capital availability to purchase costly equipment, terrain conditions and distance to roadside. All these conditions must be studied in order to select the best alternative. The various alternatives are as follows:

Manual. It is heavy work and can only be used with logs of small dimensions and over short distances. On slopes, gravity helps in sliding the logs downhill. In this case, skill is more important than effort. Newly barked logs slide down most easily. Hand tools like peaveys, pulp hooks and lifting tongs are very useful for downhill skidding. Productivity in manual forwarding of logs with an average weight of 25 kg ranges between 0.7 and 0.3 m^3 per effective working hour for distances of 30-90 m.

Animal power. Oxen, horses and mules can pull the logs to roadside by using chains, tongs or small trailers. Productivity decreases on uphill slopes. Over 10 percent, it is very low. The use of animals depends largely on local experience. Many improvements can be introduced and it can be an advantageous method from a cost and employment point of view.

Mechanical. In the case of small dimensions, agricultural tractors with winch attachments or small trailers can be used successfully. Tractors can travel in the inter-rows between stumps if the spacing is over 2.5 m, or over the stumps provided that the clearance is sufficient to avoid damage to the stumps. The recommended spacing of the skidding trails is 20 m on flat terrain. Concentration of logs toward these trails by manual work or with animals will increase loading productivity and reduce turn-around time. Loading of trailers can be done manually. Over a distance of 900 m, productivity can reach 3.5 m^3 per effective working hour.

When the total volume or the dimensions of the logs are too big for manual work or smaller equipment, skidders or forwarders should be used. Tree-length and full-tree skidding can damage the remaining stumps and impede coppicing. Forwarding is less damaging and should be preferred. There are many types of forwarders from a few tons up to 15-ton weight. A tractor and trailer with a hydraulic loader are the cheapest alternative, if terrain conditions are not difficult.

Mechanical loading increases productivity, as loading accounts for the largest proportion in working time over a normal skidding distance. The latest models of forwarders can work on very difficult terrain, but are not advisable on slopes of over 20 percent when loaded.

Production depends on the size of the forwarder, but can range from 10-16 m^3 per effective machine-hour over a distance of 500 m on easy terrain.

Cable systems. When steepness is over 50 percent, highlead and cable cranes are excellent methods of extracting wood to roadside from distances ranging from 100-1 000 m. The winches for pulling the loads can be independent or mounted on tractors or trucks for working over shorter distances.

Road transport

On flat, smooth terrain this operation can be combined with the transport to roadside, as smaller trucks can drive along the strips between the stumps. In difficult terrain conditions and when larger trucks with trailers are used, a road network must be planned and built. In the case of short rotations

47. *E. microtheca*, felled for fuel and poles, with coppice regeneration, Gezira, Sudan
L.D. Pryor

and successive thinnings the road network must be maintained periodically. The intensity of roading depends on road construction cost, skidding or forwarding cost, and transport cost. These factors must be combined so as to reach the overall minimum cost.

The loading system depends on the size of trees, employment situation and volume of wood to be handled. Hand loading a 12-ton truck can take 1.5 hours with a 4-man crew. Mechanical loading can be up to seven times faster.

The weight of wood decreases rapidly with time elapsed after felling. This lowers transport cost. Seasoning of logs in the forest may thus be an advantage, provided that the industry does not demand fresh wood and provided that there is no serious risk of insect attack or fungal decay. The weight decrease quoted in the *Handbook on eucalypt growing* (Wattle Research Institute, 1972) is shown in Table 10.1.

Table 10.1 Weight decrease with drying
(E. grandis)

Weeks after felling and barking	Timber weight
	kg/m³
0	925
1	833
2	783
3	748
4	724
6	692
8	675
10	666
12	656
Oven-dry	460

Seasoning PRINCIPLES OF DRYING AND SEASONING

Those who process or use eucalypt wood must understand the principles of the drying or seasoning of wood if they are to make a profit out of their enterprise. For detailed information readers are referred to published textbooks (e.g., Henderson, 1946; Boas, 1947; TRADA, 1962; Desch, 1968) and to technical bulletins published by the major forest products laboratories. Nevertheless a few basic facts must be included here.

Freshly felled eucalypt poles being debarked in a plantation or "green" eucalypt sawnwood leaving the sawbench usually have as much water as wood substance in them. That is, they have close to 100 percent water content by weight relative to their oven-dry weight. Wood is a hygroscopic material and it loses or gains moisture until it reaches an "equilibrium moisture content" relative to the humidity and temperature of the air round it. The equilibrium moisture content (EMC) is then maintained as long as the air humidity and temperature remain constant. The EMC of wood in the open air ("air-dry" wood) may vary from 12 percent in a fairly dry climate to 15 or 18 percent in a humid one. For wood used inside air-conditioned buildings the EMC may be between 5 and 9 percent.

Green timber, both in the round and sawn, must therefore lose moisture to the surrounding atmosphere, whether or not special measures are taken to control the process of drying. As the pieces lose water, they lose weight, but in the early stages of drying there is no shrinkage or change of shape. At "fibre saturation point" (25-30 percent moisture content) all free water and water vapour have been lost from the cell lumens, but the water intimately bound with the fibrils of the cell wall remains. Once drying proceeds beyond fibre saturation point, the pieces of wood start to shrink. They shrink very little along the longitudinal axis, more along the radial axis of the cross-section and still more in a direction tangential to the growth rings. The amount of shrinkage in volume can be considerable, e.g., 22.5 percent for *E. globulus* in California when dried from green (79 percent moisture content) to oven-dry (Henderson, 1946). The drying process continues, accompanied by loss of weight and shrinkage, until the wood reaches EMC.

The purpose of seasoning is to dry wood, as cheaply as possible and with the minimum degrade, to a moisture content which will be in equilibrium with the atmosphere in which it is to be used. The process of seasoning may be allowed to proceed slowly, as by careful air-drying, or it may be speeded up by the application of heat in a kiln.

AIR-SEASONING

The plantation owner producing massive quantities of short and long poles will normally use simple and safe methods to air-season these commodities. In places where termites and decay are not a serious problem, poles may be left debarked and lying on the ground between the rows of stools. Occasional rows of trees may be left standing to give shade to the poles, and branches may be placed over them to prevent too rapid drying from the direct rays of the sun. In one month they will have lost much of the free water in their cells and be much lighter to transport to a sorting yard where they can be systematically stacked. At that time the ends of the poles should be coated with a petroleum or tar-based product which will slow up end-drying and reduce splitting. Gang nails, clamps or wire, or boring out the ends may be used to reduce splitting also. Properly ventilated stacks, well raised off the ground, are essential. Drying under cover ensures less splitting than drying in the open and should be encouraged. Prophylactic spraying to prevent insect attack during drying is often required and may need to be repeated several times if attack is severe.

Short poles and posts may be air-dried in layered stacks with one layer at right angles to the next. This permits free circulation of air. In high rainfall areas, covering stacks or placing them in an open-sided drying shed speeds drying and prevents decay of sapwood.

If eucalypt sawnwood is to be air-dried, a well-designed yard should be laid out, cleared from weeds that hinder air flow. Foundations should be laid for the drying stacks, and in the stacks the sawn pieces should be placed layer by layer, each layer being separated from the next by slats 50 to 100 cm apart in accurate vertical alignment, and the top of the stack protected from rain and direct sunlight. A period of 4-6 months per 25-mm thickness of board may be required to air-season *E. grandis* and *E. saligna* (Stöhr, 1977).

Careful attention to drying is especially important if preservative treatment is to be applied. Poor drying is a frequent cause of poor results from preservation.

Kiln-seasoning

Application of heat in a kiln can shorten the process of drying from the months which are required for air-seasoning to a matter of days. The speed of drying reduces the risk of fungal or insect attack during the drying process. Drying can be continued until wood reaches a low moisture content (5-9 percent), which is suitable for interior use in buildings but which could never be attained by air-drying (minimum moisture content usually 12 percent or more). Speeding up the process of seasoning by applying heat requires expensive equipment, skill and supervision. The water being removed from wood must evaporate from its surface and then this surface moisture must be replaced by moisture from deeper in the wood. If the moisture from the surface is removed too quickly, the wood structure near the surface is modified and the interior water cannot get to the surface. A phenomenon called "case-hardening" of the surface develops and seasoning of the inner wood layers is seriously disrupted. Efficient control of temperature, humidity and air circulation is essential to ensure the minimum degrade during kiln-seasoning and the equipment needed for this control is expensive.

A great deal of progress has been made with seasoning kilns. There are many types and many schedules have been developed to suit different woods. The question of whether to air-dry or kiln-dry eucalypts, or to combine both methods, requires careful consideration by an owner and processor. If he air-dries he must prepare a larger storage yard which must be kept clean to be effective, and he must be prepared to carry much larger stocks. If he kiln-dries, he must have a large enough business to have a constant supply of steam for the kilns, constant power and, of course, constant skilled supervision. The possible need for reconditioning in eucalypts, which is discussed below, must also be considered when deciding on the best combination of methods to be used in the seasoning process.

Special problems

Many of the eucalypts present problems in seasoning. There is considerable variation among species. *E. deglupta* is one of the easiest of eucalypts to season and *E. grandis* and *E. saligna* are also fairly easy, while *E. globulus* and *E. fastigata* are among the more difficult species. Within a species, provenance, climatic and soil conditions, growth rate, age and position within the tree are likely to affect seasoning as well as other wood properties. Old trees are usually more difficult to season than young ones. For a minimum amount of defects during seasoning, a rotation length not exceeding 30 years is recommended for *E. grandis* plantations in South Africa and 25 years for *E. saligna*, which is somewhat more difficult to season (Stöhr, 1977). The thickness of sawnwood also has an important effect. Research is necessary in order to find out the seasoning methods best suited to local conditions. In general, eucalypt sawnwood of many species needs considerable care in seasoning if it is not to suffer an excessive amount of degrade. Particular attention must be paid to the phenomenon of collapse and the means of reducing it which are discussed below.

Collapse and reconditioning

Many eucalypts and most of those grown in plantations are liable to an excessive or irregular form of shrinkage during drying known as collapse. Collapse occurs above fibre saturation point when liquid is being removed by drying from the cells of the wood, and before normal drying shrinkage occurs. Collapse affects sawnwood mainly in thicknesses less than 7.5-8 cm. Roundwood and thick sawnwood are rarely affected. The radial and tangential faces of sawnwood are affected differently. On the radial or quarter-sawn face, collapse shows as a "washboard" or fluted surface which can be felt easily with the fingers. On the tangential or back-sawn face, it shows as heavy open checks with distortion of the surface as well. Since the washboard effect on quarter-sawn faces can be overcome by oversize sawing and later planing, and checking is not present, this form of sawing is preferred when collapse is a problem. However, as mentioned under sawing, it is not usually a practical option with small-diameter plantation logs. Fortunately severe face checking due to collapse on back-sawn faces is not usually encountered with boards 2.5 cm thick and less if air-seasoned carefully. The top of the stacks should be covered to avoid direct sun and the boards should be kept out of the sun before stacking, as face checking under direct sun is very rapid.

It was the discovery of the method of removing collapse by reconditioning which has permitted efficient drying of eucalypt timber in commercial quantities. Reconditioning involves steaming the stacked boards in saturated steam at atmospheric pressure in the drying kiln, or preferably in a special chamber called a reconditioner, for about 2 to 6 hours. Prolonged steaming should be avoided as it tends to increase checking. The shortest steaming time which allows satisfactory dimensional recovery is best. Not all collapse can be removed by steaming, but in practice around 90 percent can be. The recommended process for commercial drying of eucalypt plantation sawnwood 2.5-8 cm in thickness is to first air-dry it to about 22-26 percent moisture content, then recondition it by steam treatment which removes collapse and improves subsequent kiln-drying. After reconditioning it is kiln-dried using a mild schedule in about one or two days. It is usual to use a combination of air- and kiln-drying with reconditioning since the same steam plant serves for both the kiln and the reconditioner.

Combining air- and kiln-drying is also beneficial where eucalypts are sawn and air-seasoned for shipping dry-state and then sold and transported to urban centres for manufacture into furniture and parquet. In this case, reconditioning and kiln-seasoning are carried out advantageously at the secondary processing plant, eliminating the need for complex seasoning equipment at the plantation.

If partially and unevenly dried stock is reconditioned before kiln-drying, then further collapse of some boards will occur during kiln-drying. This kind of sawnwood should be first kiln-dried and then reconditioned. Likewise, if boards are kiln-dried green in one step, then one must recondition after kiln-drying. Careful control is necessary to kiln-dry eucalypts successfully without prior air-seasoning but, with subsequent reconditioning, it is quite feasible industrially. If reconditioning is carried out after final kiln-drying, it will raise the moisture content of the outer layers of the wood to about 16 percent. Excess moisture is removed usually by leaving the stock to stand some days before manufacture. A reconditioning chamber is much cheaper to construct and operate than a drying kiln, since expensive machinery for circulation of air and control of temperature is not required. Where the quantities of eucalypt wood to be seasoned do not justify use of kilns, there may be a case for careful air-seasoning to 12-15 percent followed by reconditioning. The steaming process should remove case-hardening effects as well as collapse.

Preservation

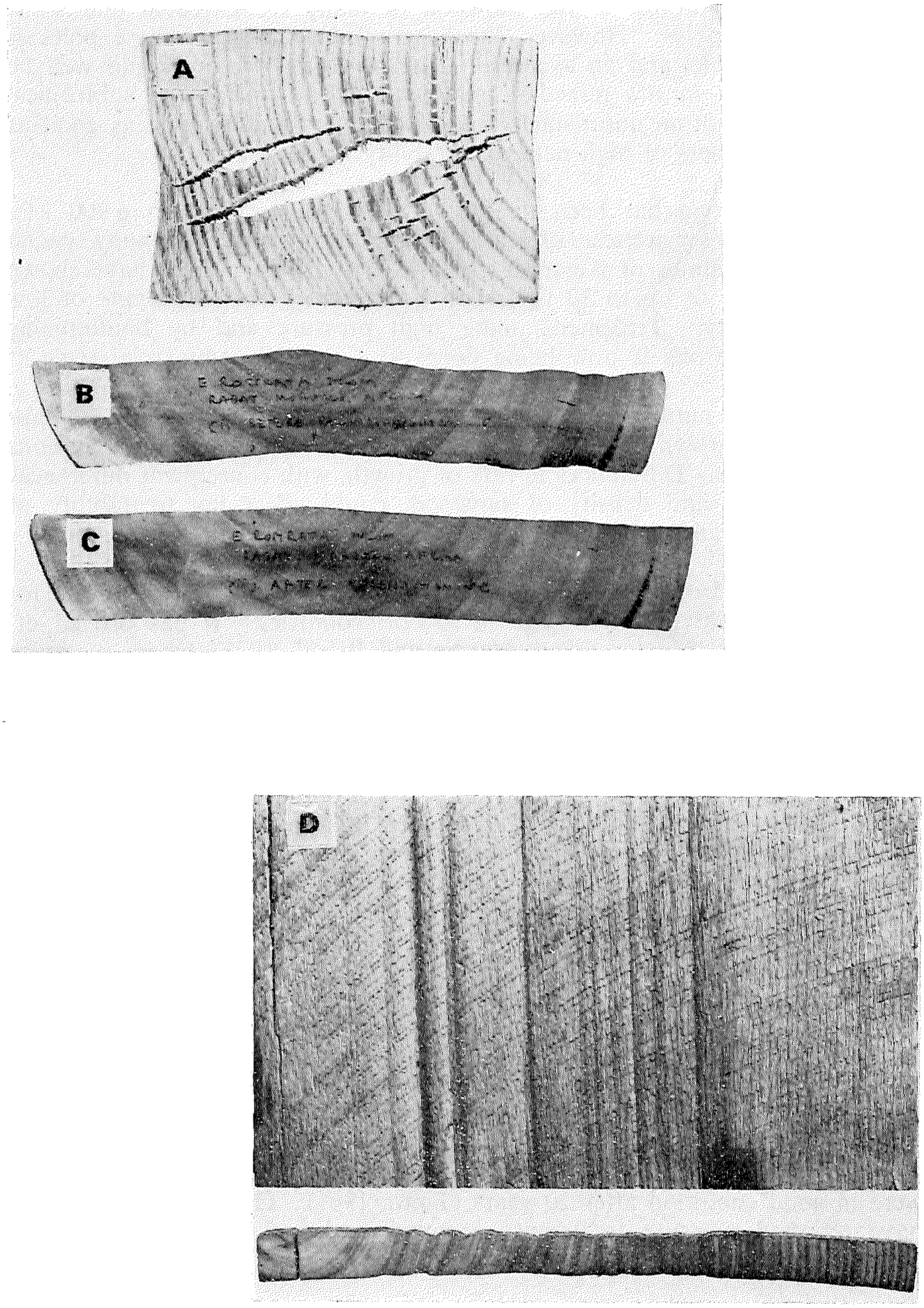
GENERAL [1]

In Australia tests of treated eucalypt poles set up in Victoria in 1934 showed that treatment of the sapwood with low-temperature coal-tar creosote, using both pressure and hot and cold bath treatments, has proved very effective in preventing termite attack and decay both in the sapwood and in the enclosed, untreated heartwood. Two thirds of the test poles are still in good condition after 40 years. These results have been matched by eucalypt saplings treated with creosote in Western Australia in 1929-30 and from other treated eucalypt pole tests in New South Wales (1936) and Victoria (1936). Commercial pressure treatment was started in 1957 in Victoria and New South Wales and since then over one million power and telephone poles of many species of eucalypt have been treated with either creosote or CCA (copper-chrome-arsenic) preservative, from tropical northern Queensland to cool, temperate Tasmania.

In the main these treatments are giving very satisfactory protection. In Victoria, Tasmania and New South Wales creosote-treated poles are standing up very well, although a small proportion of premature failures due to internal decay has occurred in some poles having low natural durability

---

[1] Most of the section on preservation was kindly contributed by F.A. Dale, Preservation Group, CSIRO, Highett, Australia.



48. A, internal checks caused by collapse in *E. regnans*; B, end section of *E. camaldulensis* distorted by collapse; C, similar adjacent section showing recovery after reconditioning treatment; D, washboard effect caused by collapse in *E. regnans*
Forest Products Laboratories, CSIRO, Melbourne

such as *E. obliqua*. In spite of this it appears that the minimum average life of 30 years expected from these poles will be obtained. In Queensland and northern New South Wales this life may not be obtained because of early attack by soft rot in the sapwood of many CCA-treated and some creosote-treated poles. However, the heartwood of most of these poles is moderately durable, and an average life of 20 years or more could well be obtained without *in situ* remedial treatment. For tropical and subtropical climates this is not an unsatisfactory service life, as it is at least as good as that of most timbers of high natural durability in these areas.

Eucalypt heartwood has been treated *at high pressure*, up to 6 900 kPa (1 000 lbf/in^2)[2], in service tests of nearly 5 000 railway sleepers of many species installed in five States of Australia from 1925 to 1961. These have shown that service lives of up to 30 years can be expected from eucalypts of low natural durability. Treatment under high pressure and by boultonizing with preservative oils is now being done on a limited commercial scale.

Experience with natural eucalypt trees in Australia is not necessarily applicable to fast-grown exotic eucalypt plantations grown on short rotations in other countries. Differences in rate of growth, with consequent differences in the thickness and density of sapwood, could effect the treatability of round eucalypts and their performance in service.

The hot and cold open-tank creosote process has been used successfully for impregnating eucalypt roundwood in several countries. It has proved efficient in Zambia (Mostyn, 1966; Hardie and Wood, 1973), where a service life of 25 years is predicted for *E. grandis* in ground contact. It is still commonly used in that country for fencing posts and building poles, but pressure treatment is now in common use for transmission poles. In Argentina the creosote hot and cold bath has been used in rural communities, but less commonly than partial immersion in waterborne salt solutions (Tinto, 1961). In Brazil hot and cold bath creosote treatment of *E. saligna* posts was effective provided that moisture content did not exceed 16%. Posts which absorbed about 100 kg/m^3 of creosote were still intact after 10 years (Ghilardi and Mainieri, 1961).

Pressure treatment of eucalypt roundwood has also been used successfully in a number of countries, most commonly with creosote. In South Africa the life of treated telephone poles was expected to be 20-30 years, provided that absorption of creosote was not less than 80-90 kg/m^3 (Scott, 1946). In Argentina *E. globulus, E. camaldulensis, E. saligna, E. tereticornis* and *E. viminalis* have been treated with creosote by the Rueping process (average retention, 70-80 kg/m^3) and with waterborne salts by the Bethell process (average retention of dry salt 6-7 kg/m^3). The earliest creosote-treated posts were in good condition after 20 years (Tinto, 1961). Other countries which have reported pressure treatment of roundwood include Spain, Portugal, Malawi and Zambia.

---

[2] Units of pressure: kPa = kiloPascals; lbf/in^2 = pound-force per square inch (1 kPa = 0.01 k/cm^2 = 0.145 lbf/in^2).

Common experience is that, while eucalypt sapwood is comparatively easy to treat, the heartwood cannot be impregnated at normal pressures. It is also subject to attack, especially by termites.

A number of treatment processes other than the well-known pressure and hot and cold bath methods are described here because of the need for simple treatments, particularly in the developing countries. These processes may not work with all eucalypts in every situation but they must be considered in any proposals for treatment, particularly in places where skilled labour or spare parts for conventional plant are difficult to obtain.

Hazards

The main aim of round-timber preservation is to prevent biological attack in both heartwood and sapwood by treatment of the latter. Attack can be separated into these categories:

- External rot, or decay due to common wood-destroying fungi (basidiomycetes) at or below ground level.
- Soft rot, due to micro-fungi (ascomycetes) at or below ground line.
- Subterranean termites, below or above ground level.
- Other insects, including dry-wood termites, usually above ground level.
- Internal decay, concealed fungal decay, at any level but usually at or below ground line.

The relative importance of these will vary with location and type of timber. Treatment of round timber to overcome these hazards has to be more effective as the sapwood thickness decreases for two reasons: the strength of round timber depends on the soundness of the treated sapwood if the untreated heartwood fails; and the treated sapwood provides the only protection against attack in the untreated heart.

Sawn eucalypts usually require protection against weathering and mechanical breakdown as well as protection against biological attack. Railway sleepers (ties) are a major example, as in their case end-splitting, rail-cut and loss of grip of the fastenings are generally the main causes of failure, but decay can be a major cause in dirt ballast, especially in the wet tropics. Even termites can be a hazard. Timbers of smaller cross-section are mostly dried to equilibrium moisture content before exposure for such uses as exterior joinery and weatherboards.

Mode of penetration

Eucalyptus sapwood can only be penetrated along the vessels from a cross-cut surface or incisions or physical breaks in the vessels. With lighter eucalypts (e.g., *E. regnans*) limited radial penetration under pressure can take place from the cambial surface to a depth of perhaps 3-5 mm, otherwise all penetration is along the vessels. The amount of wood substance that is penetrated around and between the vessels then depends on many factors, such as wood density, moisture content, type of liquid (oil or water), viscosity, temperature and pressure. Ideally all the wood substance between the vessels should be penetrated but this is generally only possible with the lightest eucalypts using liquids of low viscosity and surface tension.

Spotted gum (*E. maculata*) with an air-density of 990 kg/m³ is a eucalypt commonly treated as a pole in Australia and in this species it is very difficult to obtain a retention of creosote in the sapwood of more than 192 kg/m³ because penetration beyond the walls of the vessels is very limited. With waterborne preservatives the liquid retention can be raised to about 350 kg/m³ but complete penetration of the wood substance of such timbers with toxic materials can only be obtained by diffusion which has limitations to be discussed later.

Penetration of sawn eucalypt *heartwood* is important in relation to the treatment of structural timbers such as railway sleepers (cross-ties). Here again penetration can only be obtained through the vessels, but special techniques such as high pressure treatment (pressures of 35-70 kg/cm²) are usually required, because of obstructions which collect in the vessels as the heartwood is formed. In lighter species good penetration (up to 1 000 mm) from the exposed end grain can be obtained but in species with air-dry densities of 800 kg/m³ or more, incising of the other surfaces is virtually essential if an outer case or envelope of uniformly treated wood is to be obtained. "Boultonizing," or heating in preservative oil under vacuum, is now being used for the treatment of incised, green eucalypt sleepers in Australia with considerable success, but a great deal has yet to be learned about the process.

Acceptable preservatives

Of the many preservatives that have been used only a few are suitable for large-scale treatment of eucalypts. Acceptable preservatives are as follows:

Preservative oils and oil-soluble preservatives

(*a*) Creosote oil

A distillation produced from coal tar, nowadays mostly produced from coke-oven tar and commonly called high temperature creosote (HTC). It has a long reputation of satisfactory protection against biological attack and the effects of weathering. It is viscous at low temperatures and is usually heated to at least 70°C for treatment. Creosote-treated wood is moderately water repellent but can cause skin irritation. It may be used alone, or combined with mineral oils such as furnace oil or diesel fuel (to increase water repellency and reduce cost) and it can be easily fortified with other fungicides or with insecticides such as dieldrin for areas of very high termite hazard.

(*b*) Pentachlorphenol

This is a highly toxic, stable compound which can be dissolved in a range of mineral oils and organic solvents. Heavy oils such as furnace oil are preferred for permanence in the ground but lighter coloured, less viscous oils or volatile solvents may be used where clean or paintable treatments are required. "Penta" or PCP, as it is commonly known, may need fortifying for maximum protection against some insects, particularly termites.

Creosote and pentachlorphenol in oil are generally accepted as being equally effective but each has certain specific advantages. Creosote is often cheaper, has proven fire resistance and does not require any special equipment for mixing. Pentachlorphenol on the other hand can be dissolved in a range of oils and may be cheaper in a country producing its own oil. It may also prove to be more effective against soft rot.

(*c*) Chlorinated hydrocarbon insecticides

These compounds such as aldrin, dieldrin, lindane and heptachlor are often used in small amounts in preservative oils to reinforce their resistance to insect attack, particularly that of termites.

Waterborne preservatives

All these are used in acqueous solutions, but the term "water soluble" is deliberately not used because some of them "fix" or become insoluble after the wood is treated.

(*a*) Diffusion preservatives

These include borax (sodium borate), sodium fluoride and arsenical compounds used either singly, to prevent specific attack by insects such as *Lyctus* borers, or in combination to prevent insect attack and decay in building timbers.

(*b*) Fixed waterborne preservatives

These consist of two or more inorganic compounds which form a stable solution used to impregnate the sapwood of round timbers. Once they are in the wood the components react to form insoluble compounds which cannot be easily extracted. The best known are the copper-chrome-arsenic or CCA preservatives. The degree of fixation varies with the timber being treated. In softwoods (conifers) which are penetrated radially, as much as 97 percent of the preservative stays in the wood after prolonged exposure in service. In eucalypts, preservative may not move far from the vessels and the figure may be considerably less.

Fixed waterborne preservatives such as CCA give no protection against the mechanical effects of weathering, although they improve the life of paint and clear finishes. They are clean and non-irritant and timber treated with them is non-toxic and, when dried after treatment, safe to handle. Waterborne preservatives can be produced as dry powders or concentrated, readily soluble pastes, so that they can be transported long distances at much less cost than the equivalent volume of preservative oil. They can be used with timbers at moisture contents approaching fibre saturation (25-30 percent) or higher and can be readily applied, without heat, by simple pressure and non-pressure methods.

Apart from their susceptibility to soft rot in certain situations, discussed elsewhere, CCA-treated eucalypts have been criticized because of their tendency to continue to glow once ignited and their reputed low electrical resistance and danger to linesmen in wet weather. In fact very few CCA-treated poles have been lost by fire, because they require a severe fire to ignite them. They have also proved safer than green untreated poles in Queensland, where they have been put into service immediately after treatment, without being allowed to dry out for a reasonable period.

The choice between preservative oils and waterborne preservatives is generally a matter of economics. The waterbornes are mostly cheaper and easier to apply to a wider range of timbers, but creosote and PCP in oil have distinct advantages, particularly in reducing splitting and weathering.

Treatment processes

The treatments listed are all applicable to eucalypt sapwood for particular purposes. They are: diffusion; sap replacement; sap displacement; hot and cold bath; low pressure treatment; standard pressure treatment; variations of pressure treatment; boultonizing. For more detailed information on treatments, readers should refer to standard textbooks such as Hunt and Garrat's *Wood preservation*, Nicholas' *Wood deterioration and its prevention by preservative treatment*, Cartwright and Findlay's *Decay of timber and its prevention*, and technical papers by various forest products laboratories.

Diffusion is used in Australia almost entirely for the immunization of *Lyctus*-susceptible sapwood of eucalypts and rain-forest timbers. The basic process involves the movement of salts as ions through wet wood, usually those of boron or fluorine. Pressure treatment and the hot and cold bath are also commonly employed for sapwood which may have partially dried, in order to saturate the sapwood and speed up the process. Heating by itself accelerates the rate of diffusion. Borax diffusion for treatment of *E. globulus* and *E. viminalis* sapwood has been used in Argentina (Santoro and Labate, 1961).

Other toxic elements, such as arsenic, may be used to make timber resistant to termites and the other insects, and the process is widely used in its simplest form, that of dip-diffusion, for the treatment of sawntimber, both heartwood and sapwood, in Papua New Guinea, using a boron-fluorine-chromium-arsenic preservative, developed by CSIRO for house framing and joinery timbers.

Because the chemicals used remain water soluble these treatments are not suitable for timber used in the ground or exposed without protection from weather, nor can the CCA preservatives be used for diffusion treatment because they "fix" too rapidly in the wood. It is to be hoped that slow-fixing diffusible preservatives will eventually be developed to overcome these objections.

The various diffusion processes are attractive because of their simplicity, low cost, versatility and above all their ability to give limited protection to a very wide range of timbers using the same basic techniques.

Sap replacement. This process relies on the upward movement of water or "sap" which takes place in the sapwood of the growing tree. A tree is cut, the bark removed and the bottom end of the post or trunk put in a vessel containing aqueous preservative solution before the water column in the capillaries is broken. The solution, usually of CCA, is drawn up to replace the sap as it evaporates from the exposed surface of the trunk. Leaving a greater length of trunk than is finally required should increase the flow rate. The timber is left in the bucket or trough until at least three quarters of the solution needed for adequate treatment has been drawn up, when the other end is put in the bucket and left there until the solution is all used up. This treatment of both ends is possible because the flow can be reversed in the vessels provided the liquid column remains unbroken. A plastic cover tied around the log and the bucket is needed to prevent evaporation of the solution or dilution by rainwater. Maximum evaporation from the sides of the post or trunk is essential for success. Only one row of posts should be exposed, preferably in a windy site.

In countries where labour is cheap and money for equipment is scarce, this process can effectively convert otherwise useless round timber into fence-posts and small poles, but it requires careful supervision and regular examination of the penetration being obtained. The operation must be protected from children and animals to prevent accidental poisoning. It is not as reliable as pressure or hot and cold bath treatment, so that it would be unwise to use it to treat round timber for sale unless the results are consistently good (as the more reliable treatments are).

Sap displacement. This process was invented by Boucherie in France in 1839. The application of aqueous preservative solution under pressure to the bottom end of a green pole, thereby forcing the sap out of the sapwood and replacing it with preservative, is very attractive and has led to the development of pressure caps, designed to fit over the end of the pole and deliver the solution to it without leaking. When treating hardwoods by sap displacement it is vital that *all* the vessels in the sapwood at the cut end be exposed to the solution under pressure and that the outer surface is not damaged by axe cuts, screws or clamps which can block off vessels, causing untreated streaks in the outer sapwood.

Although the process is simple, it may be difficult to treat each pole adequately without overtreating some. Mixed species and sizes will require different concentrations and amounts of solution respectively. Ideally each pole should be treated until the effluent has the same concentration (determined by measuring specific gravity rather than colour) as the treating solution. Alternatively each pole of a given species and length can be treated with a certain concentration for a period determined by trial. A reasonably practical system of quality control must lie somewhere between these extremes. Neither this method nor the previous one is suitable for use with preservative *oils*

Hot and cold bath. This very simple and effective method has been used with creosote and other preservative oils for generations and deserves more consideration for eucalypts. Dry round timber is treated in oil, in steam, or even in boiling water before being allowed to cool in the oil, which replaces the air expelled from the sapwood. Prolonged heating at 100°C will help to dry partly dried sapwood and so improve penetration and retention.

Where fuel is cheap and the cost of creosote or other oil is not too high, it is an attractive method of treatment, particularly so because full treatment can be confined to the high-risk zone at the bottom of the pole. The part above ground can be protected, primarily against insect attack, by soaking in hot preservative, followed by limited cooling so that a lower retention is obtained.

The main objection to the process is that light permeable timbers can be overtreated. It also tends to give a tarry surface, particularly if the oil is not desludged from time to time. Both these defects can be partly overcome by reheating after cooling, to the original treating temperature or even higher, before removing the poles from the bath. This expels excess preservative and helps to give a clean treatment.

Low pressure treatment. A mobile plant for treating with cold preservative at low pressure, up to 345 kPa (3.5 kg/cm^2), was developed in 1954 by the CSIRO Division of Forest Products for the treatment of round eucalypt fenceposts with CCA salts or creosote oil suitably diluted with light tar oil to allow its use with heating. While treatment with the latter was only successful in the lighter species, treatment with CCA proved quite successful. The only improvement found desirable for low pressure treatment was the fitting of a simple vacuum pump of the type used for milking machines, to prevent excessive "drip" after treatment and facilitate filling the cylinder. As the plants need to withstand only 345 kPa hydraulic pressure they can be made of thin steel plate and the door seal can be very simple. Their great advantage is that they can be completely mobile or can be loaded on a light truck with the storage tank inside the cylinder.

Their main disadvantage is that, like any machinery, they must be properly maintained and the moving parts protected from the weather. It is also essential that they be delivered with all the spare parts needed for normal maintenance, otherwise they can lie idle for months waiting for a washer or a seal.

One of the most vulnerable and expensive parts of a low pressure plant is the engine needed to drive the pumps. If vacuum is not used, this pressure can be applied by a hand pump with a deadweight hydraulic accumulator.

The simplest arrangement of all is to have a small tank elevated 20-30 metres above the cylinder and connected to it by a pressure hose. If a steeply sloping site is available, this elevated tank can be used as the mixing tank. It will only need to hold "make-up" solution, while the preservative needed to fill the cylinder can be stored in a working tank alongside the cylinder.

STANDARD PRESSURE TREATMENTS

Full-cell treatment. The Bethell, or "full-cell," process aims to remove most of the free air from dry sapwood by means of an initial vacuum, before saturating it with liquid under pressures up to 1 380 kPa (14 kg/cm^2). It is used for the great bulk of treatment with waterborne solutions to ensure maximum penetration of solution in a minimum time. The final vacuum removes only a small part of the total absorption so that the sapwood contains as much water or more than in the green tree. This water can double the weight of small round timbers, making them costly to transport. At least partial air-drying after treatment is therefore desirable, while full drying is essential for sawntimber in many applications.

Full-cell treatment using preservative oils is called for when treating heavy hardwoods such as spotted gum (*E. maculata*) which may not otherwise accept enough preservative to give adequate protection when very heavy loadings are required for protection against marine-borers; or when the utmost possible protection is needed for round timbers in the ground, e.g., for house supports or high-tension power poles where premature failure would be very costly.

The use of a high initial vacuum is desirable in any full-cell treatment with CCA preservatives, to ensure maximum penetration and minimum "drip" after treatment. A system devised by Cokley and Smith (1965) uses an initial vacuum approaching 750 mm of mercury (i.e., less than 5 kPa absolute pressure) for about an hour. This is maintained while the charge is flooded and for another hour before applying pressure in the usual way. The method is claimed to give improved penetration in the sapwood of heavy eucalypts and allows their treatment at moisture contents up to 40 percent within a month of felling, before the sapwood can be damaged by insects or decay, which can commonly occur in normal air-drying in the tropics.

Empty-cell treatments. These aim to purge the cells or voids of liquid in the wood at the end of treatment, while leaving the cell walls or fibrous tissue saturated with preservatives. The main reason for their use is economy, because lighter, more permeable timbers can be overtreated with preservative oils if full-cell treatment is used. Lower treating pressures, shorter pressure periods and lower temperatures will reduce final preservative retentions, but they will not ensure uniform penetration and minimum "scatter" or variation in retention between different pieces in one cylinder charge.

The simplest empty-cell treatment is the Lowry method, in which the cylinder is filled with liquid at atmospheric pressure, the free air being allowed to escape from the cylinder as it fills, while the air in the wood is trapped and compressed as the liquid is put under pressure. During the final vacuum this air escapes and purges the cells. The Lowry treatment is used in treating light, permeable hardwoods with oil and sometimes in treating permeable timbers with CCA to reduce their final weight and to cut drying times after treatment.

The Rueping treatment, in which compressed air at up to half the treating pressure is used to fill the cylinder before pumping in liquid, is used to treat very permeable timbers with oils but not with waterborne preservatives. The plant for Rueping treatment is considerably more expensive and the process is longer and more costly than the simpler pressure treatments.

The use of higher pressures than 1 380 kPa (14 kg/cm^2) can substantially improve penetration in the *heartwood* of medium and low density eucalypts. It is very likely that penetration in the sapwood of heavy, refractory eucalypts could be greatly improved by treatment at pressures up to 3 450 kPa (35 kg/cm^2). The design of plant to suit these pressures is not a major problem and the extra cost might well be recouped by using it to treat a wider range of round and sawn eucalypts.

Boultonizing. This process for the treatment of green timber consists of heating it for up to 24 hours in preservative oil, usually creosote, at 100°C or more while the vacuum is applied. Because the boiling point of water falls as the absolute pressure is lowered this results in rapid drying without serious degrade. Drying is then followed immediately by the standard pressure treatment. Boultonizing has been used successfully with round eucalypts. It could have potential for treating plantation eucalypts where normal air-drying takes too long and requires excessive capital or where attack by decay and insects during drying may be inevitable. It has also been used in the Hager process, in which poles are boultonized in mineral oil or creosote immediately after pressure treatment with CCA. This could be useful where double treatment for extra protection is required, e.g., in marine piles.

Preparation for treatment

The best preservatives and the most reliable methods of treatment will be less than 100 percent effective if *round* timber is not properly prepared for treatment.

Bark removal must be complete. The only exception is timber to be treated by sap displacement. Leaving the bark on encourages insect attack and slows drying, so that debarking should be done as soon as possible after felling.

Proper drying is vital if oil treatment is to be used. Probably more poor treatment results from imperfectly dried sapwood than from any other cause: in South Africa eucalypt poles are air-dried until a maximum average moisture content of 25 percent is obtained in the outer 75 mm of the pole to ensure full development of barrel or surface checks and maximum retention in the sapwood when treated with creosote. Checks and splits which form *after* treatment can provide access for both fungal and termite attack in the untreated heartwood in service. Methods designed to reduce end-splitting are described above under seasoning. Where it cannot be controlled, extra length must be allowed for cutting off split ends before treatment. The use of properly fitted galvanized iron or aluminium caps on poles *after* treatment will reduce subsequent top-splitting and also the risk of internal decay.

Good housekeeping is the mark of an efficient treatment plant. Proper drainage, labelling of pole stacks, weed removal and planned layout are all part of the process.

Preservative retention

Any proposals for the preservative treatment of eucalypts, particularly round eucalypts, should pay particular attention to preservative retention. Expe-

Table 10.2 Retention in treated eucalypt sapwood in kg/m^3 ($16\ kg/m^3 = 1\ lb/cu.\ ft$)

Preservative	Hazard			
	Item	Normal	Severe	Very severe (wet tropical)
Creosote	Posts	128	170	225
	Poles	192	262	290-320
PCP	Poles	8	11	14-16
CCA	Posts	12	16	20
	Poles	20	25	30 or more

rience over more than 10 years in Australia has shown that treatment to a minimum charge retention of around 240 kg/m^3 of creosote is desirable to ensure that few if any poles in the charge have retentions less than 144 kg/m^3. This extra protection is cheap insurance against premature failure of odd poles when the total cost of a pole in place and its probable cost of replacement are considered.

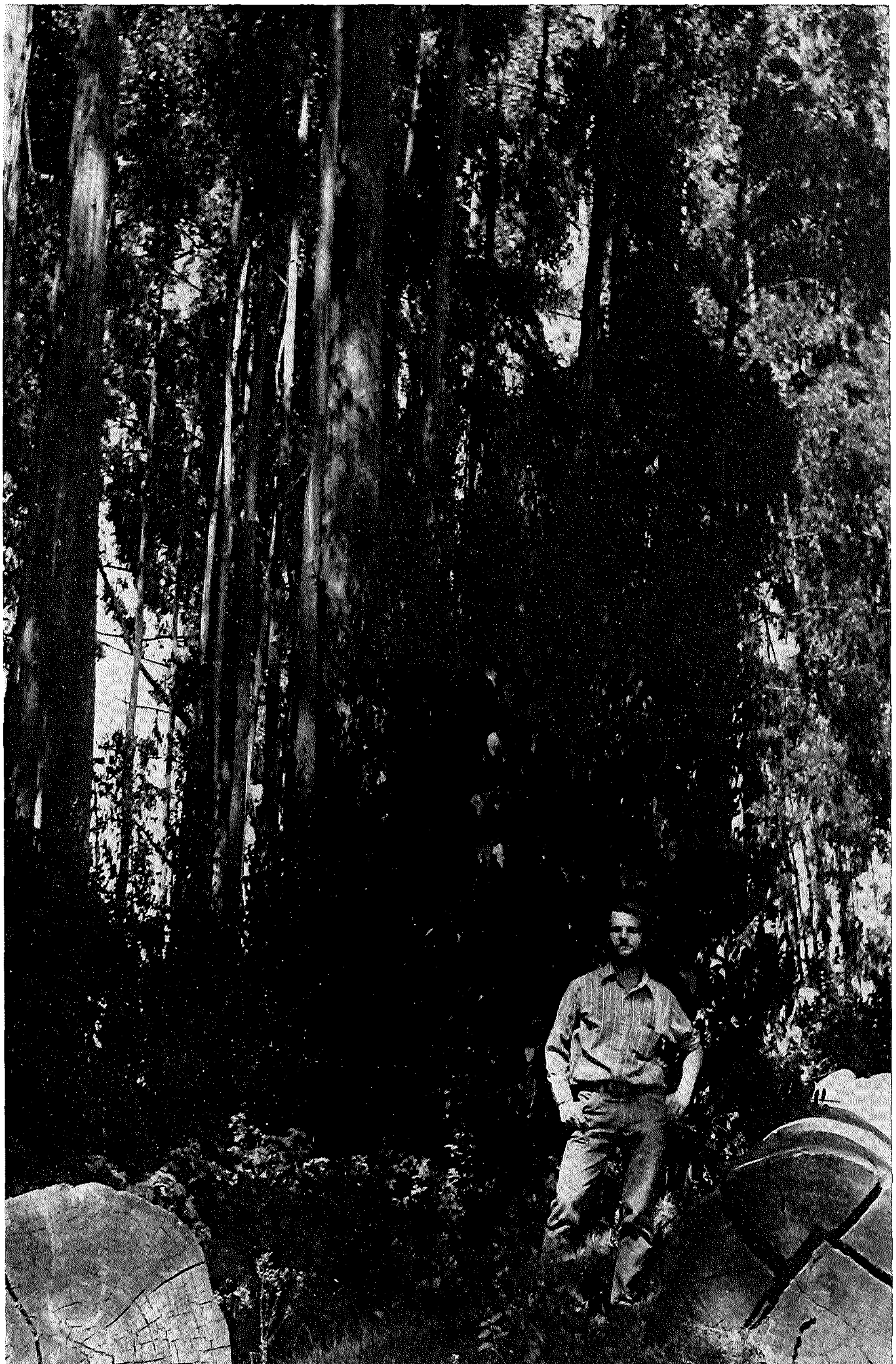
It is now generally agreed that retentions adequate for conifers are inadequate for hardwoods, particularly as the severity of hazard increases. Table 10.2 gives *suggested* retention to allow for this.

Because of the variations that can occur in sapwood retention along the length and around the circumference of a single pole, quality control by analysis of plugs taken from a few poles is far inferior to weighing a certain number (say 5 percent) of poles in each charge before and after treatment, or all the poles in every twentieth charge. Pressure treatment should be carried to refusal, i.e., until the amount of preservative absorbed in the preceding 15 minutes is less than 1 percent of the total absorbed up to that time. Timbers of different sizes, species and moisture contents should not be treated in the same charge. Concentration of the preservative can then be adjusted to the type of material being treated, so as to facilitate adequate and uniform retention after treatment to refusal.

These recommendations can be readily applied to pressure and hot and cold bath treatments. Control of retention and penetration in other types such as boultonizing and sap displacement is more difficult, and simple, reliable methods have yet to be devised. Above all the operators must be prepared to take numerous samples to check penetration.

Treatability of various species

Table 10.3 was compiled after discussions with the operators of treatment plant throughout Australia. The ratings are based on the treatment of natural round poles with creosote, supplemented with information from plant using CCA waterborne solutions. In general the ratings for both types



49. *E. regnans* at south Kinangop, Kenya. Splitting in felling or in drying in the open may be severe, but tests have shown that timber from this plot makes excellent joinery and plywood
W.G. Dyson

Table 10.3 Treatability of round eucalypts based on Australian experience

Category	Species
Very easy to treat	*E. regnans* *E. delegatensis*
Treatable to 240 kg/m^3 of oil in the sapwood, or sometimes more	*E. sieberi, E. obliqua, E. pilularis* *E. grandis, E. marginata, E. diversicolor* *E. patens, E. calophylla, E. cladocalyx* *E. saligna, E. viminalis, E. eugenioides* *E. muellerana*
Treatable to 192 kg/m^3 of oil in the sapwood	*E. hemiphloia, E. cypellocarpa* *E. sideroxylon, E. globulus* *E. tereticornis, E. microcorys* *E. gummifera, E. resinifera, E. propinqua*
Treatable with difficulty to 160 kg/m^3 of oil in the sapwood	*E. maculata* [1] *E. macrorhyncha* *E. paniculata*

[1] Note: **E. maculata** sapwood must be fully dried for oil treatment but can be treated with CCA solutions using high-vacuum technique at 35-40% moisture content.

of preservatives agree fairly well, but treatment with waterborne solutions is less difficult and solution concentrations can always be increased for the more refractory species. Treatability is roughly related to air-dry density, with a few exceptions, such as *E. sideroxylon.* As the sapwood widths of plantation eucalypts are generally greater, and wood densities less, than in natural eucalypts in Australia, plantation eucalypts should be easier to treat.

The treatability of eucalypt heartwood, as sawn timber, generally follows the same pattern as that of sapwood, i.e., the heavier the timber the harder it is to penetrate. Higher treatment pressures than normal will give acceptable penetrations in low and medium density eucalypts, but excessive pressure and temperature can cause crushing and collapse in the lighter ones.

Choice of treatment

As a rough guide to the reader, Table 10.4 sets out treatment method and type of preservative most suited for each end-use. Where two or more methods or preservatives are shown, the choice must depend on factors such as class of labour available, life required, size of market and cost of preservative.

Uses for energy

Changing attitudes

During the last twenty-five years the world has seen changes that have sometimes moved full circle in the attitude to wood as a fuel. Its use has created hostility among pollution-oriented conservation groups in urban communities because it produced smoke. Pure-air acts were passed in several countries, and have served many useful purposes. Nevertheless, poor, cold and hungry people tend to ignore pure-air acts, and few governments would enforce them against this section of their population. There

Table 10.4 Choice of treatment

Treatment method	Preservative	Commodity					
		Round timbers: Fence-posts	Round timbers: House supports	Round timbers: Transmission poles	Rail sleepers	Sawn building timbers (structural)	Cladding and exterior timbers
Sap replacement	CCA	*	Limited	Limited	—	—	—
Sap displacement	CCA	Limited	*	*	—	—	—
Diffusion	Diffusing compounds	—	—	—	—	*	Limited
Low pressure	CCA	*	Limited	Limited	—	—	—
Standard pressure	CCA	*	*	*	—	*	Limited
Standard pressure	Oils	*	*	*	—	—	Limited
Standard pressure	Diffusing compounds	—	—	—	—	*	*
High pressure	Oils	—	Limited	Limited	*	—	Limited
High pressure	CCA	—	Limited	*	—	—	Limited
Boultonizing	Oils	—	—	*	*	—	—
Hot and cold bath	Diffusing compounds	—	—	—	—	*	Limited
	Oils	*	*	*	—	—	—

Note: * Suitable; — not recommended.

have been movements toward the replacement of wood as a fuel by electricity or oil. The movement toward the use of oil fuels showed great promise in the 1960s. Oil-derived household fuels were convenient, efficient, easily transported and they promised to be cheap. Then came a sudden change in oil prices and wood again became acceptable in many places. Eucalypt plantations and other forest resources can supply a substantial part of the household fuel needed in middle and low latitudes through the efforts of communities themselves. In fact, they are sometimes most needed in poor districts in oil-rich countries.

The oil crisis of 1973 led to many studies on alternative forms of energy, one of these, *Beyond petroleum*, was published by Stanford University in 1975. Among other sources of energy the potential of growing eucalypts for fuel was studied and the conclusion reached that a potential to use eucalypt wood fuel to make electricity or other "piped" industrial fuel was a real possibility in suitable frost-free localities. The estimated costs were higher than present coal-fed generating systems, but lower than expected nuclear-fed costs.

FUELWOOD

Several country reports stressed the fact that eucalypts were first introduced into their countries to supplement fuelwood supplies. All reports would agree that they fulfilled that function very well during the earlier years of their introduction.

Short coppice rotations are a simple and effective method of producing fuelwood. There is a large amount of raw material produced per hectare on a seedling or coppice rotation of eight years. The volume per hectare might vary from a low figure of 50 m^3 in eight years on poor sites in savanna woodland country to 150 m^3 on good soils in regions of good rainfall. With the most simple implements, axes or machetes, the crop can be harvested and stacked with a minimum of investment in harvesting equipment. If the crop is required as fuelwood, it may be transported from the stump by hand or on shoulders or head by the people who wish to use it. This method may not be efficient in a mechanical sense but in many countries it may add significantly to the real standard of living of the people needing the fuel.

Wood may be transported green or air-dried. Air-dried, it is a much better fuel and weighs less than when green. The principal eucalypts grown for fuelwood (*E. camaldulensis, E. tereticornis, E. globulus, E. grandis* and *E. saligna*) weigh between 900 and 1 200 kg per m^3 when green and lose half of their moisture by air-drying for eight weeks in an average dry season. This lowers their weight by one third and leaves the wood a good fuel.

Plantation eucalypts vary a great deal in green or dry weight per m^3, but their calorific value per kg of dry fuel does not vary a great deal, having a low value of 19 700 kilojoules (4 700 kilocalories) up to 21 000 kilojoules (4 800 kilocalories) per kg for heavier species such as *E. paniculata.* The lighter species dry out more quickly than the heavier ones.

In addition to variation between species, the density and hence the heating value per m^3 of wood may vary considerably with the age of the tree and with growth conditions. Table 10.6 shows the comparative density of some of the more important eucalypt species in natural forest in Australia and in plantations in Africa (Bolza and Keating, 1972). Wood density at 12 percent moisture content was higher in Australian natural forest in 20 out of the 30 species; in five species there was no difference, while in five others the African plantation eucalypts had a higher density. As an example of the effect of age on density, *E. saligna* aged 9-11 years had an air-dry density of 500 kg/m³, while 34-year-old trees of the same species had a density of 750 kg/m³ (Banks, 1954).

The wood of most eucalypts burns well when air-dried and leaves little ash. There is not much difference between the species which make up the greater part of the plantations of the world. Within Australia the heavier species such as the ironbarks and the boxes are preferred. Of these, *E. paniculata* is the main plantation species planted outside Australia.

CHARCOAL

Eucalypt wood easily makes good strong commercial charcoal. By the usual carbonizing methods there is a substantial loss of heat energy mainly in the off-gases amounting to about two thirds of the heat energy content of the original wood. But though wasteful energy-wise, charcoal is worthwhile for the following reasons:

- It has about twice the calorific value of air-dry wood, weight for weight, making it easier to transport. (Charcoal has 28 000 kilojoules per kg compared to about 16 000 kilojoules per kg for air-dried eucalypt wood at 20 percent moisture content).

- It keeps indefinitely without deterioration, simplifying marketing and storage in the domestic fuel distribution chain.

- It can be burned without smoke at about 25 percent efficiency in very simple stoves. (But in a poorly ventilated room there is a real danger of lethal poisoning from carbon monoxide fumes.)

- It is a useful source of high-purity reactive carbon for metallurgy and chemical processes where wood itself would not be suitable.

Therefore, while preference should always be given to burning dry eucalypt wood in suitable stoves for domestic and light industrial heating, there are sufficient advantages for charcoal in certain situations to ensure a continuing market for it.

Where charcoal is made industrially using continuous methods on a large scale, by either hot rinsing gas shaft furnaces (Lambiotte) or rotary hearth furnaces (Herreshoff), and the off-gases are collected and burned to produce steam and then electric power, the overall thermal efficiency of the process is quite high in contrast to the 15-30% efficiency of all kiln and pit burning methods. Large capital investment and good organization, however, are needed for success with continuous charcoal furnaces but they should always be considered wherever there is a continuous need for charcoal in large quantities and a need for power.

In Argentina, Australia and particularly in Brazil, there are important iron smelting industries based on charcoal derived from eucalypt wood. Rising coal costs are making the charcoal iron industry more closely competitive, but the principal advantage of charcoal over coke is the high purity of the former which enables high-purity special-purpose pig irons to be produced from appropriate grades of iron ore.

Charcoal iron industries can also operate on a much smaller scale than normal coke-based plants and this has attracted interest from developing countries interested in small-scale iron and steel production. Brazil provides the outstanding example of a viable large-scale iron and steel industry based on a renewable eucalypt plantation forest resource.

Charcoal can be used as a fuel in the form of "producer gas" for internal combustion engines. It was used this way during the Second World War in some countries and, as liquid fuel shortage develops, may find renewed use.

Apart from its uses as fuel, charcoal is an important industrial chemical raw material and industrial countries regularly import it. The speciality barbecue market in developed countries can also be served by imported charcoal.

Uses in building and construction

THE RAW MATERIAL

Effective utilization of eucalypts in log form, whether small or large logs, depends upon the characteristics of the raw material. In this regard the genus has both favourable and unfavourable features.

Favourable features

The better plantation eucalypts allow small straight logs to be grown in vast quantities much more quickly than is the case with most other trees. In the winter-rainfall regions, *E. regnans, E. diversicolor, E. delegatensis, E. nitens* and *E. cladocalyx* are outstanding examples as are *E. cloeziana, E. grandis, E. saligna, E. dunnii, E. pilularis, E. paniculata, E. maculata* and *E. citriodora* in summer-rainfall regions.

Small or large poles of all the species mentioned above can be treated with preservatives in high-pressure cylinders to give them great durability. They then become construction materials that can stand up to rigid standards and gain a respectable position in the market-place.

Unfavourable features

Unfortunately eucalypt stems have certain unfavourable characteristics also. These must be known and counteracted in some way. They include: growth stresses, shrinkage on drying, collapse, spiral grain and starch in the sapwood.

Table 10.5 Uses made of African eucalypt plantation wood

1. Structural timber (heavy)	17. Interior trim
2. Structural timber (light)	18. Core stock
3. Flooring (heavy) - parquetry, etc.	19. Matches
4. Flooring (light)	20. Joinery
5. Mine-timbers	21. Railway sleepers
6. Use in boat building	22. Hardboard, particle board
7. Use in vehicle building	23. Poles and piles
8. Furniture & cabinet-work	24. Carvings
9. Handles, ladders	25. Vats
10. Sporting goods	26. Battery separators
11. Use in agricultural implements	27. Toys and novelties
12. Veneer and plywood	28. Turnery
13. Pulpwood	29. Wood wool
14. Fuelwood	30. Draining boards
15. Charcoal	31. Food containers
16. Boxes and crates	32. Pattern making

Source: Bolza and Keating, 1972.

Table 10.6 Densities and uses of African plantation eucalypts

Species	Range of density at 12% moisture content (kg/m³)		Use (as defined in Table 10.5)
	Australian natural forest	African plantations	
E. astringens	1 010	950-1 010	9, 11, 14, 15, 23, 28.
E. camaldulensis	810-900	810-1 010	1, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 20, 21, 23, 30.
E. citriodora	910-1 010	910-1 140	1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15, 17, 20 21, 23, 24, 28.
E. cladocalyx	910-1 010	910-1 010	1, 3, 5, 6, 7, 10, 11, 20, 21, 23.
E. cloeziana	980	100-900	5, 14, 15, 23.
E. dalrympleana	730-800	580-640	2, 4, 6, 7, 8, 9, 10, 11, 12, 13, 15, 17, 18, 20, 23, 25, 27, 27.
E. delegatensis	650-720	650-800	1, 2, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 22, 23, 25, 27, 28, 29.
E. diversicolor	910-1 010	810-900	1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15, 16, 17, 20, 21, 23, 27, 30.
E. elata	810-900	580-640	2, 4, 7, 8, 9, 13, 14, 15, 16, 20, 23.
E. fastigata	650-720	580-640	2, 3, 4, 6, 8, 11, 12, 13, 14, 15, 16, 17, 18, 20, 27, 28.

Table 10.6 Densities and uses of African plantation eucalypts *(concluded)*

Species	Range of density at 12% moisture content (kg/m³)		Use (as defined in Table 10.5)
	Australian natural forest	African plantations	
E. globulus ssp. *globulus*	730-800	650-720	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14, 15, 16, 17, 18, 20, 21, 23, 27, 28.
E. globulus ssp. *maidenii*	910-1 010	650-900	1, 2, 3, 4, 6, 7, 8, 9, 11, 14, 15, 20, 21, 23.
E. gomphocephala	990-1 060	660-980	11, 14, 15.
E. grandis	650-720	580-640	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 20, 21, 22, 23, 27, 28, 29.
E. macarthurii	730-800	810-900	2, 4, 8, 14, 15, 16, 20, 23.
E. maculata	910-1 010	730-800	1, 3, 4, 5, 6, 8, 9, 10, 11, 12, 14, 15, 17, 20, 21, 23, 27, 28.
E. microcorys	910-1 010	730-1 010	1, 3, 4, 5, 6, 7, 9, 10, 11, 14, 15, 20, 21, 23, 30.
E. nitens	650-720	650-720	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 22, 23, 25, 27, 28, 29.
E. obliqua	730-800	650-800	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 20, 21, 22, 23, 25, 27, 28, 29, 30.
E. paniculata	1 020-1 140	910-1 010	1, 3, 5, 6, 7, 8, 9, 10, 11, 14, 15, 20, 21, 23, 27.
E. pilularis	810-900	650-900	1, 3, 4, 5, 6, 7, 9, 10, 11, 12, 14, 15, 17, 20, 21, 23, 27, 28, 29.
E. propinqua	1 020-1 140	1 020-1 140	1, 3, 5, 6, 7, 11, 14, 15, 17, 21, 23.
E. regnans	650-720	510-570	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 22, 23, 25, 27, 28, 29.
E. resinifera	910-1 010	650-900	1, 3, 5, 6, 7, 8, 11, 13, 14, 15, 20, 21, 22, 23.
E. robusta	810-900	650-800	1, 3, 5, 6, 7, 8, 11, 13, 20, 21, 22, 23
E. saligna	810-900	730-1 010	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14, 15, 16, 17, 18, 20, 21, 22, 23, 27.
E. sideroxylon	1 020-1 140	1 020-1 140	1, 3, 5, 6, 7, 10, 11, 20, 21, 23, 28.
E. tereticornis	410-1 010	730-800	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 25, 27, 28, 29.
E. viminalis	730-800	810-900	1, 2, 3, 4, 6, 7, 8, 9, 10, 12, 14, 15, 16, 17, 20, 23.

• *Growth stresses.* As described in Chapter 2, strain gradients develop in eucalypt trunks as they grow, both along the longitudinal axis of the stem and across it, and these manifest themselves in unfavourable ways, particularly in poles. There is always a powerful longitudinal tension stress in the outer layers of the trunk, irrespective of its size, and a compensating longitudinal compression of the inner layers. If a piece is cut or split out of the trunk, it assumes a shape and a size that are different out-of-tree than in-tree. It assumes the shape of an arc of a circle with its convex side facing the pith and the concave side the periphery of the stem. These strain gradients tend to make the trunks split when the trees are cut.

Across the cross-section it can be demonstrated that in a green trunk the newer wood on the periphery is in tangential compression and this imposes a compensating radial tension on all parts of the circumference toward the pith. This type of strain gradient tends to make star-shakes open up near the pith.

• *Shrinkage on drying.* In all tree trunks there is a wood and a water complex. The water complex is intimately in contact with the surface of the cell walls, and with the fibrils in the cell walls. In a fast-growing coppice crop there is at least as much water as wood in the stem. When the stem is cut and allowed to dry out, not much happens except a loss of weight until the water starts to dry out of the intimate structure of the cell walls themselves. At this stage, there is a moisture content of between 25 and 30 percent of the oven-dry weight of the log. If drying proceeds past this point the wood shrinks in size in all directions. There is very little longitudinal shrinkage but considerable shrinkage across the cross-section, both in a radial and tangential direction. In this characteristic the eucalypts behave more unfavourably than many trees. Their rate of shrinkage in drying from "fibre saturation point" (about 25-30 percent) to "air-dry" (12-15 percent) is more than in many trees, and it is more in a tangential direction than a radial direction. This tends to make the drier logs crack from the circumference toward the pith, whereas in the green state the strain gradient across the cross-section tends to make star-shakes open up from the pith outward.

• *Collapse.* An unfortunate feature of many tropical and subtropical hardwoods when they dry out below fibre saturation point is the phenomenon of "collapse". The eucalypts are particularly prone to this defect when they are being kiln-dried. Irregular shrinkage takes place within the wood, leading to a washboard effect on the surface and the development of many small cavities in the wood. Methods of overcoming this defect are described in the section on seasoning in this chapter.

• *Spiral grain.* Spiral grain is a fairly common sight in very old trees in Australian eucalypt forests. This type of spiral grain on old trees is laid down on trunks which have been hollowed out by growth stress compression, fungi, termites and fire, such as the logs shown in Figure 44. It is not usual, in Australia, to see extensive spiral grain in healthy vigorous saplings of the better eucalypts when they are growing "on-site".

When eucalypts are taken to other countries and planted "off-site" they frequently develop a spiral twist before they have been hollowed out by time and its problems. Frequently these spirals follow one direction — either clockwise or anticlockwise looking down the trunk. *E. nitens* may twist badly in South Africa even though it is very vigorous. The defect makes poles unsuitable for various high-value purposes.

- *Starch in the sapwood.* It is almost inevitable that a very vigorous eucalypt crop will have residual starch in the sapwood. If sapwood containing starch is sawn or even left with its ends exposed as poles, the powder post-borer *Lyctus brunneus* will bore into it unless the wood is treated. The treatment is very simple — as simple as including a borax bath in the production line in the sawmill — and is required by regulation in those Australian States which mill *Lyctus*-prone wood.

ROUNDWOOD

General comment

If an owner is able to market a proportion of his plantation-grown eucalypt crop as industrial poles, he may be able to sell it at a higher unit price than if it must be sold as pulpwood, fuelwood or charcoal billets. There are several categories of poles which may provide this advantage. The more sophisticated and "developed" the community, the greater the market is likely to be for these pole categories, and the more likely administrations of the community are to lay down minimum standards for each category. These standards are usually developed by national standards associations through committees on which growers, merchants, engineering experts and customers are invited to take part. The purpose of the committees is to ensure that a reasonable grade of pole which will pass an acceptable engineering standard is made available to the community at a just price for consumer and producer. In new eucalypt-growing countries, owners should welcome grading rules and make sure that representatives of their associations are invited and take part in committee discussions. The growers will be given a chance to indicate what can be produced from their plantations. It is most likely that the engineers and the consumer interests will collaborate to ensure that the greatest volume of standardized produce will go into the economy of the community.

Standards

Once a schedule of acceptable and unacceptable defects is laid down for various categories, each better category is likely to command a higher price. Growers can then review their plantation practice and make their own judgement as to whether a higher investment in better treatment is likely to give a financial advantage. In the more sophisticated eucalypt-growing countries the standards are already helping growers and making eucalypt plantations of greater value to their national economies.

Categories

In the plantation countries it must be stressed again that by far the greater part of seedling and coppice crops is likely to go to low unit value products.

Nevertheless, with the passage of time, and collaboration with national standards organizations, more and more of the eucalypt crop may be diverted to higher unit value categories.

- Small poles and posts

Eucalypt seedling and coppice crops are likely to produce a large number of small short poles per hectare. In the seedling crop little separate treatment after planting should be necessary for short poles which pass an acceptable standard. Coppice crops will require additional treatment if the owner wishes to improve the unit value or even to keep it at the level of the seedling crop. The coppice shoots from each stool should be thinned down to three or two well-placed shoots in the manner described in Chapter 5. This should be done or commenced by the second year of the coppice crop and completed by the third year.

The small short poles must be straight for the length of the category required, such as 2 m or a little more for fenceposts and up to 5 or more metres for building poles. They should be prevented from splitting at the ends by methods indicated later in this chapter and to ensure a high-quality product they should be preservatively treated. If this is done, a very large market can be serviced from plantations of 6-12 years.

- Pitprops and matpacks

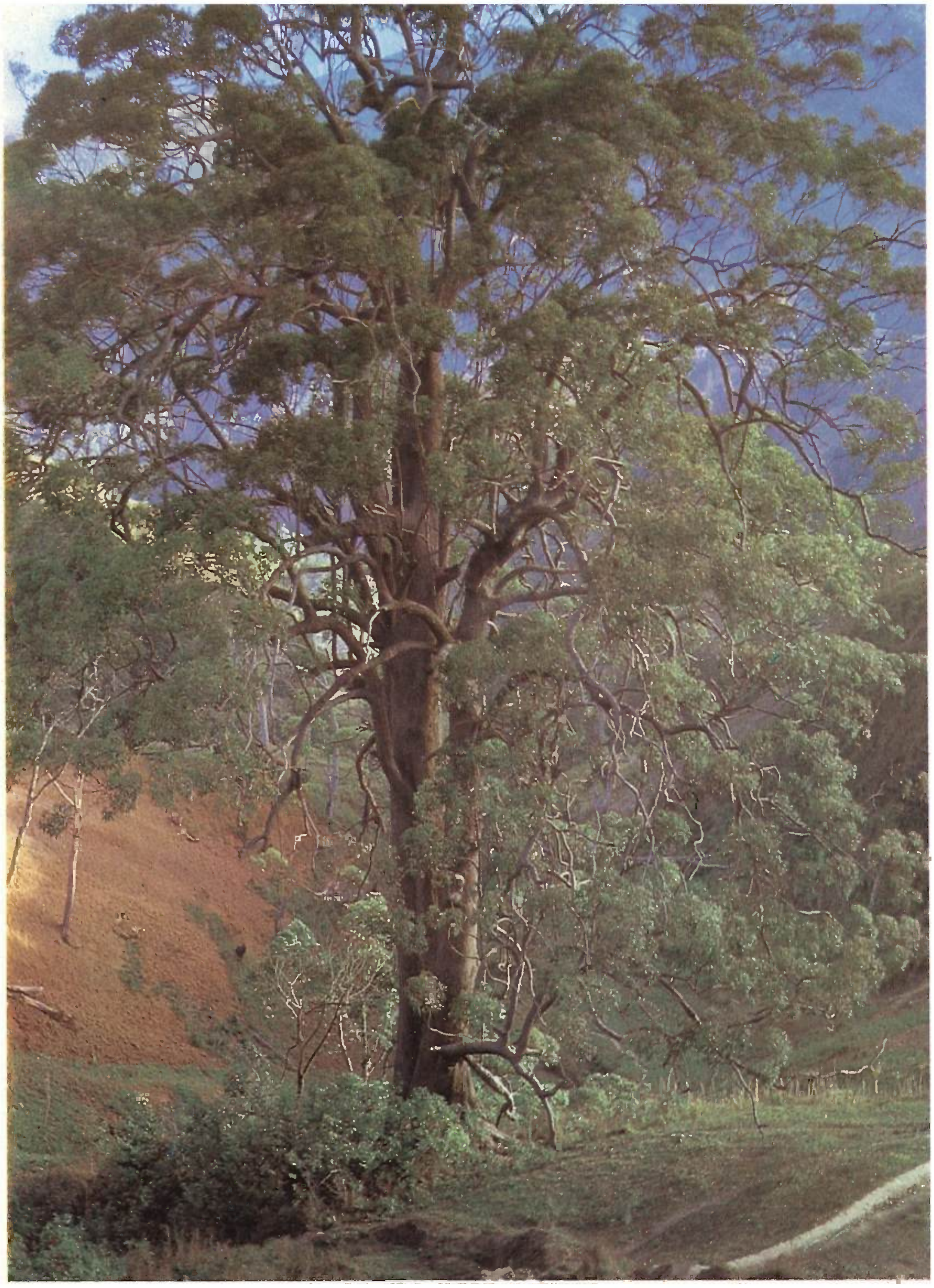
Pitprops are an example of a product which enables an owner to increase the unit value of at least part of his crop. Eucalypt poles may not be the best mine-timbers because they do not give the warning (groaning) before collapse that was such a feature of Douglas fir mine-timbers. Nevertheless eucalypt pitprops are widely used in Australia and planting countries. The criteria for straightness and freedom from cracks or other defects are more stringent for mine-timbers than for pulpwood but an increase in income can be gained by treating coppice so that a substantial number of pieces meet the criteria.

Sound butt ends of poles that are larger than normal may be slabbed and the squared beams bunched together and sold as matpacks for deep mines with narrow stopes.

The safety of mines is an important social factor in all countries and the suppliers of pitprops and matpacks which pass certain standards should be able to negotiate for a reasonable price.

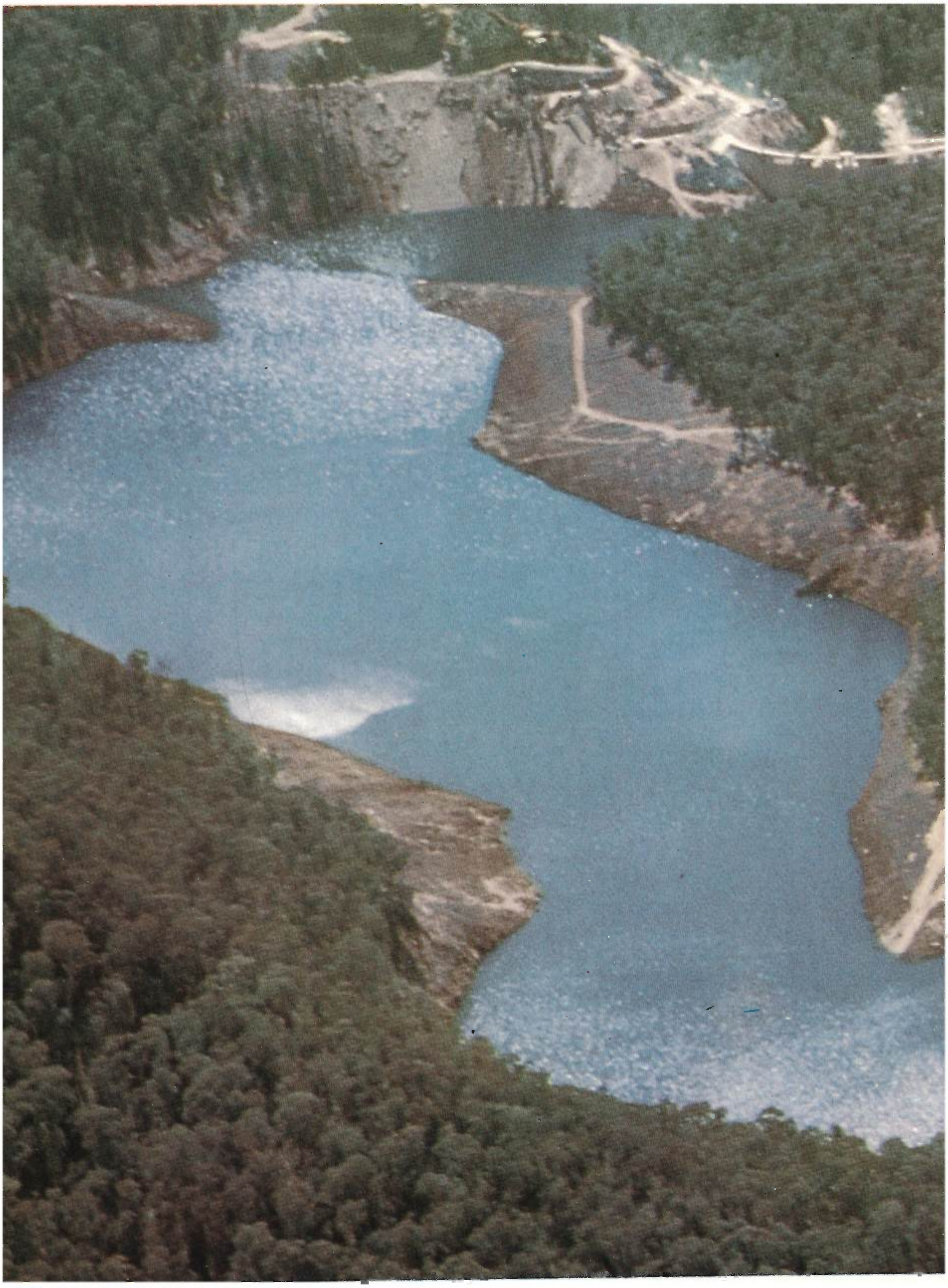
- Telephone poles and transmission poles

Poles of this type, when preservatively treated, claim a high unit value if they pass straightness specifications and do not split. They can be produced from normal or special thinnings in stands being grown for the sawlog market, or from clear-felling 8- to 12-year-old stands which have been pruned and lightly thinned. If labour is available and not too expensive, the pruning of odd large branches can improve the yield of long poles.



Eucalyptus urophylla, Maubisse, East Timor

L.D. Pryor



2b

Natural eucalypt forest in catchment area,
Brindabella Range, Australia

L.D. Pryor

E. regnans, natural, Tasmania ~~*E. grandis*, natural forest in Tasmania~~

L.D. Pryo

Larger poles should be tightly banded at each end with heavy-gauge galvanized wire or hoop iron when the poles are fully dried. The use of gang nails driven into the ends of the poles restrains splitting. In addition, a sleeve of bark about 20 cm in length may be left on the end of each log while it is drying. The ends of larger poles should also be coated and sealed with a watertight compound and sprayed with insecticides and fungicides to reduce danger of insect or fungal attack. The value of the base portion of a large pole is considerable and every effort must be made to prevent splitting.

- Fencing droppers

These small pieces of wood can be produced in considerable numbers as additional shoots that develop in coppice crops, particularly when they are thinned. One dropper is not worth very much but they are required in enormous numbers to service the fences of certain agricultural areas. They must be preservatively treated before going into service. An owner who watches this small commodity can obtain a useful additional return from his coppice crops.

SAWNWOOD

General

Owners aiming at the sawnwood market must make up their minds whether they will use the Australian method for natural forest or develop a new method. The Australian method has been to aim at large logs so that the inevitable arc which outside boards will assume (as described in Chapter 2) is the arc of a circle of large radius — at least 137 m. Processors will then be able to cut commercially acceptable timber from the outside of these logs, but will demand from the owners an allowance for the inside 20 cm of the logs. In effect, the owners will be growing the trees until they are 20 cm in diameter before they produce any saleable produce. This is unacceptable for plantation eucalypts. A better way to get sawnwood from eucalypts is to grow them quickly to a diameter of, say, 40 cm in 15-20 years and saw them through and through in a gang-saw.

The feature which usually makes it difficult to produce sawnwood from fast-grown eucalypts is growth stress (expressed as longitudinal tension in the outer part of the log and a compression zone which forms brittle heart — brittle wood containing micro-compression features) in the central zone of the log. But manipulation of growth rate, age at harvesting, selection of species and provenance and especially method of sawing allow saleable sawnwood to be produced from fast-grown plantation eucalypts.

Sawing techniques

Not enough is known quantitatively yet about the factors which influence growth stress development to offer advice on how plantations should be managed to minimize its effects except in the most general terms. The only options available usually in practice are to choose suitable sawing techniques and develop markets which fit the characteristics of the sawnwood — short-length wood for parquet and laminated products, etc.; and thin boards for strip flooring, packaging and concrete forms.

The basis of sawing technique to cope with growth stress of the magnitude found in plantation eucalypt logs is balanced cutting and separation of the outer zone of the log from the central core during cutting. Balanced cutting means simultaneously making two or a larger even number of sawcuts symmetrically disposed on each side of the pith, so that the central cant remains straight during sawing.

Two machines are widely used for balanced cutting of eucalypt logs — the gang-saw and the twin circular log edger. Twin and quad band-saws have also been used effectively though they may not fit economically the small volume typical of most plantation eucalypt sawmills.

The key to success with balanced cutting to minimize the effect of stress is to limit the thickness of sawnboards to a maximum of 3.5-4 cm thickness and preferably not more than 2.5 cm. Market requirements may call for greater thicknesses, for example, 5 cm but recovery of saleable wood will be less due to distortion and end-splitting. It is much better to adapt the utilization system to use thin sawnwood. In house framing for example, maximum use would be made of round poles in subfloor construction and thick beams would be built up by nail-laminating 2.5-cm boards and limiting their use by appropriate design of the framing system.

In a small sawmill the twin circular log edger using thin steel-plate circular saws about 100-cm diameter is the ideal machine for primary cutting of small eucalypt logs. This would be followed by one or two re-saws, either band- or thin circular type, preferably with power-driven hobs to keep the stock pressed against the fence to ensure uniform-thickness boards despite the curving of the cant due to stress. The final operation is to trim the boards using a pendulum-type trim-saw. The cants should be cut so as to produce the maximum number of back-sawn boards, as the curvature of the wide face of these boards due to growth stress causes few problems due to their flexibility, and curvature is also easily removed when the boards are stacked flat for seasoning. End-splitting is also minimized compared with quarter-sawn boards.

This type of mill is suitable for annual log volumes per shift of up to about 5 000 cubic metres.

Larger mills can be based on one or two high-speed gang-saws with edgers and trim-saws. A single gang-saw can be used to reduce the log to boards in a single pass. Alternatively, the logs can be passed first through the saw so as to cut boards and leave a central cant about 10-15 cm thick. The cants are accumulated and later in the shift the spacing of the saws in the sash is reset and the cants are resawn into boards. The sash may be set to cut thicker lumber from the core of the log and thin back-sawn boards of high quality free of brittle heart from the outer zone of the log.

Where two gang-saws are used they are combined to form a single line, the first saw cutting logs and the second cutting cants. An edger is used to handle the side cuts from the log saw.

Depending on markets, end-trimming may be carried out green or after seasoning. The latter may be preferred if seasoning is carried out at the mill since end splits which develop in sawing and seasoning can then be removed in one operation and the total loss due to splits is less than if boards must be trimmed both green and again after drying.

Problems caused by growth stress are reduced when the length of log sawn is reduced. However, handling problems are increased and market opportunities reduced with short wood, and the usual compromise is to saw logs around 5 m in length. Generally, it is better to saw plantation logs fresh after harvesting. Storage, preferably under water sprays, for some months, however, reduces stress in logs and is found worthwhile by some sawmills.

At the present stage, few plantation countries could put more than 10 percent of the volume of eucalypts they grow into sawnwood and an improvement on this percentage may depend upon a change in attitude to house types and separate houses and also to the use of eucalypt sawnwood *vis à vis* sawnwood from coniferous plantations. The conifers do not have the same strain gradient problems as eucalypts. Zambia is using eucalypt sawnwood in the Copperbelt but anticipates changing to conifer sawnwood as the pine plantations mature.

Quarter-sawing versus back-sawing. Because of the large difference in shrinkage between the tangential and radial direction in most species of eucalypts and because of the incidence of defects, such as gum rings in some species, it is worthwhile to consider the option of back-sawing versus quarter-sawing.

Back-sawn boards show higher shrinkage across the board, are more prone to surface checking and cupping in seasoning and in the weather when used for such purposes as fencing and wall cladding. Their figure on the wide face tends to be plainer than quarter-sawn, though for mosaic-type parquetry back-sawn boards are needed to produce parquetry with quarter-sawn figure. As mentioned earlier, there are far less problems due to growth stress. Because of the tendency of gum or kino to occur as rings in the log, such defects in back-sawn boards appear as a disfiguring blaze of gum on one or two boards whereas the same defect appears as a narrow line of gum in quarter-sawn boards. Collapse-type shrinkage is also generally more severe in back-sawn material. For a given log size, back-sawing generally produces wider boards than quarter-sawing. In cutting plantation logs, the balance usually favours back-sawing versus quarter-sawing.

Where large-diameter logs are available from old plantations or natural stands, quarter-sawing is a practical option and is worthwhile for species prone to collapse and gum rings, and which show a pleasant radial figure. For production of slicing flitches for veneer, quarter-cutting is essential for high-grade decorative veneer.

Sawing methods such as sawing through and through on a single gang-saw which produces wide boards from the centre of the log containing a mixture of back-sawn and quarter-sawn wood in the same board are undesirable, because of severe distortion which occurs with most species on seasoning. This is a further advantage of the sawing methods described earlier which aim at separating the core material from the outer zone wood.

- Railway sleepers

One of the earliest items of export of eucalypt wood from Australia was the railway sleeper, millions of which were sent to New Zealand, China, India, the Near East, Africa and America. In addition, most Australian railways are laid on wooden sleepers. For several decades the standard of export sleepers has been supervised by Australia's forest services and a product of good quality has usually been maintained. Occasional difficulties have arisen, sometimes because of inadequate inspection and sometimes because of the extreme dryness and heat of the countries wishing to use the sleepers. Jarrah (*E. marginata*) has been the main export sleeper and has given good service.

In southern Australia the sleepers have been hewn or sawn from large logs outside the regions of the "heart." This means using large trees. Several countries have grown large eucalypts with the intention of using them for railway sleepers. Brazil has an active industry based on species such as *E. tereticornis, E. botryoides, E. maculata* and *E. citriodora.* The enterprise has had varying results, but since the practice of giving a high-pressure preservative treatment has been introduced it is reasonably satisfactory. If a preservative treatment can be applied, the preservative will insure the life of the sleeper against attacks by termites and fungi, but not against mechanical failure. Strong woods with interlocked grain are needed for sleepers in any case. Free-splitting woods are likely to be troublesome.

In the Australian State of Queensland, the northwest interior has difficult conditions with long dry seasons (in the cooler months) and frequent droughts. The railways there use "half-round sleepers" made by sawing smallish sound trunks from the several durable tropical ironbarks, boxes and gums which grow there. Species with an interlocked grain are necessary. Several countries have climates comparable with northwest Queensland, that is, latitude 14°-24°. The "half-round" might be a useful sleeper for them to aim for, particularly if it can be given added durability by a high-pressure preservative treatment. *E. paniculata, E. crebra* and *E. citriodora* are possible species.

- Blocks for houses, roads and gardens

In the course of time, plantation owners are likely to have a wide variety of sizes of eucalypts in their plantations. They can then look at a wide range of potential uses for odd sizes. One use is the "block". The blocks are pieces of wood which are usually short and serve as supports.

Eucalypt parquet flooring is popular and a very useful product. Moreover, although larger logs are preferable, the floor members are short and log selection is not as demanding as for normal sawlogs. An efficient plant requires 4 000 m^3 per year.

Wooden house-blocks have been used in Australia in lieu of other foundations for 200 years. In the past they have been made out of short lengths of very durable species. At the present time, preservatively treated blocks of any reasonably strong eucalypt will support its share of a load.

Wooden blocks of durable Australian eucalypts were used to make roads in London and several other cities. They were about the size of a large brick and very convenient to lay and use. Preserved blocks of non-durable species might revive this useful market.

Garden blocks — also preserved — can be made an attractive feature of a well-planned garden. They are used as "stepping stones" and are fully effective. They can be an outlet for odd butt lengths.

Laminated wood

The gluing together of a series of short lengths of various cross-sections to make a long beam of a considerable cross-section has enabled large wooden structures to be designed and built from pieces cut from small trees or from off-cuts. In the main, this practice of lamination has been done with coniferous off-cuts, and major buildings up to the height permitted by local regulations for wooden buildings have been successfully constructed.

Laminating can be done with kiln-seasoned eucalypts and could prove a useful addition to the ways owners and processors may produce categories of products of higher unit values from plantation-grown eucalypts. It is believed that laminated beams of eucalypts could be produced at a price that would be competitive with metal beams, strength for strength, and make an attractive exposed beam which would add to the appearance of rooms.

One difficulty with laminated beams is that if they are to become popular on the market, producers must build up and maintain adequate stocks. This would be an expensive enterprise to initiate, although a small laminating plant requires only 2 000-3 000 m^3 of dry sawnwood per annum.

Hewnwood

Several plantation countries have reported the presence of curved stems of considerable size in their plantations and the inevitable presence of tension wood on the upper side of these stems. It is possible in the future that the ancient craft of the hewer may be revived to make straight beams out of stems with a sweep in them and so give a greatly added value to the tree trunk. If "heart-in" beams which include the pith are acceptable, the hewer can make straight beams from hardwood trees with a slight sweep. This applies to all hardwoods, not only eucalypts.

Wood-based panels

Plywood and veneer

Plywood. Eucalypt logs, especially those from plantations, are not preferred materials for peeled veneer production because growth stress produces excessive end splits in the peeler blocks when they are crosscut and in the peeled veneer. An additional problem is that some species show marked collapse on seasoning, which produces veneer of uneven thickness. Nevertheless, by careful choice of species and technique, it is possible to produce commercial plywood entirely or substantially from eucalypt. Naturally, where other species are available at competitive prices, they will be preferred.

Because growth stress is less in older logs, for example from natural forests, they are preferred over young plantation logs for peeling. Nevertheless, providing a certain amount of end-splitting can be tolerated, it is possible to operate successfully with plantation logs, particularly *E. grandis* which does not collapse. *E. deglupta* also should be a suitable plantation species. Other species which are used from natural stands are *E. diversicolor, E. obliqua, E. maculata, E. regnans* and *E. delegatensis*.

There are two methods for minimizing end-splitting problems. On the one hand, if the species requires heating to soften it, for example *E. diversicolor*, then it is best to heat logs in lengths as long as possible and crosscut them after heating. Growth stresses are reduced during heating but not eliminated. On the other hand, if the logs are peeled cold, and this method works successfully with even quite hard species such as *E. maculata*, then they should be either peeled fresh from the forest or they should be stored before peeling in full log lengths for some months, either in water or under water sprays. Both methods can be used to balance supplies of logs.

Growth stresses are significantly reduced by storage. End-splitting during storage can be largely controlled if desired by applying nail plates to the end of the logs. These are cut off when logs are crosscut for peeling.

Where 100 percent eucalypt plywood is to be made, it is best to select the milder well-grown logs to produce thin face veneer from the outer part. For example, 1-mm face and back veneer can be produced from the outer part and the remainder peeled into thicker veneer for core material.

End splits become worse as block diameter is reduced in peeling and the face veneer should only be produced from the outer part of the best logs. This is no problem unless the plant must produce large amounts of three-ply, when it is difficult to obtain enough cover veneer. An alternative, where other superior species are available in limited amounts, is to peel cover veneer from them and use eucalypt for the centre construction. For species which do not show collapse, drying presents no particular problems and the final veneer, though somewhat prone to splits in handling, is tolerable. Eucalypts glue well with urea resins but tests must be made with phenolic resins as some species are difficult to glue with phenolics and tannins. *E. grandis* and *E. deglupta*, however, glue well.

Veneer. Eucalypts, both native and plantation grown, are used for sliced decorative veneer. The veneer should be quarter-cut, the figure of back-cut veneer being too plain. Quarter-cutting also usually prevents collapse occurring on the veneer during drying and it has lower shrinkage.

The following species are used commercially: *E. camaldulensis, E. delegatensis, E. diversicolor, E. globulus, E. maculata, E. marginata, E. obliqua, E. regnans* and *E. viminalis.* Generally, the paler coloured veneers are more acceptable, but greenish shades such as are obtained from *E. maculata* are valued. Generally, pale reddish shades are not so desired but strong reds and browns are quite acceptable. Fiddle-back grain, if present, can be very attractive. Eucalypts are capable of providing a sound, medium-grain, medium-price veneer very suitable for panelling and furniture, but because of the quarter-cut requirements, trees must reach a certain diameter, say 40 cm, before it is practical to slice them.

Steaming is not usual for plantation-grown logs and may cause undesired slight darkening. However, old logs of the harder species require careful steaming to soften them for cutting. Eucalypt veneer is very susceptible to staining when in contact with iron, and great care should be taken at all times when the veneer is green to avoid this problem. The sapwood of the paler eucalypts is not differentiated from the heartwood and need not be trimmed. It may be *Lyctus* borer-susceptible and care should be taken in warm climates to prevent attack in stored veneer. Thin sliced veneer is rarely attacked in finished panels.

Particle board

Eucalypt wood, especially low density wood from fast-growing plantations, is suitable for particle board production. It may be used alone or in combination with other woods. For example, in three-layer boards bark-free poplar or pinewood may be used for the surface layer and eucalypt, including the bark, may be used for the core.

When using eucalypt with bark, it is best to avoid bark from the lower part of the main trunk which may carry charcoal from earlier fires in the plantation and small stones picked up in logging. Species which produce fibrous bark are preferable, though flaky bark is satisfactory. Corky bark and bark rich in kino, such as from the bloodwood group, should be avoided. Wood carrying bark from the upper trunk and branches is satisfactory from almost all species.

Where binders other than urea resin are to be used, e.g., phenolic resins, tannins and cement, careful tests should be made before commercial use, since some eucalypts are difficult to bond with these materials and binder formulations require adjustment to suit the particular conditions.

Some eucalypt species which have given good commercial results in particle board are: *E. camaldulensis, E. dalrympleana, E. delegatensis, E. globulus, E. grandis, E. obliqua, E. regnans, E. viminalis.*

Hardboard

Eucalypt wood is a good raw material for hardboard production. There are many large plants, mainly wet process type, producing for domestic and export markets based on eucalypts, both from plantations and natural forests, and there are some small batch-type plants based on plantation eucalypts, serving local markets.

Practically all eucalypts are suitable, but lower density wood, especially that from plantations, tends to be preferred because it produces a lighter colour, lower density board. In most instances, the wood is used with the bark. A full range of board densities is possible with eucalypts. Addition of resin is normally not required for high density board when eucalypt is used. These advantages combine to make eucalypts a raw material of choice for wet process hardboard production.

Since wet process eucalypt base hardboard can be made without addition of resin, it has an advantage when the cost of resin is high — compared with plywood or particle board which requires 5 to 10 percent of added resin binder.

Although in principle eucalypt can be used for dry process hardboards, experience seems to show that it is not as suitable as softwoods and some other hardwoods. For this reason, the majority of hardboard plants based on eucalypts are wet process.

Hardboard plants require much more investment per unit of production than either plywood or particle-board plants. A plant of economic size to be competitive on world markets requires more than twice the unit investment of a plywood or particle-board plant and a considerable area of plantation to back it.

But the small batch-type plant require a much smaller investment and serving a restricted local market may be quite viable.

Pulp and paper

Much attention has been given in the past to the possibilities of using eucalypt wood for the manufacture of paper-grade pulp. In this field Australia has some remarkable industrial enterprises to its credit, mainly based on indigenous forests. Plantation eucalypts are already used in several countries such as Brazil, Portugal, Spain and the Republic of South Africa, to furnish the raw material for the pulp industry.

Although a very good-quality short-fibre pulp can be manufactured from some species of eucalypts, there are others which are less suitable. In general it can be said that an important anatomical feature of hardwood fibres suitable for papermaking is the wall thickness. Thick-walled fibres which are common in denser eucalypts do not in general give strong paper. Thus, when deciding upon the suitability of a given eucalypt wood for papermaking, the thickness of the fibre walls must be taken into account. Fibres with a wide overall diameter and thin walls usually exhibit good papermaking characteristics, whereas slender, thick-walled fibres are inferior from the paper-making point of view.

Another anatomical aspect of some importance for papermaking is the fibre length. However, the fibres of the genus *Eucalyptus* are never very long — the length varies from 0.6 to 1.4 mm.

Suitability for pulping is also affected by the presence of coloured substances in the wood cells, as the removal of these substances increases the cost of bleaching the pulp. Especially if mechanical or semi-chemical pulp for printing papers is to be manufactured, highly coloured wood is generally avoided.

The world production of pulp from *Eucalyptus* species is over 1 million tons annually. All types of paper-grade pulps are produced; chemical, chemi-mechanical, semi-mechanical and mechanical. Of these 1 million tons, about three quarters are produced in Australia and Portugal.

As regards suitability of *Eucalyptus* species for pulping, a distinction must be made firstly between natural stands and plantations and secondly between different locations of the plantations. However, in general, species such as *E. botryoides, E. camaldulensis, E. deglupta, E. delegatensis, E. globulus, E. grandis, E. maidenii, E. obliqua, E. occidentalis, E. regnans, E. saligna* and *E. viminalis,* listed in alphabetical order, have proved to be of interest for the pulp industry, both according to laboratory tests and judging from pulp manufactured on a commercial scale. There are possibilities of pulping bark of young *E. viminalis* with the wood.

In 1970 pulping tests were carried out on *E. grandis* from plantations in Zambia (Palmer and Gibbs, 1977). The results of the tests were summarized as follows:

1. *E. grandis,* 5½ years old, included about 12 percent bark by volume and had an average density of 440 kg/m^3. The difference in density both within and between trees was small.

2. Chemical analysis found 69.5 percent holocellulose, 41.2 percent α-cellulose and 23.3 percent lignin. These results indicated that no special problems would be expected in pulping by the sulphate process.

3. The fibre length was 0.78 mm, the width 16.6 μm and the wall thickness was 2.9 μm. These fibres were shorter than those from many *Eucalyptus* species.

4. Sulphate cooks with increasing severity yielded 57.9 percent of screened pulp with a Kappa number of 88.5 to 51.8 percent of screened pulp with a Kappa number of 22.3. The pulps contained a proportion of fine cellulosic material. When this fine material was retained by collecting the pulp in a linen sack, the yield was 2.5 percent higher than when the pulp was collected on a 150 mesh wire screen and most of the fines lost.

5. The most severely cooked pulp was bleached using a four-stage sequence of chlorination, alkali extraction, hypochlorite and chlorine dioxide. The bleached pulp had a brightness of 84 (Elrepho, MgO = 100). On bleaching the yield was reduced by about 5 percent and the pulp strength characteristics by about 10 percent.

6. The pulp strength characteristics compared very favourably with strength characteristics of pulps made from other hardwoods.

It must not be forgotten that eucalypt pulp must be mixed with long-fibre pulp for most grades of paper, except for certain writing and printing papers, corrugating medium and low-quality wrapping paper. The meeting of pulp and paper experts convened by FAO in Rome in December 1952 to discuss the possibilities of new raw materials for paper drew up a table summarizing the possible uses of eucalypt pulp (see FAO, 1953). The table was printed in the first edition of the present work. In general, experience over the past two decades has confirmed its validity and it is therefore reproduced again in this edition as Table 10.7.

In addition to paper-grade pulp, eucalyptus wood can be used for the manufacture of dissolving pulp for further processing into viscose or acetate films or filaments. The anatomical characteristics of the wood fibres are of minor importance for this type of pulp, as the fibres will eventually be dissolved for the manufacture of films or filaments. What are important, however, for this type of pulp manufacture are the economic aspects such as yield of pulping and bleaching and the chemical consumption in the different parts of the manufacturing process. Among the species used or considered for production of dissolving pulp are *E. botryoides, E. camaldulensis, E. globulus, E. grandis, E. maidenii, E. regnans* and *E. saligna.*

Other products

Eucalypts in Australia provide several valuable minor products. Some of these are recognized and made use of by overseas planting countries.

Honey

The greater part of the honey consumed in Australia is eucalyptus honey, which is also a useful export item. It is of interest to note that the bees which collect eucalyptus honey in Australia are European bees, mainly Italian. These bees have acclimatized themselves completely to the Australian environment and, in addition to collecting honey, are probably the most important agent in pollinating eucalypt flowers.

There is a distinctive flavour to eucalypt honey and between the honeys produced from various species of the genus, which are frequently kept separate by producers and shopkeepers to meet the demand of customers who have favourite flavours.

Most honey obtained in Australia is produced by professional beekeepers, a skilled group of producers who live a semi-nomadic life in trucks and caravans for much of the year, following the flowering of different species. Their associations keep them advised of the districts where flowering is about to start and then each beekeeper must make his own arrangements to lease an area where he can set out his hives, on state forest, other crown land or private property. The beekeepers pay a nominal fee for the right to exploit the flowers in their allocated area. Private landholders and even suburban householders may erect one or several hives to gather honey from the full range of flowering plants in a district. On some occasions beehives can be hired by orchardists when fruit trees are in blossom in order to improve the pollination of their fruit. In this case care must be taken that insecticidal

Table 10.7 Possible uses of eucalypt pulp

Type of paper	Type of pulp										
		Semi-chemical					Chemical				
	Groundwood	Cold caustic soda		Hot caustic soda	Neutral sulphite		Sulphite		Sulphate		Soda
	Sbl	Ubl	Sbl	Ubl	Ubl	Bl	Ubl	Bl	Ubl	Bl	Bl
Newsprint	+ B		+ B								
Magazine and 2nd-quality book	● BD		● BD								
Book, 1st quality			* BD					+		+	+
Fine, 1st quality								● D		+	+
Fine, 2nd quality								+			
Wrapping 1st strength									● C		
Wrapping, 2nd strength					● BC		● C		+ C		
Wrapping, 3rd strength		● BC		● BC	Δ		Δ		Δ		
Greaseproof						+					
Kraftliner					● C				● C		
Corrugating medium		Δ		Δ	Δ						
Rayon and cellophane								Δ		Δ [1]	

[1] Prehydrolysed.

The symbols indicate the amount of pulp which can be used for different purposes in the following ways: * up to 20 percent; ● from 20 to 60 percent; + from 60 to 90 percent; Δ 100 percent.

After symbols one or more block letters (A, B, C, D, E) are given to indicate the kind of pulp which has to be blended, in accordance with the following key: A — Groundwood; B — Unbleached coniferous sulphite; C — Coniferous kraft; D — Bleached coniferous chemical pulp, sulphite or sulphate; E — Bleached broadleaved chemical pulp.

In addition, the following abbreviations are used: Ubl = Unbleached; Sbl = Semi-bleached; Bl = Bleached.

Table 10.8 Honey properties of eucalypts

Species	Flowering time in Australia	Qualities of honey
E. albens	March to May and June	Finest quality pollen and nectar
E. behriana	November to January	Produces an abundance of nectar
E. blakelyi	August to September	Flowers abundantly, good honey producer
E. bosistoana	November	Produces plentiful pollen and nectar
E. bridgesiana	February to April more or less every year	Produces both pollen and nectar; the honey is amber-coloured, somewhat thin and granulated, but is highly suitable for the winter feeding of bees
E. calophylla	February	Produces abundant nectar
E. camaldulensis	Almost all the year round	Clear golden honey not as thick as that of the "yellowbox," *E. melliodora,* and less aromatic, but of very good sweet flavour (Beuhne)
E. cladocalyx	January to February	Pale yellow honey of good density with excellent flavour and aroma (Beuhne)
E. cloeziana	March-April, in profusion	Should be an excellent tree for bees
E. cornuta	January to February	Regarded as one of the most useful
E. crebra	May to January	Produces some nectar; honey resembles that of *E. bicolor*
E. diversicolor	March to December	Gives abundant nectar
E. dives	September to October	Does not give honey of high quality
E. flocktoniae	February to November	Seems to be a good producer of nectar and pollen
E. gomphocephala	January to March and sometimes September	The honey, when thoroughly matured in the comb, is very thick and crystallizes very quickly after extraction. It is light cream in colour, of very fine grain, becoming hard and dry when coagulated. It is regarded as of first-rate quality.
E. goniocalyx	March	Dark honey of good flavour
E. gummifera	March, later flowering not unusual in profusion in January	Gives abundant nectar
E. huberiana	February-April, December	
E. leucoxylon	May to December	Fine-quality honey of pale straw colour, thick, of perfect texture
E. macrorhyncha	February	Pollen. The honey is of a light but somewhat pronounced colour, has a

Table 10.8 Honey properties of eucalypts *(concluded)*

Species	Flowering time in Australia	Qualities of honey
		good flavour and when quite set is fairly thick. It crystallizes rapidly and should always be heated to 38°C (Beuhne)
E. melliodora	September to February, and June in certain districts	Honey is the finest in Victoria
E. microcorys	Begins flowering in October	The bees find a great deal of pollen and honey; the yellow colour of the latter disappears with age
E. moluccana	January to April	Pollen and nectar. The honey is of excellent quality, of medium density, amber-coloured; when pure crystallizes rapidly
E. obliqua	January to February	The honey is one of the darkest in colour known, particularly in moist regions. Pollen is gathered by the bees from the flower buds (Beuhne)
E. occidentalis	April to May	Contains abundant nectar
E. odorata	December to January and sometimes May	Pale honey which does not crystallize
E. ovata	April to November	Clear amber thinnish honey, resembling that from *E. viminalis*
E. pauciflora	November to December	Profusely flowering species producing golden but not very thick honey. The pollen is also gathered by the bees
E. paniculata	May to November	Gives a wealth of nectar
E. polyanthemos	September to November	Produces a clear honey which does not crystallize and has an oily taste when fresh
E. saligna	January to March	Excellent honey producer with fairly abundant pollen. Wealth of brilliant amber honey thick in consistency.
E. sideroxylon	May to February	Fine-quality honey lighter than that of *E. leucoxylon*, and appears to give an abundant harvest
E. tereticornis	August to October	One of the most useful species
E. transcontinentalis	September to December	The flowers have a deep nectar cup
E. viminalis	Flowers almost every month of the year	The honey is exceptionally sweet, is light amber in colour, not very thick, and crystallizes fairly easily
E. woollsiana ssp. *microcarpa*	February to August	Equals *E. melliodora* as a honey producer

sprays are not used while the pollinating process is in progress or there may be a severe reduction in the working population of the hives.

The value of plantation eucalypts as a source of honey is being recognized in the planting countries. The plantations are producing far more flowers per hectare than the native forests in Australia. When they are in full flower there is a veritable roar of bees around them, much more so than in Australian native forests.

The remarks by Blakely on the honey properties of the better honey-producing eucalypts are summarized in Table 10.8.

Essential oils

Nearly all species of eucalypts have oil-producing glands in their leaves which produce oils which give the leaves their characteristic odour. These oils are called "essential oils" and comprise a range of natural oils which together give the leaves of eucalypts their peculiar smell, but which can be differentiated into separate chemicals (not necessarily all in the same species) which are or could be of value in industry. The main essential oils and their properties are as follows:

Cineole: used in pharmaceuticals, stain removers.

Phellandrene: used in industry as a solvent and flotation for metals. Its presence is prescribed by pharmacopoeia in essences intended for pharmaceuticals.

Terpineol: used in perfumery (hyacinth scent).

Eudesmol: fixative for perfumes.

Eudesmyl acetate: used as a substitute for bergamot essence; it mixes well with lavender essence.

Piperitone: raw material for synthetic thymol and menthol.

The species which produce these oils in useful amounts are shown in Table 10.9.

Production

Within Australia the harvesting of essential oils has been done mainly on natural forests of *E. radiata* ssp. *radiata, E. cneorifolia, E. dives* and *E. polybractea.* The naturally grown trees may be pollarded or coppiced and the leaves repeatedly harvested. There has been a small amount of cultivation of industrial plantations where leaf-harvesting can be carried out at annual or periodic intervals, and mechanical harvesting has been successfully tried. In the main eucalypt-planting countries *E. globulus* has been the main commercial source of essential oils. Its leaves yield about 1 percent of cineol and eudesmol which has been considered an adequate return if a massive quantity of leaves can be obtained by following felling operations.

Table 10.9 Eucalypt species for essential oils

Species distilled	Yield of leaves in percentage of oil	Composition of oil	Use
E. citriodora	0.8 to 1.0	Citronellal	Perfume, insect repellent
E. cneorifolia	2.0	Cineole	Medicinal
E. dives	3.0 to 4.5	Piperitone, phellandrene	Source of piperitone for manufacture of thymol and menthol
E. dumosa	1.5 to 2.0	Cineole	Medicinal
E. globulus	1.0	Cineole and eudesmol	Medicinal
E. goniocalyx	2.0 to 2.5	Cineole and eudesmol	Medicinal
E. leucoxylon	2.0 to 2.5	Cineole	Medicinal
E. macarthurii	2.0	Geraniol, eudesmol	Perfume
E. polybractea	2.0	Cineole	Medicinal
E. radiata ssp. *radiata*	3.0 to 5.0	Cineole, terpineol	Medicinal, disinfectant, flotation

In recent years the USSR has been a leader in experimentation with a dense crop of eucalypts and mechanical harvesting of the leaves for essential oils on a very short rotation (Linnard, 1969). The USSR suffers from severe winter cold and annual leaf crops may prove the most profitable method of utilizing eucalypts. The principles followed are:

1. Stools must be protected against frost. Careful weeding, soil cultivation and fertilizing are necessary. A spacing of 2 × 2 m is used — 2 000 or more per hectare.
2. Mechanical harvesting of the shoots. It may be advantageous to harvest twice a year.
3. Frequently as many as 30 shoots may develop from a stool. It is recommended that when they are about 10 cm long they should be thinned out to leave only 6-10 of the biggest shoots well spaced around the stool. Stool height should not exceed 10 cm.
4. Insect attack on the leaves should be controlled chemically.
5. Leave one shoot per stool at harvesting. This may be killed by frost but the stools coppice better if one shoot is left.
6. Yields are 8 metric tons of green leaves in two years, 12 tons in three years. Possibly equivalent yields with annual or twice-yearly mechanical harvesting.

Plantation eucalypts already dominate the world trade in eucalyptus oil. According to statistics reported in Small (1977), during the period 1970-74 oil from Australian natural forests accounted for only 8.8 percent of world trade. In the same period oil from plantations in Portugal made up 44.2, Spain 13.6, Brazil 12.0 and Swaziland 6.3 percent.

Tannin

The only species which have been used for tannin production in Australia are *E. astringens*, the bark of which is sufficiently rich in tannin to warrant export in its crude state; *E. wandoo* and *E. accedens* of which both wood and bark are used as the basis of an extraction industry in Western Australia; and *E. diversicolor*, the bark of which is often treated industrially.

The bark of many other species has a high tannin content. The USSR (Linnard, 1969) reports a bark tannin yield of 12.4 percent for *E. nitens*. *E. alba* contains 30 percent.

Other chemicals

Another chemical of commercial interest to be obtained from eucalyptus leaves or bark is the drug rutin, which is a significant drug for therapeutic use. It is used to affect the permeability of the extremities of blood capillaries and in several other medicines. Rutin is produced in the leaves of *E. macrorhyncha* and *E. youmanii*. The leaves of *E. macrorhyncha* produce about 11 percent and the leaves of *E. youmanii* up to 18 percent. The forests where *E. macrorhyncha* can be pollarded for rutin in Australia are extensive, but the occurrence of *E. youmanii* is restricted to a small area on the New England tableland in New South Wales, mainly in national parks. The exploited *E. macrorhyncha* woodland looks very ugly after harvesting unless the crowns of the pollarded trees can be used for firewood. If this can be arranged subsequent harvesting would be less objectionable.

Both *E. macrorhyncha* and *E. youmanii* can be planted and grown for a mechanically harvested leaf crop. *E. macrorhyncha* handles fairly easily like a normal eucalypt crop. *E. youmanii* is somewhat temperamental and more work must be done on it. Healthy plants of *E. youmanii* are most attractive with very large vigorous leaves.

Liqueurs

Eucalypts are not much used for non-medicinal food purposes except where processed into honey by bees. One interesting use is the preparation of the liqueur "Eucalittino" by the Trappist monks at the Basilica of Tre Fontane, near Rome, the supposed site of the martyrdom of St Paul. This liqueur has been prepared and sold at Tre Fontane for more than 100 years (Jacobs, 1970).

11. Yields

The importance of measurement and estimate of yield

Owners and managers of forest plantations know the volume or weight of the wood they sell and the price they get for it. Frequently they do not know accurately the productivity of different sections of their estate or what rotations they should aim for on different sites. Knowledge of site productivity or quality and the distribution of areas of similar site quality is necessary for the effective management of estates, particularly substantial estates which may have to plan for expensive processing plants to absorb large quantities of produce. The plantation manager should have reliable volume tables giving the volume of trees of different sizes and preferably the log sizes which can be cut from these trees; he should also have a map showing readily recognizable site qualities, and yield tables showing the volumes which may be expected at different ages of his crop. If these management tools are available, he can work out such vital information as the rotation giving the best volume return or the rotation giving the best financial return.

These management tools have been available for many decades for European plantations, which usually have long rotations of 40 to 100 years, and in the last few decades very good volume and yield tables and site-quality maps have been prepared and published for some of the fast-growing conifer plantations in the United States, South Africa, New Zealand and Australia. These conifer plantations may be managed on rotations as short as 20 to 40 years, and very large industries are already dependent on accurate calculation of their yield.

At the present time, very large eucalypt plantations are coming into production in the lower and middle latitudes of the world and these vigorous plantations will be cut on shorter rotations than have been used in most other forest crops. On certain sites the rotation giving the greatest financial return will be as low as six years. Rotations will vary from six to twenty or so years. It is important that accurate volume and yield tables be prepared for these plantations and that they clearly state how the yield is defined. Several good studies have been made and some of them will be referred to in this chapter. More published yield tables are needed and a plea is made that they indicate precisely what is included in the listed volumes and, if possible, include factors for the calculation of bark volume, branch volume and stump volume. All statements of yield should indicate whether the figures are representative of big areas or are from small plots.

For an explanation of the most commonly used mensurational symbols, the reader is referred to Appendix 3.

Single-tree growth: volume tables

The volumes of single trees measured to different parameters are the starting point for the estimation of yields. Volume tables for eucalypts have been published in several countries, such as those for *E. grandis* in Uganda (Kingston, 1972b), South Africa (Wattle Research Institute, 1972) and India (Chaturvedi and Pande, 1973; Pande and Jain, 1976); for *E. occidentalis* and the hybrid *E.* × *trabutii* in Italy (Ciancio and Hermanin, 1974); for *E. tereticornis* (Mysore gum) in India (Chaturvedi, 1973); for grouped species in Brazil (Heinsdijk *et al.*, 1965); for *E. globulus* in Italy (Ciancio, 1966); for *E. camaldulensis* in Italy (Ciancio, 1966, 1970) and in Israel (Kolar, 1961). Each of these tables shows the volumes estimated as contained in trees of a range of total tree height (h) and overbark diameter at breast-height or 1.3 m (d). Although the independent variables of height and diameter are common to all the above tables, the exact definition of "volume" may vary in accordance with end use and local tradition. Possible variations are:

Solid volume or stacked volume

All the above tables are expressed in solid volume. In cases where produce is sold for fuelwood, it may be desirable to express volume as stacked. Factors for converting true to stacked volume which have been used are × 1.6 for *E. globulus* in India and × 1.54 for *E. grandis* in Uganda. In Brazil it was found that the factor varied from 1.9 for small trees (5- to 7-cm diameter) to about 1.4 for large trees (30 cm in diameter) (Heinsdijk *et al.*, 1965).

Branchwood

All the above tables refer to stem volume. Branchwood is excluded. The tables do not quote factors for converting stemwood volume to stemwood plus branchwood volume. However, limited information is available from other publications. In studies in young 4-year-old *E. globulus* plantations in Australia (Cromer *et al.*, 1975), it was found that branches accounted for 20 percent and stem for 80 percent of the weight of above-ground wood plus bark. In *E. microtheca* plantations in the Sudan Gezira aged 8½ to 11½ years, branches formed 4.5 percent and stems 95.5 percent of overbark volume, both measured to 5-cm top (Waheed Khan, 1966); the trees included a number of two- and three-stemmed trees, as well as single stems. In Sicily measurements in the first coppice rotation showed that the proportion of overbark volume to 2- to 3-cm tops contributed by branches decreased from 25 percent at age 5 years to 7.5 percent at age 10 years in *E. camaldulensis* and from 9 percent at age 5 years to 4 percent at age 10 years in *E. globulus* (Cantiani, 1976); there were several coppice shoots per stool.

Stump volume

In two cases (Chaturvedi and Pande, 1973; Wattle Research Institute, 1972) stem volume is stated as being to ground level and therefore includes stump volume. In other cases it is assumed that stem volume excludes stump volume. The Uganda volume tables for *E. grandis* include a table showing stump volume as a proportion of stem volume — excluding stump. The following extract summarizes the table by 5-cm BH diameter classes, expressed as percentages. Average stump height in Uganda may be considered as about 15 cm (Kingston, 1977).

Diameter (cm)	Ratio stump volume/ stem volume less stump
5	5.7
10	2.8
15	1.8
20	1.4
25	1.3
30	1.3
35 and above	1.2

Another conversion table for *E. grandis* has been published (Wattle Research Institute, 1972). It differs from Uganda's in that it is related to tree height, instead of tree diameter, it makes allowance for differences in stump height, and the stump volume is expressed as a percentage of stem volume including stump. The following extract summarizes the table for selected tree and stump heights.

Total tree height (m)	Height of stump, including kerf wastage (cm)			
	12	18	24	30
	. . . . . . *Percent*			
12.0	3.2	4.8	6.4	8.0
15.0	2.3	3.5	4.6	5.8
18.0	1.8	2.7	3.6	4.5
21.0	1.5	2.3	3.1	3.8
24.0	1.4	2.1	2.8	3.5

Top diameter

Some of the above tables (e.g., Uganda, Brazil) include stem volume to the tip. Others (India, Italy, South Africa) include stem volume to a top diameter of 5 cm overbark. The Uganda tables for *E. grandis* show volume to 10 cm and 20 cm top diameter, in addition to total stem volume; those for South Africa express similar information for a range of top diameters as a percentage of total volume to 5 cm top diameter.

The Uganda utilizable volume tables show volumes corresponding to two independent variables (d and h) while the South African tables include only one independent variable (d). However, the differences in *percentage* of utilizable volume in the Uganda tables caused by height differences within the same diameter class are very small. The following extract therefore ignores height. For Uganda. the percentage volume figures have been added for purposes of comparison.

E. grandis. Underbark utilizable volume to 10 cm and 20 cm top as a percentage of total [1] underbark volume

Diameter (cm)	Total volume	Top diameter (cm) 10		20	
		Utiliz-able volume	Percent	Utiliz-able volume	Percent
15 Uganda (h = 15 m)	.093	.070	75.3	—	—
15 South Africa			74.5	—	—
20 Uganda (h = 20 m)	.217	.195	89.9	—	—
20 South Africa			91.5	—	—
25 Uganda (h = 25 m)	.420	.401	95.5	.209	49.8
25 South Africa			95.9		45.5
30 Uganda (h = 30 m)	.720	.704	97.8	.477	66.3
40 Uganda (h = 40 m)	1.692	1.674	98.9	1.431	84.6

[1] In Uganda total underbark stem volume to tip, excluding stump. In South Africa total underbark stem volume to 5 cm top, including stump. In both cases it is assumed that there is no minimum utilizable log length.

It can be seen that, over the range of diameters covered by both tables, the percentage of utilizable volume differs very little.

Bark

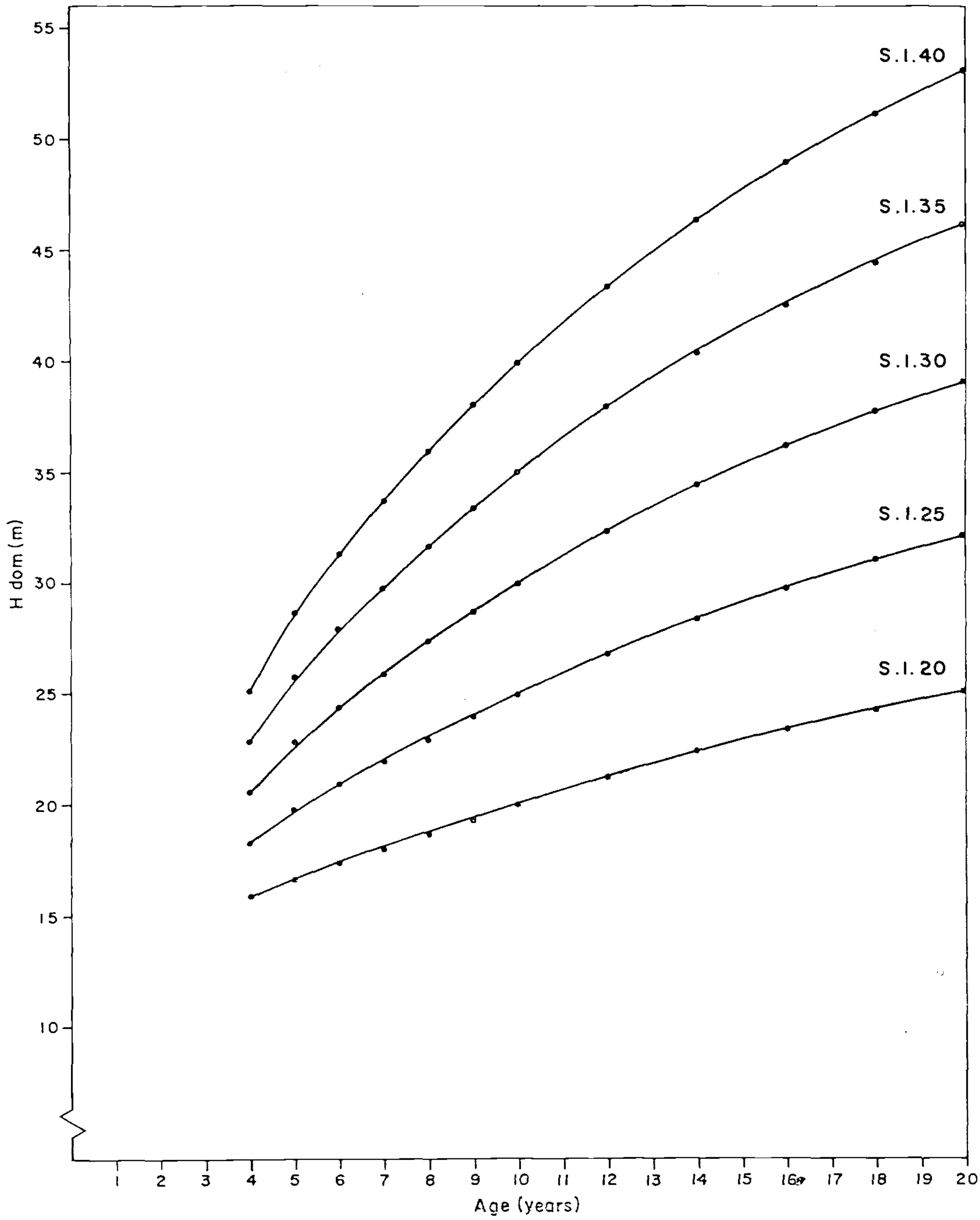
Most of the above volume tables give volumes both overbark and underbark. Others provide tables of bark percentage to facilitate conversion.

Some comparative figures for bark percent presented in, or derived from, the tables are as follows:

Source of information	Total height (h) in m and overbark diameter at 1.3 m (d) in cm			
	h10 d10	h15 d15	h20 d20	h30 d30
E. occidentalis	*Bark percent by weight*			
Italy (Ciancio and Hermanin, 1974)	(18.3)	(15.5)	14.1	—
	Bark percent by volume			
E. globulus	d10	d15	d20	d30
Italy (Ciancio, 1966)	19.8	16.4	15.1	—
E. camaldulensis				
Italy, Sicily (Ciancio, 1966)	30.0	24.2	21.6	—
Italy, Basilicata (Ciancio, 1970)	28.1	25.2	22.8	—
E. tereticornis	h10 d10	h15 d15	h20 d20	h30 d30
India (Chaturvedi, 1973)	29.0	24.8	23.3	—
Mixed species				
Brazil (Heinsdijk *et al.*, 1965)	21.8	19.5	16.9	13.6
E. grandis				
India (Pande and Jain, 1976) Age 6	30.4	15.9	12.9	10.8
India (Pande and Jain, 1976) Age 14	30.8	16.9	14.2	12.8
South Africa (van Laar, 1961)	18.2	16.3	14.8	12.6
Uganda (Kingston, 1972b)	12.1	13.9	13.5	13.5

Figures in parentheses have been derived from the published table by interpolation.

Most figures quoted (Uganda is an exception) agree in demonstrating that bark percent decreases with increasing size of tree. On short rotations (d = 15-20 cm) a bark percent of about 15 percent can be expected in species such as *E. grandis* and *E. globulus*, and a somewhat higher value (20-25 percent) in species such as *E. tereticornis* and *E. camaldulensis*.

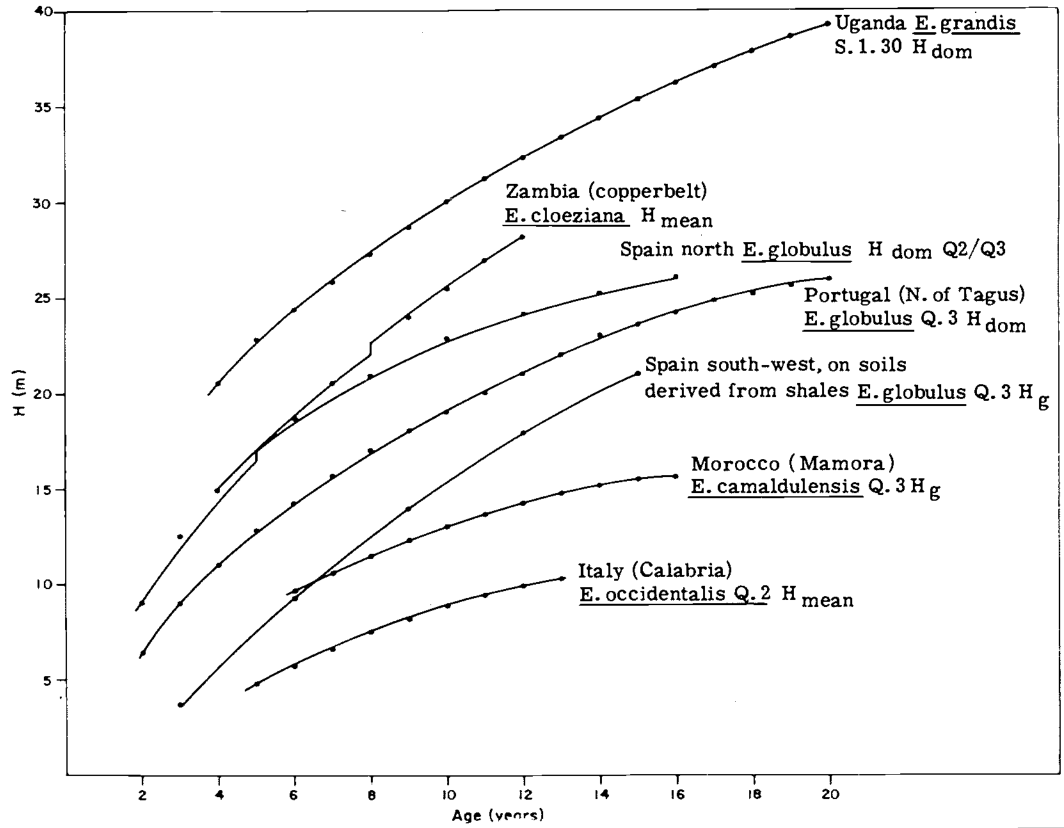


XVI Dominant height/age curves for *E. grandis* in Uganda

FORM FACTORS

Extracts from some published eucalypt volume tables are shown in Appendix 2, together with the corresponding form factors. Where published, the formula for calculation of volume is given also. Points of interest are:

1. The figures from Uganda show how important it is to *know* whether volume or yield tables are constructed on an overbark or underbark basis. The overbark volumes to 10-cm overbark are consistently greater than the total underbark volumes, although a significant section of the top of the



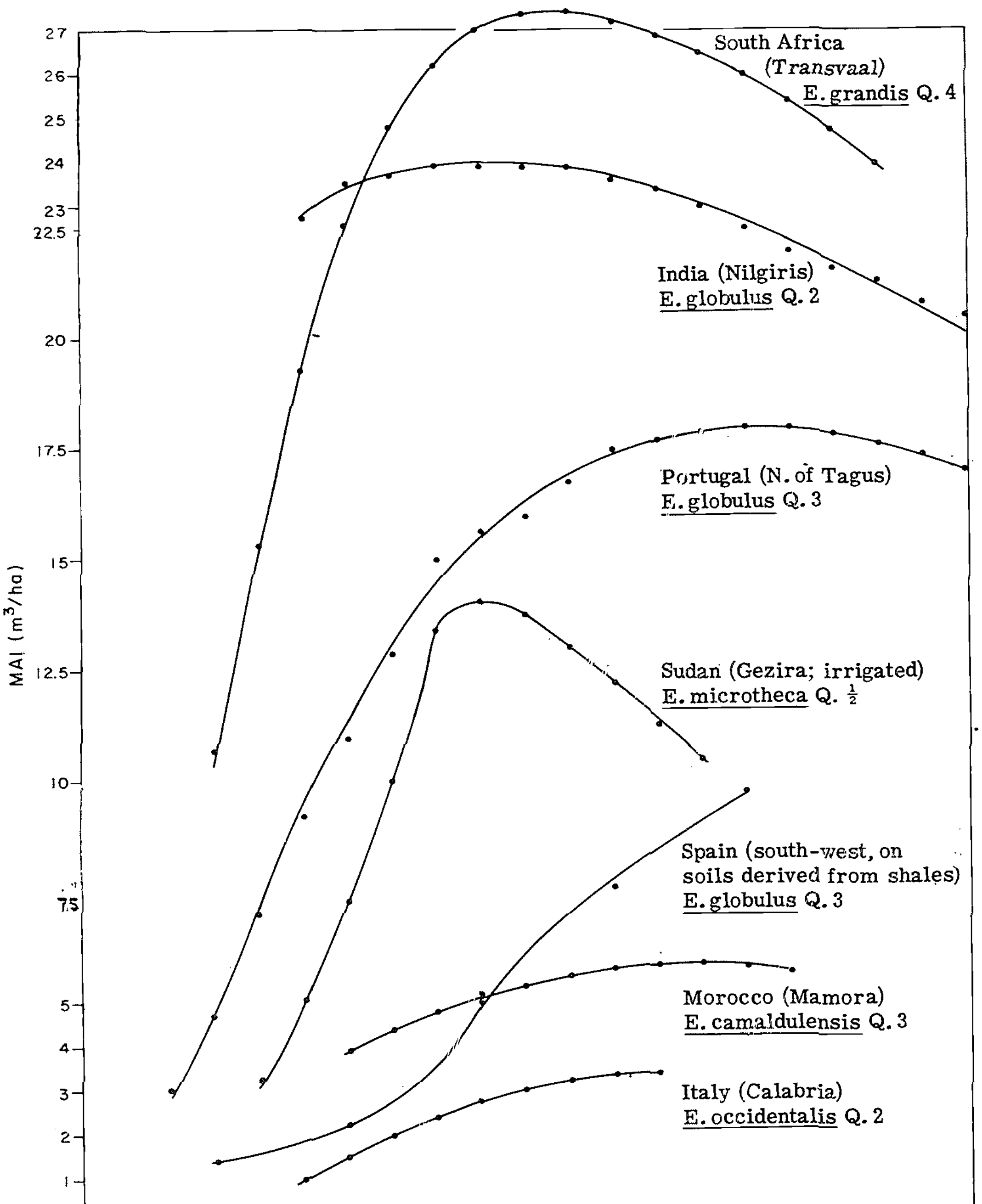
XVII Height/age curves for median site quality of various species in several countries

tree has been discarded. Yet many published reports of volume yield omit to state whether figures are overbark or underbark.

2. The overbark volume of a tree of h 20 m and d 20 cm (h20 d20), which may be considered as an average size for pole, pulpwood and fuelwood crops at rotation age, varies from 0.249 to 0.283 m^3, a difference of 14 percent of the smaller volume. The variation within a single species is nearly as much, from 0.251 to 0.282, or over 12 percent of the smaller volume. In some cases, part of the difference may be explained by differences in measuring volume (e.g., whether stump and top are measured), but most of the difference is likely to be caused by real differences in the shape of the trees.

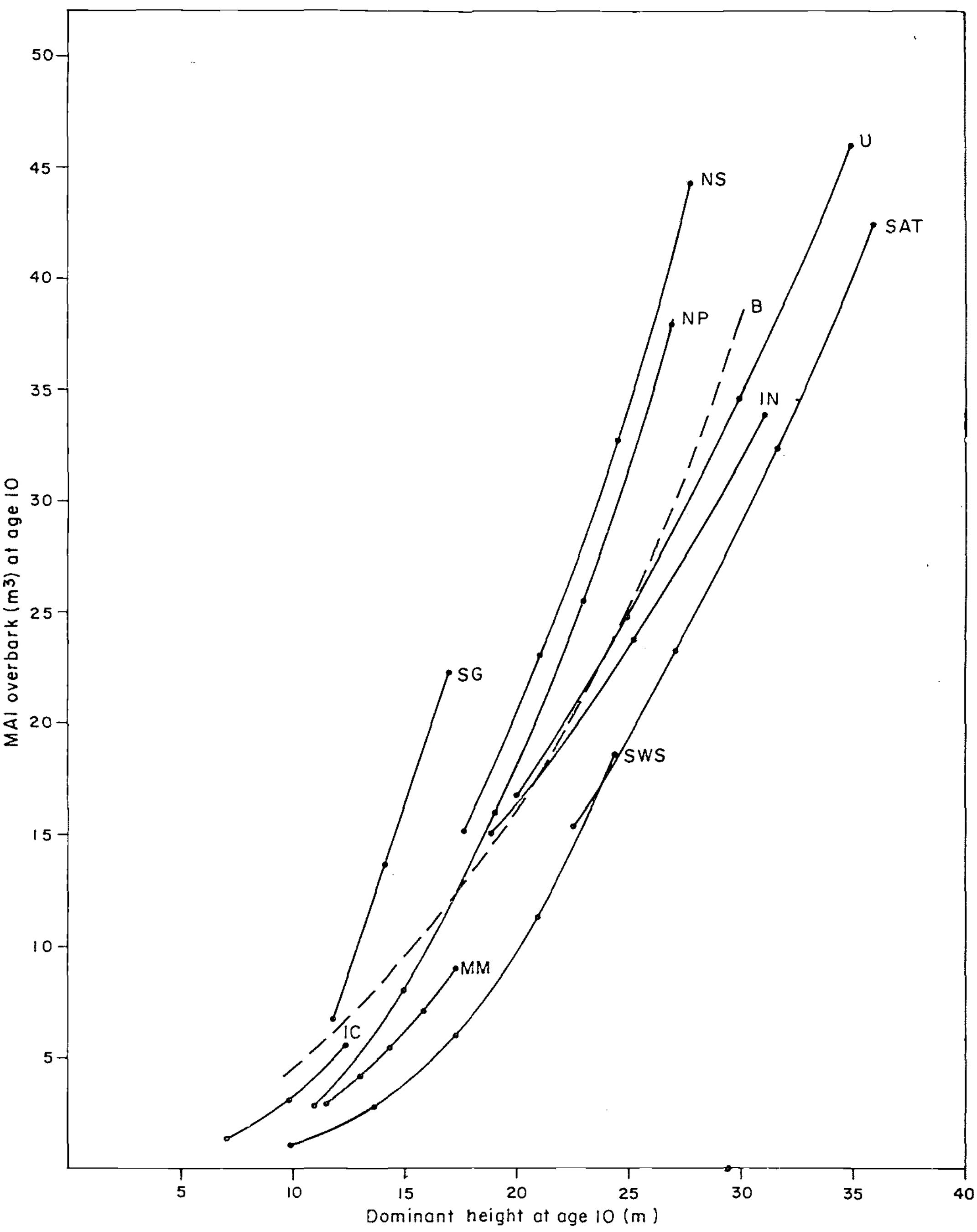
3. Since all the volume tables quoted measure the same independent variables of total height and overbark diameter at 1.3 m, any variation in volume must be caused by variation in form factor (f), the ratio of stem volume overbark to the product of basal area overbark and tree height. At h20 d20 the form factor varies from about 0.40 to 0.45. A wider range is evident from some of the yield tables shown in Appendix 3: in *E. globulus* in northern Spain (App. 3, Table A3.5) f exceeds 0.5, while in *E. camaldulensis* in Morocco (Mamora) (App. 3, Table A3.1) it is less than 0.35.

4. In some of the tables (Chaturvedi, 1973; Chaturvedi and Pande, 1973; Uganda silvolume) the form factor remains constant as the tree grows older and bigger. These examples are those in which a relatively simple formula, based on d^2h, has been used to derive volumes.



XVIII Mean annual increment (MAI)/age curves for median site quality of various species and countries

5. In most of the tables overbark form factor decreases with age and size of tree. In the Uganda tables (Kingston, 1972b) as an example, the factor decreases from 0.42 in small trees (h10 d10) to 0.39 in large trees (h40 d40). Further, in the Uganda tables, it is apparent that, within a given diameter class, an increase in height increases the form factor, within a given height class an increase in diameter reduces the form factor; and that, as a tree grows in both diameter and height, the effect of diameter normally outweighs that of height, so that the form factor goes down.



XIX Relationship of MAI(OB) to dominant height at age 10 for various localities and species (see page 311 for explanation of abbreviations)

6. In the South African tables (Wattle Research Institute, 1972) the form factor increases with increasing size of tree because the effect of height (in increasing the form factor) outweighs that of diameter (in reducing it). In the *E. grandis* tables of Pande and Jain (1976), the form factor increases with increasing tree size up to h20 d20 and then decreases. This is in line with the findings of van Laar (1961) in *E. grandis*. Using true form factor (basal area at 10 percent of total tree height), instead of breast height form factor, he found that the factor increased up to about d35 and then decreased.

7. For the tables showing a consistent decrease in overbark breast height form factor with age (see 5 above), the decrease from h10 d10 to h20 d20 is in the range of 4-8 percent. It may be noted that the variation of underbark form factor is likely to be much less than that of overbark, since the decrease in bark percent with increasing tree size tends to compensate for the decrease in overbark form factor. Yield tables published in Uganda (Kingston, 1972a) are expressed in "silvolumes," using the formula:

$$v_u = g \times h \times .3667$$

where v_u = stem volume underbark to 5-cm top
g = overbark basal area at breast height (1.3 m)
h = total tree height
.3667 = conventional form factor which does not vary with size of tree

8. The tables by Pande and Jain (1976) are of particular interest, since they are the only ones to introduce age as one of the independent variables. They show that, in *E. grandis* crops in southern India, slow-grown (and older) trees have a higher form factor than fast-grown (and younger) trees of the same height and diameter.

The above discussion refers to "standard" or double-entry volume tables which include both diameter and height as independent variables. "Local" or single-entry (diameter) volume tables, which are simpler to apply, have been compiled by Ciancio (1966), Ciancio (1970), and Heinsdijk *et al.* (1965) where they may be compared with double-entry tables for the same species and sites.

Height growth as a measure of site quality

The yield tables reproduced in Appendix 3 reveal large differences in yield within a single species. Even when identical seed source and management practice are used, yield varies according to the quality or relative productivity of the site for the species. Forest managers have long recognized this fact and have developed tables, derived from detailed measurements in sample plots, to show the yield that may be expected at different ages on different sites.

If yield tables exist for a species, their applicability to a plantation requires an estimate of the quality of the site. The relationship of height to age is commonly used as a measure of site quality, since measurement of height is much easier than measurement of volume, the parameter which might reflect site productivity most accurately; and since height, especially dominant height, is less affected by management practices, e.g., spacing, thinning, than the other easily measured parameter, breast-height diameter.

"Site class" or "quality class" is defined (Ford-Robertson, 1971) as "a measure of the relative productive capacity of a site for the crop or stand under study;" while "site index" is defined as "a particular measure of site class, based on the height of the dominant trees in a stand at an arbitrarily chosen age." In some of the examples shown in Appendix 3, the system of site or quality classes is used, the most productive site being class 1. In others the site index system has been used, based on the dominant height at age 10, e.g., site index (SI) 30 indicates a site on which dominant height is 30 m at age 10.

As an example, Figure XVI shows the development of dominant height in relation to age and site quality for *E. grandis* in Uganda. Similar graphs may be produced readily from the other tables in Appendix 3. The Uganda example is for one of the fastest-growing species in the world, growing in a climate to which it is well suited; dominant height growth over the first ten years varies from 2 m a year on the poorest to 4 m a year on the best sites. The site curves are average for the country, but there is evidence that the shape of the curve for a given site index may vary according to local conditions. Kingston (1974) showed that, in areas with a relatively low moisture deficit (MD), initial height growth was slower than in areas of high moisture deficit, but that later growth was more rapid; both areas were site index 25 (at age 10). The data were:

Age		h_{dom}	
	MD 300	MD 500	MD 700
5	16.07	17.27	18.66
10	25.21	25.06	24.91
15	31.11	29.50	28.04

A possible explanation is that, in the dry and less cloudy areas, day temperatures, sunshine hours and photosynthesis are greater, while night temperatures and respiration are lower; early growth is therefore more rapid than in the moist areas. As the trees grow bigger, competition for moisture becomes more intense and drought stress limits growth more severely in the dry areas.

There are other factors which may cause an apparent change in site quality in the course of the history of a plantation. Fertilization or drainage may improve it. The presence of an impermeable layer in the soil, changes in drainage pattern causing accumulation of salts, or incidence of pests and diseases may depress it.

A further stage in planning production from managed plantations is the preparation of maps showing the areas occupied by the various site classes and the calculation of the total area of each. Information available on the relative areas of each site class is sparse, even for those countries which have published yield tables. In the case of the Calabria yield tables for *E. occidentalis*, the distribution of sample plots was: 33 percent in class 1 or better, 50 percent in class 2 and 17 percent in class 3 or worse. Since the plots were systematically arranged, it can be assumed that the distribution of the classes over the whole plantation area was similar. In the Transvaal *E. grandis* tables, approximately 80 percent of the plantation area was considered to fall in the median class (site index IV) and about 20 percent in the poorest class (site index VI). In Brazil distribution of sample plots in stands over 4 years old was: quality class (QC) 1, 4 percent; QC 2, 10 percent; QC 3, 28 percent; QC 4, 35 percent; QC 5, 21 percent; QC 6, 2 percent.

In the absence of precise information, it is assumed that the median quality class or site index shown in each yield table in Appendix 3 is most representative of the area covered by the table. Height/age curves for some of these median classes are shown in Figure XVII. In northern Spain, where four quality classes are recognized, the curve is drawn midway between the h_{dom} curves for the second and third quality classes. It can be seen that some of the curves are for dominant height and some for mean height, so that direct comparison is not possible. In Zambia, the arithmetic effect of thinning on mean height can be seen. The figure indicates the range in height growth recorded from a number of well-documented plantation areas, as well as the variation in the shape of the curves.

Yield tables

Some examples of eucalypt yield tables are reproduced in Appendix 3. They show that mean annual increment (MAI) can vary between different species and different site qualities, from about 1 m^3 to about 50 m^3/ha.

Comparison of the yields from the median site quality class in each yield table is likely to be more realistic than those from the highest or lowest quality classes, since the latter often occupy a relatively low percentage of the total plantation area in a region. Figure XVIII compares the MAI of several median quality classes. Comparisons can only be approximate, since silvicultural treatment, e.g., the intensity of site preparation, may vary greatly and can have a considerable effect on early growth rate. Stocking also varies, but the majority of the tables are for short-rotation pulpwood or fuelwood crops, with no thinning and with stockings which range from 800-1 500 stems/ha at harvesting age. It can be seen that there is a great deal of variation in the shape of the curves.

E. grandis is the fastest-growing species represented in the yield tables, with a MAI of 25-30 m^3/ha at age 10 on median sites. It is closely followed by *E. globulus* ssp. *globulus* in the Nilgiris of India with 24 m^3 and in the northern coastal areas of the Iberian Peninsula, where yields on median sites vary from 16 to 28 m^3. In the drier and more Mediterranean climates of southern Spain and Portugal, the yield of ssp. *globulus* is much lower, varying from 4 to 12 m^3 according to soil type and the severity of the dry season.

The species *E. cloeziana* in the Copperbelt of Zambia produces 18 m^3. The Brazil yield tables indicate a yield of about 22 m^3 for the median site quality 3/4 for the species measured which were a mixture of "fast" (e.g., *E. saligna, E. grandis*) and "medium fast" (e.g., *E. citriodora, E. robusta*).

In the more severe climatic conditions of Morocco, *E. camaldulensis* produces 5.4 m^3, while in Calabria (Italy), which has a combination of difficult clay soils and a long dry season, *E. occidentalis* produces 3 m^3. In the special case of the irrigated plantations of *E. microtheca* in the Sudan Gezira the yield from the median SQ I/II is about 14 m^3. However, yield is closely related to the amount of water applied and this is often severely restricted for forest plantations in the dry season, because of the conflicting needs of agricultural crops. Average yield for much of the area is therefore likely to be close to the SQ II figure of 6 to 7 m^3 (Jackson, 1977).

In several of the yield tables, the yield on the best sites in a region is approximately four times that on the poorest sites, the median site being roughly intermediate with about twice the yield of the poorest sites. In a few cases the range from the best to the poorest sites is much greater than this, e.g., about 13 times in Portugal north of the Tagus and 18 times in southwest Spain on shale soils.

The age at which MAI reaches its maximum falls between 8 and 20 years in most cases, although there are some exceptions, with culmination apparently at less than 4 years at the lower site indices in Uganda and at over 20 in the lowest quality class in Portugal north of the Tagus. The effect of site quality on the age at which MAI culminates is not consistent. In the cases of *E. globulus* ssp. *globulus* in Portugal (north of the Tagus), *E. occidentalis* in Italy (Calabria) and *E. grandis* in South Africa (Transvaal), the lower the site quality the later the culmination of MAI. In ssp. *globulus* in Portugal (south of the Tagus), in southwest Spain and in India (Nilgiris) and in mixed species in Brazil, MAI culminates at the same age irrespective of site quality. In *E. grandis* in Uganda, ssp. *globulus* in northern Spain and *E. camaldulensis* in Morocco, the lower the site quality the earlier the culmination of MAI.

The relationship of diameter to height increment is affected by stocking. However, the yield tables indicate that, where stocking is constant, the diameter/height relationship may be related to site index or site quality; the higher the site index (a fast-growing species on a high-quality site) the higher the ratio of height to diameter. Table 11.1 shows some examples.

The great difference between the yields from good and poor sites raises an important question — why plant the poor sites? In some cases the plantations fulfil an essential protective function such as the control of soil erosion on hill slopes or the provision of shelter to agricultural crops. The yield of wood is a useful bonus but is not the primary purpose of such plantations.

Another important policy factor arises wherever there is a wide range of site qualities within an area of plantations for wood production. The protection and management of a substantial area of land are assisted if it is all under systematically managed crops. If the poorer sections are allowed to become wasteland, the danger of mis-use of the whole is heightened. The forest manager must try to get a crop from all his land, and accept the fact that there will be a range of productivity classes.

Where there is extreme variation between the yield from the best and the poorest sites in a planting area, there may be a case for considering a different species on the poorest sites. For example, on the poorest ssp. *globulus* sites in the Iberian Peninsula, appropriate provenances of the more drought-resistant *E. camaldulensis* are preferred. However, the superior hardiness of *E. camaldulensis* has to be balanced against the superior pulping quality of ssp. *globulus*, for which there are established markets in Spain and Portugal. Where the low yield of a site can be ascribed to a particular

Table 11.1 Ratio of height (m) to diameter (cm) at age 10

E. grandis	Site class	II	IV	VI	N (stems/ha)
S. Africa (Transvaal)	Height at age 10	34.8 (age 9)	28.4	20.2	1 100
	Ratio h/d	1.76 (age 9)	1.55	1.19	
E. globulus	Site class	I	III	IV	
northern Spain	Height at age 10	22.0	16.0	13.0	2 500-2 800
	Ratio h/d	1.57	1.42	1.31	
E. globulus	Site class	I	III	V	
Portugal [1] (north of the Tagus)	Height at age 10 [1]	27.0	19.0	11.0	1 100
	Ratio h/d [1]	1.39	1.26	1.29	
E. camaldulensis	Site class	I	III	V	
Morocco (Mamora)	Height at age 10	15.6	13.0	10.4	800
	Ratio h/d	0.95	0.95	0.95	
E. occidentalis	Site class	1	2	3	
Italy (Calabria)	Height at age 10	11.2	8.8	6.4	970
	Ratio h/d	0.91	0.89	0.88	

[1] Reference is to dominant height.

deficiency, it may be possible to increase the yield by suitable treatment, e.g., fertilization.

The relationship of MAI overbark at age 10 to dominant height (site index) at age 10 for various yield tables is shown in Figure XIX. In order to make the curves as nearly comparable as possible the following conversions were made before plotting:

(*a*) For Uganda and South Africa (Transvaal), underbark MAI was converted to overbark MAI by use of the bark percentage figures available for these countries.

(*b*) For Morocco, southwest Spain and Italy, mean height was converted to dominant height by multiplying by the factor 1.11, which was found to be suitable for *E. grandis* in Uganda (Kingston, 1972a) and is close to that used for the same species in South Africa (van Laar, 1961).

Abbreviations for the countries and areas represented in Figure XIX are as follows:

B = Brazil (mixed species)
IC = Italy, Calabria (*E. occidentalis*)
IN = India, Nilgiri hills (*E. globulus*)
MM = Morocco, Mamora (*E. camaldulensis*)
NP = Northern Portugal (*E. globulus*)
NS = Northern Spain (*E. globulus*)
SAT = South Africa, Transvaal (*E. grandis*)
SG = Sudan, Gezira (*E. microtheca*)
SWS = Southwest Spain, shale and slate soils (*E. globulus*)
U = Uganda (*E. grandis*)

There are still considerable differences between the curves, which may be partly due to differences in methods of measuring volume (inclusion or exclusion of stump and top), differences in stocking affecting the height diameter relationship and differences in form factor. The general shape of the curves, however, is fairly similar. The one exception is *E. microtheca* in the Sudan Gezira, which is a special case because many of the trees there are two- or three-stemmed; this may have depressed dominant height growth while increasing volume growth, in comparison with single-stemmed trees.

Other data on yield for certain species

Although only a few yield tables are available for extensive areas, less detailed information on yield can be quoted for a number of species of potential interest. The precise definition of mean annual increment (MAI) is often unknown. In cases where the prescribed definitions of IUFRO (1965) are followed, volumes would refer to total overbark stem volume from ground to tip (i.e., including stump and tip but excluding branches) and MAI, expressed in m^3/ha/yr, would refer to the total volume increment of the stand per hectare at a given age, including the volume of thinnings, divided by that age.

E. camaldulensis

Growth varies greatly according to climate and soil. A MAI of 20-25 m^3 is reported from Argentina, 17-20 m^3 from Turkey and 20-30 m^3 on the best sites in Israel. On the poorer and drier sites much lower yields can be expected. In Portugal the range is from 2 to 10 m^3, very similar to that in the Morocco yield tables in Appendix 3. In Uruguay the range is from 4 to 18 m^3. In Italy an average of 6.5 m^3 is expected. On the driest sites in Israel the MAI is only 2 m^3. In the median Guinea zone of Nigeria a MAI of 15-20 m^3 is expected (Jackson, 1974).

E. cloeziana

In Malawi a MAI of 19 m^3 at age 10 is reported, very close to that of the Zambia Copperbelt plantations shown in Appendix 3. In the median Guinea zone of Nigeria a MAI of 10-15 m^3 is expected.

E. deglupta

Ovington (1972) quotes a MAI of 31 m³ at ages 12-15 in one plantation in Papua New Guinea. This is in line with the more recent country statement which reports a standing volume of 520 m³/ha at age 20 for a stocking of 133 stems/ha, a main crop MAI of 26 m³, excluding thinnings. In the Philippines a range of 17-25 m³ is expected (Tagudar, 1974) and in the Ivory Coast 30 m³.

E. globulus ssp. *globulus*

In Peru the average MAI in the highlands is 10 m³. In Ethiopia the average under present management is 10 m³ at age 10 and the best 20 m³, but with improved management on favourable sites 35 m³ are considered possible. In Uruguay on good, but not exceptional, sites a MAI of 25 m³ is obtained.

E. globulus ssp. *maidenii*

A MAI of 14-19 m³ is reported from Malawi. In Tanzania the best plantations in the Southern Highlands had a MAI of about 35 m³ at age 13 (Streets, 1962).

E. gomphocephala

In Morocco in the Mamora area an average MAI of 10 m³ at age 9 is expected, although up to 27 m³ have been recorded on exceptional sites. On highly fertile soils in the Deroua area with irrigation for the first five years, yields have varied between 21 and 44 m³. On more typical sites in the semi-arid zone, yield is less than 7 m³. In Israel it varies from less than 6 m³ on sandy soils to over 10 m³ on rendzina soils.

E. grandis

The range of yields reported is of the same order as those in the yield tables in Appendix 3. In Australia (New South Wales), Angola and Kenya MAIs between 20 and 22 m³ are reported. In Zambia the MAI is considerably reduced on the drier, more southerly sites. At age 4 the MAI is 10 m³ on the central plateau and 8 m³ on the southern plateau, compared with 24 m³ in the Copperbelt (Appendix 3). In Zimbabwe the MAI on rainfed sites varies between 7 and 30 m³ and in irrigated plots it is as high as 40 m³. In Argentina on the red soils in Misiones province a MAI of 50 m³ has been obtained at 14 years, while on good sites in Uruguay the MAI varies between 35 and 45 m³. In the median Guinea zone of Nigeria a MAI of 13-18 m³ is expected.

E. microcorys

In Malawi a MAI of 15-19 m³ at age 10 is reported.

E. nitens

Underbark MAIs cited by Hillis and Brown (1978) for unthinned 12-year-old plots in Australia were 15 m³ in Tasmania and 21 m³ in Victoria.

E. occidentalis

A MAI of 2 m³ is reported from Israel in Zone C (see country statement in Chapter 4) and 1 m³ in the still drier Zone D. This compares with the

1.5-6.5 m³ obtained in the moister conditions of Calabria, Italy (see yield tables in Appendix 3).

E. regnans

In New Zealand a MAI between 20 and 30 m³ at ages 9-14 has been recorded in several plots, but in one plot it was as low as 11 m³. A sample plot in a 9-year-old plantation in Victoria, Australia, had a MAI of 28 m³ (Carter, 1974).

E. robusta

In Papua New Guinea a MAI of 21 m³ has been recorded at age 4½ and stocking of 1 500/ha. In Madagascar the MAI varies between 10 and 35 m³ at age 11.

E. saligna

The fastest species in Hawaii, where a MAI of 42 m³ is commonly obtained and the best unfertilized plots produce 50 m³. The most widely planted species in Brazil, where the estimated national average MAI for mixed eucalypt species is reported as 18 m³.

E. tereticornis

In India, which has the biggest area of plantations of this species, the average MAI at 8 years of the better plantations in eight separate States is about 18 m³. The average of the poorer plantations in the same States is 4 m³.

On good sites in the Congo, Argentina, the Ivory Coast and Uruguay a MAI of 18-25 m³ is expected, but on poorer sites this drops to 12 m³ in the Congo and to 6 m³ in Uruguay. In Malawi the Zanzibar "C" strain has a MAI of 14 m³ at ages 8-12. In the median Guinea zone of Nigeria a MAI of 15-20 m³ is expected.

E. trabutii

Yield tables for *E. trabutii* (a hybrid of *E. botryoides* and *E. camaldulensis*) growing in Calabria, Italy, have been published (Ciancio and Hermanin, 1976). The MAI at age 10 is very close to that of *E. occidentalis* growing on the same site quality classes (QC) (see Appendix 3). *E. trabutii* grows more slowly initially, but by age 13 the MAI, 7.5 m³ on QC I, 4.2 m³ on QC II and 1.7 m³ on QC III, is higher than that of *E. occidentalis*.

Coppice yield

The previous section dealt with the yields which might be expected from the initial seedling rotation. For some species of eucalypt there is evidence that the next (first coppice) crop should give substantially higher yields. Métro (1955) quoted an increase of 20 percent as common experience in *E. globulus* ssp. *globulus* in Portugal. In Turkey an increase of 50 percent is expected in *E. camaldulensis*. In India the average MAI in first coppice in *E. tereticornis* crops from seven areas was 23 m³, compared with an average of 18 m³ in seedling crops on the best sites in eight States, but the localities were not identical.

More precise evidence is available from Sicily (Cantiani, 1976), where the increase at age 11 years was 93 percent in *E. camaldulensis* and 44 percent in *E. globulus* ssp. *globulus*, and from Kenya (Howland, 1969) where the increase was 50 percent in *E. grandis/saligna* at age 8 years.

In contrast, Carter (1974) quotes examples from South Africa in which yield was reduced in the first coppice crop of *E. saligna* and *E. grandis*. In *E. saligna* the decrease was 8 percent and a similar reduction occurred in each later coppice rotation. In Brazil the average MAI is estimated to be 21 m^3 in the seedling crop (rotation 7 years), 17 m^3 in the first coppice crop (rotation 5 years) and 15 m^3 in the second coppice crop (rotation 5 years), but the apparent decrease may be associated with the reduced rotation in coppice crops. In *E. gomphocephala* in Morocco there was an apparent decrease in the MAI at age 9 of 40 percent from the seedling crop to the first coppice crop, but *E. gomphocephala* is a weakly coppicing species; it is not lignotuberous and is not considered a coppicing species in Australia.

Provided that the species is a strong coppicer; the felling of the seedling crop is done carefully (see Chapter 5); and an average of 2-3 stems per stump is retained in the coppice crop, to compensate for any stumps that fail to coppice, then the first coppice crop should yield 25 percent or greater increase over the seedling crop. But the diameter of individual stems will be less at a given age.

There is very little information about the yield of second and subsequent coppice crops, but a gradual decline from that of the first coppice crop may be expected. For *E. globulus* ssp. *globulus* in Portugal, Métro (1955) quotes the second coppice crop as producing 80-100 percent of the yield of the initial seedling crop and the third coppice crop less than 80 percent. In India where four coppice crops of *E. globulus* ssp. *globulus* are grown, after the initial seedling crop, and the rotation of each crop is 15 years, a fall in yield of 9 percent in the third coppice rotation and of 20 percent in the fourth and final rotation is reported.

Yield in thinned plantations

Most eucalypt crops are grown on short rotations without thinning. Information on yields in thinned stands grown for sawlog production is sparse. Yield tables for heavily thinned *E. grandis* in the Transvaal in South Africa are shown in Appendix 3, and may be compared with the table for unthinned stands in the same area. Total volume yield is reduced by 15 percent, but diameter increment is nearly double that in the unthinned stand.

Weight yield

For some purposes, weight yield per hectare is more important than volume yield. Knowledge of the specific gravity of the wood under local conditions is necessary in order to convert volume to weight. In a few cases tables show directly the weight of wood produced at a given age or size, e.g., those for *E. globulus* ssp. *globulus* of Cantiani (1976) and for *E. occidentalis* of Ciancio and Hermanin (1974). In both these cases the weight is for freshly felled trees including bark, of which the specific gravity is about 1.075 for ssp. *globulus* and 1.1 for *E. occidentalis*.

Biomass

Studies of above-ground biomass production in young plantations of *E. globulus* ssp. *globulus*, as affected by fertilization, have been reported by Cromer *et al.* (1975). By age 4 there were big differences resulting from the treatments, the oven-dry weight in tonnes/ha varying from 6.3 in the unfertilized plots to 30.3 in the plots which received the most fertilizer. By age 6 production varied from 12.5 tonnes/ha in the unfertilized plots to 45 tonnes/ha in the plots which received the most fertilizer (Cromer, 1978). However, the percentages of the totals supplied by the different components were comparable in all treatments; the average is shown in Table 11.2. The proportion of leaves had shown a big decrease between age 2, when it varied between 46 and 33 percent of the total, and age 4, when it varied from 16 to 17 percent. The increase in the percentage of stem bark between age 4 and age 6 is somewhat surprising.

Table 11.2 Above-ground biomass percentages in ssp. *globulus*

	Age 4	Age 6
Stemwood	55.5	57.1
Stem bark	*11.5*	*14.6*
Total stem	67.0	71.7
Live branches	12.0	9.8
Dead branches	*4.5*	*2.9*
Total branchwood	16.5	12.7
Leaves	16.5	15.6

Little or no work appears to have been done on measuring total eucalypt biomass, including roots.

Factors affecting yield

Factors which affect yield in the genus *Eucalyptus* are discussed in other chapters. The main factors and the degree to which they may affect yield are indicated below.

SITE

As mentioned above, the yield of the same species within a geographic region commonly varies in the ratio of 4:1 between the best and the worst sites. In certain cases, e.g., ssp. *globulus* in the Iberian Peninsula, the ratio may be of the order of 10 or 15:1.

SPECIES

Within the same geographical area, commonly planted and healthy species may vary in yield in the ratio of 3 or 4:1, e.g., the difference between *E. grandis* and *E. sideroxylon* in the wattle-growing area of South Africa (Wattle Research Institute, 1972).

Provenance

In a wide-ranging species of great variability such as *E. camaldulensis*, the variation in yield between the best- and the worst-suited provenance for a given site is considerable. In examples of *E. camaldulensis* provenance trials quoted from Israel and Nigeria, the ratio of best to worst volume yield varied from 3:1 to 8:1 (Lacaze, 1977).

Silvicultural treatment

In the example of fertilization quoted above (Cromer *et al.*, 1975), the ratio of above-ground biomass production in the most heavily fertilized plots to that in the unfertilized plots was 6:1 in 4-year-old ssp. *globulus*. A ratio of the same order may be expected from differences in the intensity of site preparation and early weeding, operations which may make all the difference between vigorous growth and near-stagnation. In arid areas, growth may be directly related to the amount of irrigation water available (Foggie, 1967).

Pests and diseases

Yield may be affected severely by the appearance of a pest or disease on previously healthy crops. Ssp. *maidenii* in Muguga arboretum in Kenya grew very well for the first two years, after which both growth and form were severely depressed by heavy attacks of *Gonipterus scutellatus* (Gottneid and Thogo, 1975). Fungal diseases such as "pink disease" in India have similar effects.

Interaction

Interaction or differences in the relative performance of different species and provenances on different sites, or differences in the relative effects of different treatments on different sites and on different species and provenances, are commonly observed in eucalypts as in other genera. On a good "*grandis* site" such as Lushoto arboretum in Tanzania, *E. grandis* out-produces *E. salubris* by about 35:1 (Borota, 1969); on a typical semi-arid "*salubris* site," *E. salubris* would survive and grow, albeit slowly, where *E. grandis* would die. Fertilization may have a remarkable effect on naturally infertile soils but none at all on a rich volcanic loam.

Although some of the examples quoted are more extreme than will commonly be found in practice, they help to explain why, in such a variable genus as *Eucalyptus*, yields in published yield tables can vary by 50:1.

12. Costs of establishment and returns from eucalypt plantations

Tabulated establishment costs

In an effort to present a general picture of the overall financial aspects of raising eucalypts, and to identify possible economies and improvement of techniques through cost comparison, countries were asked to provide detailed and up-to-date data on plantation costs and returns. A tabular statement of the results of this survey covering the direct costs of eucalypt plantation establishment is presented in Table 12.1.

The table illustrates a great range of establishment costs as reported by different countries, from less than $100 to nearly $1 200/ha. Much of the variation can be attributed to differing techniques, site conditions, etc., but a substantial portion is also due to variable recording and accounting practices. On the whole, the data are fragmentary and incomplete and are not available in a form which allows valid comparison of costs. For this, more comprehensive information on work norms, wage rates, machine output and costings, incidental revenues, overheads and administrative costs, among other items, is required. The inflation prevalent in many countries during the past few years will have out-dated many of the costs.

Factors affecting establishment costs

As already mentioned, detailed analysis of the costs in Table 12.1 is not possible, since much of the variation is due to differences in local wage rates, in local capital and operating costs of mechanical equipment and in local methods of recording. It is, however, possible to identify certain site factors which have a major effect on the amount of *work* involved in successful establishment and thus, indirectly, on the cost. These are discussed below.

Clearing of woody vegetation

Where pre-existing woody growth is heavy, its clearing may constitute over half of total establishment costs. In contrast, on grassland sites the cost of this item is negligible. Examples are $630/ha for clearing and site preparation in dense high forest in the Ivory Coast, $277/ha in "miombo" woodland in Zambia, less than $20/ha on grassland sites in Sri Lanka, Lesotho and Uganda.

Grass

Since eucalypts are notoriously intolerant of grass competition, the vigour of local grass growth has a considerable effect on the intensity of establishment work, which may include ploughing before planting and frequent weeding between planting and canopy closure.

Table 12.1 Direct costs of establishing

Country	Date	Exchange rate		Nursery			Site preparation	
		Currency units	Equiv-alent in US$	Potted stock	Bare-root stock	Costs	Remarks	Costs
Argentina	1975	1 000 pesos	40.00	X			Clearing and burning; ploughing and discing in grassland	
Bolivia	1975	1 000 pesos	50.00		X		None	
Brazil	1975	10 cru-zeiros	1.20	X			Mechanical clearing and discing	
British Solomon Islands	1974	1 Austra-lian $	1.33	X		47	Poisoning and line cut-ting in logged forest	91
Chad	1975	1 000 CFA fr.	4.50	X			Clearing and subsoiling	
Colombia (warm)	1974	1 000 pesos	37.04	X		30	Ploughing and raking	33
Colombia (cool)	1974	1 000 pesos	37.04	X		61	Included as planting cost	
Comoros	1975	1 000 CFA fr.	4.50	X		225		90
Congo (on sands)	1971	1 000 CFA fr.	3.60	X		58	Clearing, burning, discing	26
Congo (on clays)	1971	1 000 CFA fr.	3.60	X		58	Clearing, burning, discing	61
Cyprus (on plains)	1974	1 pound	2.80	X		34	Mechanical clearing and ploughing	196
Cyprus (on slopes)	1974	1 pound	2.80	X		34	Mechanical construc-tion of terraces	252
Ethiopia	1975	1 dollar	0.48	X		40	Manual clearing and cultivation	14-41
Guyana	1974	1 G. dollar	0.45	X		119	Clear-felling and burn-ing	200
Iraq	1975	1 dinar	3.38	X			Clearing, ploughing	
Israel	1975	1 pound	0.17	X		122	Clearing, ploughing, road construction	93
Italy	1975	1 000 lire	1.49	X		364	Ploughing on plains, terracing on slopes	
Ivory Coast	1974	1 000 CFA fr.	4.50	X		90	Manual and mechani-cal clearing of high forest	630

eucalyptus plantations (US$ per hectare)

Planting and casualty replacement			Tending and protection		Total costs/hectare
Number of trees per hectare	Remarks	Costs	Remarks	Costs	
1 111-2 500			Frequent weeding for 2-3 years		500-600
625			Manual weeding in second year		250
1 372-1 667	Occasional fertilizing		Mechanical weeding mainly in first year		300-600
494-741	Line planting	40	Fertilizing, frequent manual weeding, climber cutting	133	311
1 111	Includes insecticide		Fire protection, watering, frequent weeding		540
1 666		19	Fencing, 4 mechanical/manual weedings, fertilizing	178	260
2 500	Includes some manual site preparation	48	Fencing, 3 manual weedings, fertilizing	224	333
2 500		90	2 manual weedings	90	[1] 540
1 600	Includes fertilizing and insecticide	79	Mechanical weeding over 15 years	55	[2] 245
1 600	Includes insecticide	26	Mechanical weeding over 15 years	69	[2] 241
746		230	1 mechanical weeding and spot cultivation	104	564
746		230	1 weeding	104	620
2 500		27-36	Manual weedings	14-39	95-156
2 197		30	3 weedings	133	482
625-1 111					203
1 200		373	Frequent spot hoeings and mechanical weedings	314	902
1 111			6 hoeings		1 192
1 250-1 600	Includes fertilizing	63	4 weedings	117	[3] 1 004

Table 12.1 Direct costs of establishing eucalyptus

Country	Date	Exchange rate		Nursery			Site preparation	
		Currency units	Equivalent in US$	Potted stock	Bare-root stock	Costs	Remarks	Costs
Jordan	1975	1 dinar	3.17	X			Ploughing	
Lesotho	1975	1 rand	1.45	X		47	Weighted avg. for occasional machine cultivation and ripping	12
Madagascar	1975	1 000 MG francs	4.25	X	X	43		34
Malawi (manual, Zone D)	1975	1 kwacha	1.15	X		7		32
(manual, Zone L)	1975	1 kwacha	1.15	X		7	Felling and burning, pitting and cultivation around pits	52
(manual, Zone M)	1975	1 kwacha	1.15	X		7		17
(mechanical, Zone D)	1975	1 kwacha	1.15	X		7		56
(mechanical, Zone L)	1975	1 kwacha	1.15	X		7	Clearing and stumping, complete disc-ploughing, two harrowings	86
(mechanical, Zone M)	1975	1 kwacha	1.15	X		7		26
Mozambique	1975	1 000 escudos	40.47	X		21	Clearing 50% of terrain, ploughing and discing	103
Nepal	1975	1 rupee	0.09	X		25	Site preparation, terracing, shrub cutting	106
Nigeria	1973	1 naira	1.52	X		15	Survey, roading, mechanical clearing, burning, ploughing	61
Papua New Guinea	1974	1 kina	1.44	X		15	Poisoning, survey, manual site preparation (after commercial clear-felling for chips)	80
Peru	1975	1 000 soles	25.84	X	X	107-142	Brush clearing	
Portugal (on plains)	1973	1 000 escudos	38.52		X	5-6	Ploughing, ripping and discing	41

plantations (US$ per hectare) *(continued)*

Planting and casualty replacement			Tending and protection		
Number of trees per hectare	Remarks	Costs	Remarks	Costs	Total costs/hectare
1 111			Weedings twice annually		190
2 153	Includes fertilizing	58	Includes fencing but not costs of 1-2 weedings	39-73	156-190
1 667-2 500	Includes fertilizing	102	1 spot-weeding and fire protection	49	[4] 254
1 330-2 200	Includes fertilizing, termicide and tending 1-2 years	95	Protection only	18	152
1 330-2 200	Includes fertilizing, termicide and tending 1-2 years	94	Protection only	18	171
1 330-2 200	Includes fertilizing, tending 1-2 years	49	Protection only	18	91
1 330-2 200	Includes fertilizing, termicide and tending 1-2 years	125	Protection only	18	206
1 330-2 200	Includes fertilizing, termicide and tending 1-2 years	124	Protection only	18	235
1 330-2 200	Includes fertilizing, and tending 1-2 years	56	Protection only	18	107
1 600	Includes insecticide	63	Mechanical and manual weeding for 2 years	51	238
1 682	Includes fertilizing	39	Includes fencing and 4 weedings and hillings	98	268
1 111	Includes fertilizing	43	Spot hoeing, mechanical weeding, fire protection for 2 years	33	152
625	Includes fertilizing	35	3 weedings over 1st 18 months	69	199
2 500					365-607
1 111-1 333	Planting and tending for 2 years	131	See planting		178

Table 12.1 Direct costs of establishing eucalyptus

Country	Date	Exchange rate		Nursery			Site preparation	
		Currency units	Equivalent in US$	Potted stock	Bare-root stock	Costs	Remarks	Costs
Portugal (10-30% slope)	1973	1 000 escudos	38.52		X	5	Mechanical construction of contour furrows	44
Portugal (> 30% slope)	1973	1 000 escudos	38.52	X		15	Mechanical construction of terraces	216
Spain (Badajoz)	1974	1 000 pesetas	17.82	X		53	Burning or chaining, terracing, subsoiling	134
Spain (Hueva)	1974	1 000 pesetas	17.82	X		53	Burning or chaining, terracing, subsoiling	134
Spain (Oviedo)	1974	1 000 pesetas	17.82		X	89	Burning and clearing	481
Spain (Santander)	1974	1 000 pesetas	17.82		X	125	Burning and clearing	535
Sri Lanka (forest)	1974	1 rupee	0.15	X		22	Clearing and burning	32
Sri Lanka (grass)	1974	1 rupee	0.15	X		22	Contour weeding	13
Tanzania	1974	1 shilling	0.14	X		8	Clearing and burning; strip ploughing in grasslands	28-56
Tunisia	1975	1 dinar	2.49	X			Manual land clearing, occasional burning, terracing on slopes	
Turkey	1974	1 000 liras	71.48	X			Clearing and ploughing	108
Uganda	1972	1 shilling	0.14	X		22	Nil clearing	7
Uganda	1972	1 shilling	0.14	X		22	Nil clearing	7
Upper Volta	1975	1 000 CFA fr.	4.50	X		71	Clearing, ripping, firebreaks	112
Zambia	1975	1 kwacha	1.55	X		21	Clearing, ploughing, road construction	277

[1] Includes $45/ha general expenses. — [2] Includes $27/ha general expenses (not supervision). — [3] Includes general expenses.

lantations (US$ per hectare) *(concluded)*

Planting and casualty replacement			Tending and protection		
Number of trees per hectare	Remarks	Costs	Remarks	Costs	Total costs/hectare
1 250	Planting and tending for 2 years	204	See planting		253
1 250	Planting and tending for 2 years	358	See planting		589
625		71	Annual mechanical weeding or spot-hoeing	89	347
625		71	Annual mechanical weeding or spot-hoeing	89	347
2 500	Includes fertilizing	196	Hilling and 2 weedings	214	980
000-2 500	Includes fertilizing	196	Hilling and 2 weedings	214	1 070
1 076		22	Fencing, 4 manual strip- or spot-weedings, fire protection	80	156
1 076		22	Fencing, 4 manual strip- or spot-weedings, fire protection	80	137
1 680	Includes insecticide	17	At least 4 manual weedings	42-84	95-165
500-2 000			Manual weeding for 2 years and watering for 2 years in arid zones		300
		24	Hoeing and mechanical weeding	217	[5] 384
1 736		6	Manual weeding for 2 years	148	183
1 736		6	Chemical weeding for 2 years	48	83
625	Includes insecticide	169	Manual weeding and fire protection	42	407
751	Includes fertilizing	58	6 mechanical and 4 manual weedings	52	408

i/ha general expenses (not infrastructure). — [4] Includes $26/ha general expenses. — [5] Includes $35/ha

Slope

Planting on steep slopes often involves special measures to prevent erosion, such as contour terracing. This increases costs. The examples from Portugal indicate a cost ratio of 1:1.4:3.3 for flat land, 10-30 percent slope, and over 30 percent slope respectively.

Special site deficiencies

Special measures may be essential to ameliorate deficiencies of the site. Invariably they add to the cost. Examples are drainage of swampy sites, irrigation of arid sites, fertilization of infertile sites, deep ripping of hardpan soils.

Returns

The wide variation in establishment costs from different countries has already been remarked. Variation in the financial return from plantations is no less. As has been pointed out in Chapter 11, MAI may vary from 1 m^3 to 50 m^3/ha/yr, depending on climate, site, species or provenance, and cultural treatment. There are also considerable variations in the stumpage value of eucalypt plantations from country to country and in accordance with the end use. For fuelwood, stumpage values may be less than $5 per m^3, while for transmission poles and sawlogs they may exceed $30 per m^3. Pulpwood prices are intermediate.

In practice some of the most extreme combinations, which would indicate huge profit or loss on the plantations, are unlikely to occur. Where costs are high, prices are often high also. The heaviest clearing costs are frequently associated with the most favourable sites and therefore with high yields from the plantations which are established there. The most valuable types of product, such as sawlogs, need longer rotations and may involve additional costs, e.g., in thinning, which to some extent offset the increased value of the product.

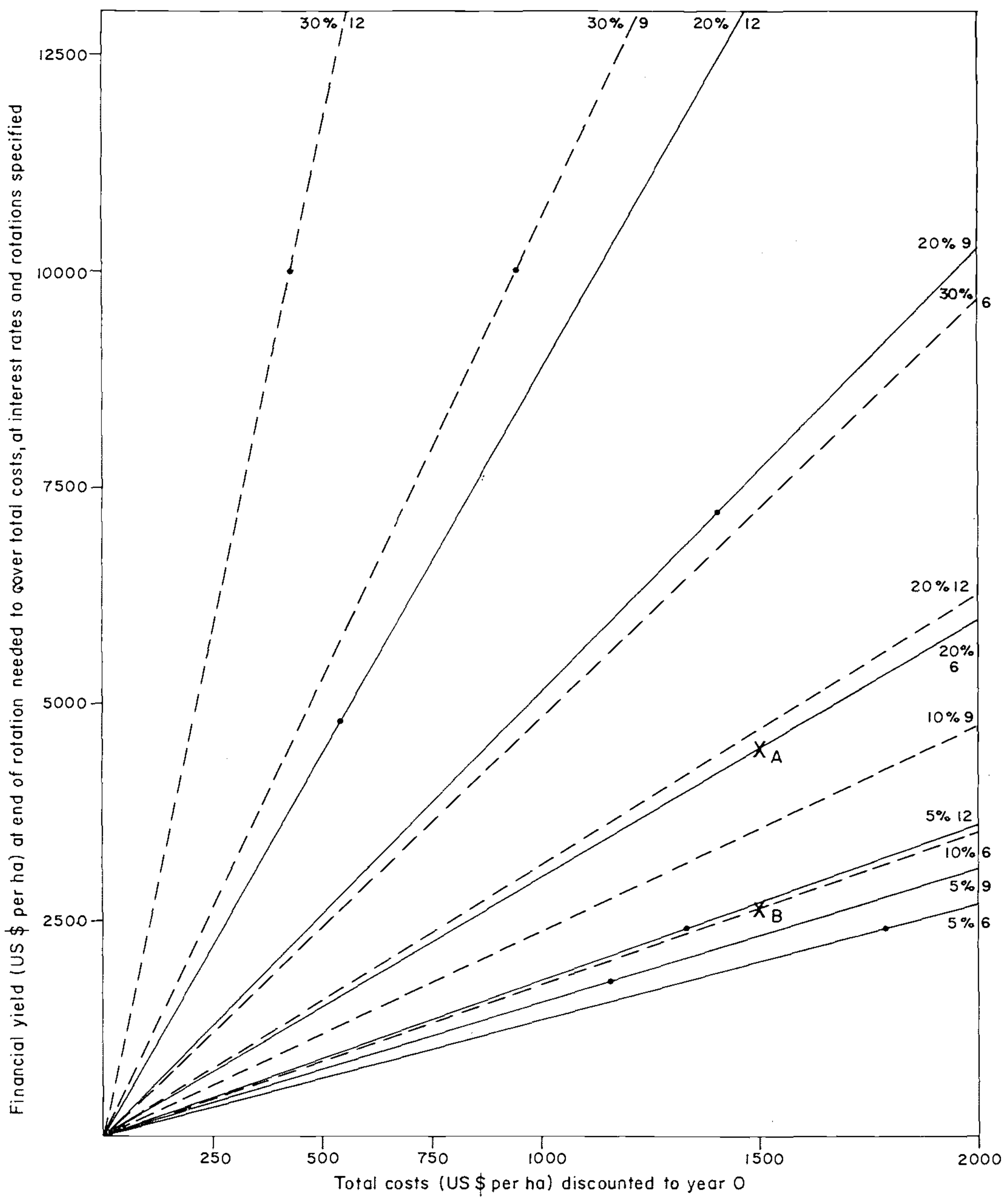
In arid or semi-arid conditions, relatively high establishment costs (e.g., for deep subsoiling, irrigation) must be incurred if the plantation is to be successfully established, but the rate of growth may still be low. In some cases this may be offset by the high value of wood in an area where there are no alternative sources. In others the plantations could not be justified financially for wood production alone, but may be fully justified for a combination of wood production and environmental benefits such as shade, shelter, soil stabilization. The problem of quantifying environmental benefits has exercised foresters for a long time but is outside the scope of this book.

Comparing costs and returns, determining profitability

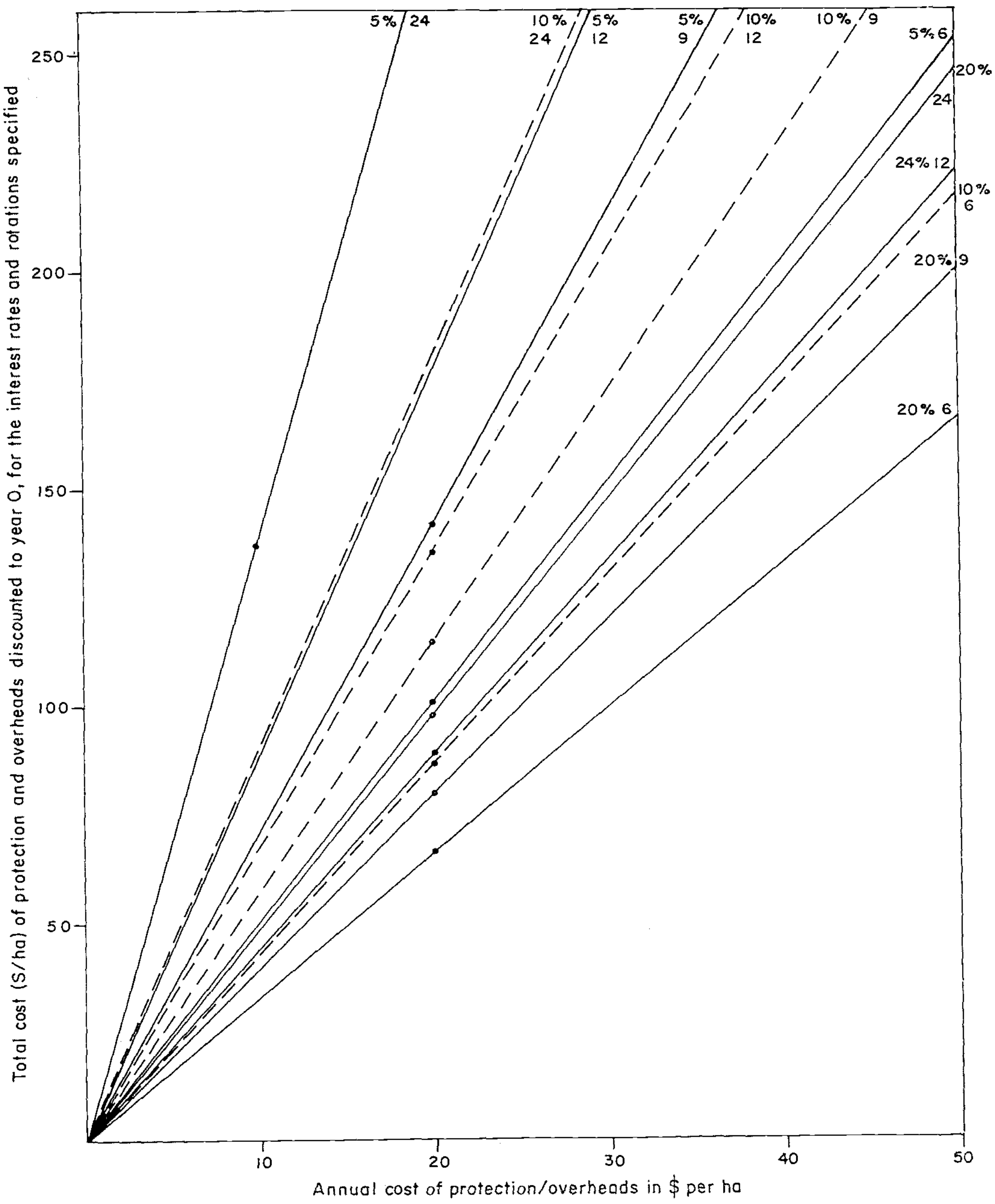
An important reason for calculating costs and returns is to obtain some idea of the profitability of a given plantation project — whether or not, given estimates of rotation length, expected yields, prices and costs, one can expect returns at least to equal costs when both are discounted back to the beginning of the project at some minimum acceptable discount rate or rate of interest. For more detailed treatment of the methods of economic analysis readers are referred to such published guides as Gittinger, 1972; Johnston *et al.*, 1967; Watt, 1973; FAO, 1974b.

From the above discussion of costs and returns for eucalypt plantations, it is evident that the relationship between costs and returns will vary widely with local conditions. Thus, the profitability associated with eucalypt wood production will also vary widely depending on the nature of the relationships.

Figure XX provides some idea of the relationship between (*a*) returns expected at the end of a rotation, i.e., price multiplied by yield; (*b*) rotation length; (*c*) total costs discounted to the beginning of the project; and (*d*) financial rate of return. Given any three of these factors, the fourth can be



XX Relationships between returns, discounted costs, rotation length and financial rate of return approximated. For example, given a situation where we expect the discounted costs to be 1 500 for a eucalypt plantation with a 6-year rotation, no thinning and no coppicing, then we can determine from Figure XX that we would have to obtain a financial yield or return of 4 500 at the end of the rotation in order to get a 20 percent rate of return (point A on Figure XX), but only between 2 600 and 2 700 if we would accept a 10 percent rate of return (point B). Similarly, we could estimate the maximum acceptable discounted costs if we knew what returns are expected to be, what the rotation length will be and what the minimum acceptable rate of return is. This type of figure can be used in any number of ways to make



XXI Relationships between annual costs discounted to beginning of project, rotation length and discount rate a rough approximation of financial profitability associated with different conditions. Also, the figure can easily be expanded to include other discount rates, rotations and cost and return conditions. Naturally, before investing funds in a plantation project a more detailed calculation of profitability is desirable in order to take into account factors not included in the items shown in Figure XX.

Two points about Figure XX are worth clarifying. First, note that costs are expressed in terms of "present value" (i.e., discounted back to the beginning of the project). For all plantations there is an initial cost (site preparation and establishment cost), but in addition there are generally some annual costs during the life of the plantation for protection, overheads, etc. These costs have to be included in the calculations and the easiest way to do so is by discounting them all back to the beginning of the project and adding them to the initial cost. Figure XXI illustrates the relationship between a series of equal annual management costs and their "present value," given the interest rate and the expected rotation for a plantation. The "present value" of annual costs is then added to establishment costs to arrive at the total discounted cost shown on the horizontal axis of Figure XX.

The second point is that the financial yield figure shown on the vertical axis of Figure XX is equal to the assumed physical yield at the end of the rotation times the expected unit price. The figures presented for financial yield therefore could represent various combinations of expected prices and quantities. For example, the value of 5 000 can be arrived at by many different assumptions concerning price and yield — a price of 25 times a yield of 200 m^3, a price of 10 times a yield of 500 m^3, etc.

The assumption is that there are no intermediate yields. If such were to be included, then the final harvest return and the intermediate returns could be discounted back to the beginning of the project and the total "present value" entered on the vertical axis.

Examples of calculating the profitability of eucalypt plantations are shown in Appendix 6.

Effect of coppice rotations

Successful regeneration of eucalypts from coppice costs a small fraction of the cost of establishing the initial seedling crop, as can be seen from the tables (in the following section) from Zambia, Nigeria and Malawi.

The rate of return from the plantation enterprise will therefore be increased appreciably if the seedling rotation is succeeded by one or two coppice rotations. As an example, the Malawi figures for Zone L Mechanical indicate a rate of return of about 11 percent on the first rotation. This is increased to 14 percent over two rotations and to nearly 15 percent over three rotations (one seedling plus two coppice). The effect of coppicing ability on profitability needs to be considered when comparing a non-coppicing species such as *E. regnans* with a strongly coppicing species such as *E. grandis*.

Selected examples More detailed estimates of the direct costs of establishment, as well as estimates of indirect costs, post-establishment direct costs and returns, were available from only a few countries. Selected examples are given below for plantation schemes aimed at the production of pulpwood, sawtimber, fibre- and particle board, fuelwood and poles, and for one line-planting enterprise. The information and analyses presented are those provided by the countries.

A. Spain — Pulpwood

Estimated costs and incomes from four of the most important Spanish provinces for growing eucalypt pulpwood are given in the following table. The figures apply to large-scale operations devoted largely to *E. globulus* in Oviedo and Santander, to *E. camaldulensis* in Badajoz, and to both *E. globulus* and *E. camaldulensis* in Huelva.

Table 12A. Costs and income from eucalypt pulpwood plantations in four provinces in Spain (US$/ha)

Item	Badajoz and Huelva	Oviedo	Santander
Costs			
Site preparation	134	481	535
Digging holes	14	—	—
Transport of plants	12	—	—
Cost of plants	53	89	125
Planting	45	89	89
Fertilizing	—	107	107
Weeding	89	214	214
Pruning	45	—	—
Administration and overheads	21	—	—
Total costs	413	980	1 070
Income			
Rotation age (yrs)	15	12-14	10-12
MAI (m^3/ha/yr)	6	15-18	19
$ value per m^3	11.58	23.76	23.45
Total income ($)	1 042	4 277-5 987	4 456-5 347

Exchange rate used: 1 000 pesetas = $17.82.

B. Zambia — Sawntimber

In Zambia industrial eucalypt plantations on the Copperbelt are grown on an 8-year rotation. Sawlogs represent about 60 percent of the total wood volume with the remainder going to transmission poles and fenceposts. Representative costs and the sawntimber sale price are given below.

Table 12B. Costs and income from eucalypt sawntimber plantations in Zambia (US$/ha)

Direct costs of:		Overall plantation costs (in US$)		
			First rotation	*Subsequent rotations*
Land clearing	209	Direct cost	417	22
Roads	37	Overheads	345	345
Nursery	21	Stumpage costs	5.5/m³	3.8/m³
Planting	58	Logging costs (average)	6.0/m³	6.0/m³
Hand-weeding (×4)	14	Cost at mill	11.5/m³	9.8/m³
Mechanical weeding (×6)	38	Milling costs (per m³ sawntimber)	50/m³	
Pruning	9	Sale price (per m³ sawntimber)	117/m³	
Road maintenance	31			
Total	417	Recovery of sawn-timber is 48% of log volume.		

Notes: Labour costs are low by the standards of developed countries at US$2 per man per working day but high in relation to Africa. — Machinery costs are high, probably 200% above European levels. — Sale prices of timber are exceptionally high because of severance of economic links and ensuing transport problems.

C. Sri Lanka — Pulpwood and sawntimber

In Sri Lanka costs and financial returns have been estimated for both eucalypt pulpwood and sawntimber rotations on three types of land: montane grasslands, forest land and marginal tea land. The figures are summarized in the following table.

Table 12C. Costs and returns from eucalypt sawntimber and pulpwood plantations in Sri Lanka (US$/ha)

Item	40-yr sawntimber rotation		15-yr pulpwood rotation		
	Montane grassland	Forest land	Montane grassland	Forest land	Marginal tea land
First year					
Clearing	—	30	—	30	—
Burning	—	2	—	—	—
Contour weeding	13	—	13	—	—
Ground preparation	—	—	—	—	111
Pegging out	3	3	3	3	3
Digging holes	9	9	9	9	9
Cost of plants	22	22	22	22	22
Planting	9	9	9	9	9
Fertilizing	—	—	—	—	11
Fencing	19	19	19	19	—
Firelines	9	9	9	9	—
Weedings (2)	15	15	15	15	15
Overhead (20%)	20	24	20	23	36
Subtotal first year	119	142	119	139	216
Second year					
Weeding and firelines	19	19	19	19	30
Third year					
Weeding and firelines	19	19	19	19	30
Fourth-15th/40th year					
Annual weeding and firelines	6	6	6	6	6
INCOME					
9th yr thinning of 57 m^3/ha firewood at profit of .20/m^3	11	11	—	—	—
19th yr thinning of 70 m^3/ha timber + poles at profit of 5.30/m^3	371	371	—	—	—
29th yr thinning of 95 m^3/ha timber at profit of 7.95/m^3	755	755	—	—	—
40th yr felling of 175 m^3/ha at profit of 10.60/m^3	1 855	1 855	—	—	—
Pulpwood felling at 15 yrs of 121 tonnes/ha at profit[1] of 3.06/tonne	—	—	370	370	370
Estimated financial return (percent)	8.7	8.5	4.1	3.5	0.8

[1] Sale price = 7.65/tonne; extraction costs = 4.59/tonne. — Exchange rate used: 1 rupee = $0.15.

D. Israel — Fibre- and particle board

The principal use for *Eucalyptus* wood in Israel is for fibre- and particle board; secondary uses are for stakes, posts, poles and sawntimber. The costs of growing the wood for these products, and the sale price of three classes of round wood are given below.

Table 12D. Costs and income from eucalypt plantations in Israel (US$/ha)

Item	Cost ($)	Year	Remarks
Site preparation	93	1	5 caterpillar and 5 wheel tractor-hours
Planting (includes pegging out and distribution of plants)	140	1	80 man-hours
Cost of plants	122	1	10 cents per plant
Cultivation (2)	70	1	10 wheel tractor-hours
Hoeing (1)	70	1	40 man-hours
Overhead (25%)	93	1	Plants excluded
Subtotal, first year	*588*		
Tending	174	2	Overhead included
Tending	140	3	Overhead included
Total establishment	902		

INCOME		
Rotation age (yrs) 7-8		
MAI (m^3/ha/yr) 20-30		
$ value per m^3		
a. for fibre-/particle board	$29.00	minus $11.60-17.50
b. for stakes, posts, poles	34.00	for logging, transport
c. for sawntimber	43.00	and overheads

Notes: Exchange rate used: 1 IL = $0.12 (November, 1976). — 77% of 1974/75 annual cut was for fibre-/particle board; 14% for stakes, posts and poles; and 9% for sawntimber.

E. Nigeria — Fuelwood and poles

Ferguson (1973) compiled detailed costings for the establishment of eucalypt plantations in the savanna region aimed primarily at the production of fuelwood and poles. Costs are projected to cover the first four rotations, assuming an annual planting of 200 hectares at 3 × 3-m spacing (1 111 plants/ha) and a 6-year coppice rotation. Overhead costs include allowance for a modest increase in provincial office staff.

Table 12E. Estimated costs of establishing eucalypt plantations in the Guinea savanna of Nigeria

Item	Costs		Year	Cumulative cost to age 25	
DIRECT COSTS					
	£N per hectare	*$ per hectare* [1]		*£N per hectare*	*$ per hectare* [1]
Survey	0.50	1.40	0	0.50	1.40
Roading	6.00	16.80	0	6.00	16.80
Road maintenance (per year)	1.00	2.80	0 to 25	25.00	70.00
Knocking down	3.50	9.80	0	3.50	9.80
Firewood revenue [2]	(+8.50)	(+23.80)	0	(+8.50)	(+23.80)
Heaping and burning	5.50	15.40	0	5.50	15.40
Ploughing	8.00	22.40	0	8.00	22.40
Harrowing	5.10	14.28	0	5.10	14.28
Raising plants	10.00	28.00	0	10.00	28.00
Planting	17.00	47.60	1	17.00	47.60
Fertilizing	11.50	32.20	1	11.50	32.20
Mechanical cultivation	8.00	22.40	1	8.00	22.40
Mechanical cultivation	4.00	11.20	2	4.00	11.20
Hand cultivation	2.00	5.60	1	2.00	5.60
Protection (per year)	4.00	11.20	0 to 25	100.00	280.00
Coppice thinning	1.00	2.80	7, 13, 19	3.00	8.40
Total to year 25 if firewood saleable				200.60	561.68
Total to year 25 if firewood unsaleable				218.60	612.08
ALLOCATION OF OVERHEADS PER HECTARE					
				Overheads to age 25	
	13.50	37.80	0	13.50	37.80
	13.50	37.80	1	13.50	37.80
	10.80	30.24	2	10.80	30.24
	2.70	7.56	7	2.70	7.56
	2.70	7.56	13	2.70	7.56
	2.70	7.56	19	2.70	7.56
	2.70	7.56	25	2.70	7.56
Per hectare per year	0.30	0.84	0 to 25	7.50	21.00
Total overheads per hectare to year 25				56.10	157.08

[1] Exchange rate used: £1 Nigerian (N) = US$2.80. — [2] Where the firewood cannot be sold, there is no revenue and there is an additional windrowing cost of £N9.50 ($26.60).

F. **British Solomon Islands** — Line-planting

Although only 6 hectares of experimental plantings of *E. deglupta* have been established in the British Solomon Islands, costs and returns from line-plantings to produce pulpwood and sawntimber or veneer logs on a 20-year rotation have been estimated. These are detailed below:

Table 12F. Costs and returns from eucalypt line plantations in British Solomon Islands (US$/ha) (revised May 1978)

Costs per hectare	US$	Remarks
Nursery costs	46.6	500 plants/ha
Land preparation		
Poisoning	34.6	5.2 man-days
Line cutting	56.5	8.5 "
Planting	40.0	6.0 "
Tending	133.0	20.0 "
Thinning	Assumed to be borne by pulpwood exporter	
Total direct costs	310.7	39.7 " say 40
Overheads (estimated)	289.3	
Total gross costs	600.0	

Estimated returns	
Pulpwood	$1.41 per m^3 for yields 44 m^3/ha at 8-11 years plus 38 m^3 at 20 years
Saw-/veneer logs	$3.91 per m^3 for 65 m^3/ha at 20 years
Total yield at 20 years =	147 m^3/ha
=	7.35 m^3/ha/year

Exchange rate used: 1 $A = US$1.33.

G. Upper Volta — Direct costs

Table 12G. Direct cost of eucalypt plantation in Upper Volta, 1975 (US$/ha)

Item	Cost	Remarks
Land clearing and subsoiling - Caterpillar D6C	112.00	4.5 hrs/ha
Pegging out, hole digging, planting, insecticide	169.00	80 man-days/ha
Cost of plants	71.00	625 plants/ha
Weeding two times	42.00	20 man-days/ha
Transportation	4.00	
Supervision	9.00	
	407.00	

H. Malawi — Fuelwood and poles

In Malawi eucalypts are planted principally for the provision of fuelwood and poles for both domestic and agricultural uses. The tobacco industry in particular has a large requirement for constructional poles and fuelwood for curing.

In the table that follows, costs are based on average national costs and assume a normal forest of 400 ha, one of three similarly sized forests under single charge. There are assumed to be three rotations of 8, 7 and 8 years, the first involving clearing and planting, the subsequent two being coppice. The yields and revenue are average figures. Interest charges are excluded.

Costs are shown separately for manual and mechanical operations and for three different climatic zones. For an explanation of the climatic zones see the section on Malawi in Chapter 4.

Table 12H. Malawi: cost of eucalyptus plantation - interest charges excluded

First rotation *(planted)*	Zone D		Zone L		Zone M	
	Manual	Mechanical	Manual	Mechanical	Manual	Mechanical
			US dollars			
Land preparation [1]	32.20	56.20	51.90	86.20	17.40	25.80
Nursery [2]	7.30	7.30	7.30	7.30	7.30	7.30
Establishment [3]	95.06	124.81	93.81	123.97	49.09	56.16
Protection [4]	18.00	18.00	18.00	18.00	18.00	18.00
Felling [5]	59.36	59.36	118.72	118.72	89.04	89.04
Total direct	211.92	265.15	289.73	354.19	180.83	196.30
Roads [6]	3.96	3.96	7.92	7.92	2.65	2.65
Buildings [7]	31.52	31.52	31.52	31.52	31.52	31.52
Plant/vehicles [8]	107.20	122.32	107.20	122.32	107.20	122.32
Supervision/admin.[9]	118.77	116.70	128.46	126.72	118.40	116.15
Miscellaneous [10]	33.00	33.00	33.00	33.00	33.00	33.00
Total indirect	294.45	307.50	308.10	321.48	292.77	305.64
Total cost	506.37	572.65	597.83	675.67	473.60	501.94
Anticipated revenue	560.00	560.00	1 120.00	1 120.00	840.00	840.00
Second rotation *(coppice)*						
Establishment	13.35	25.35	18.10	32.60	11.02	14.22
Protection	15.75	15.75	15.75	15.75	15.75	15.75
Felling	59.36	59.36	118.72	118.72	89.04	89.04
Total direct	88.46	100.46	152.57	167.07	115.81	119.01
Roads	3.74	3.74	7.48	7.48	2.50	2.50
Buildings	27.58	27.58	27.58	27.58	27.58	27.58
Plant/vehicles	93.80	107.03	93.80	107.03	93.80	107.03
Supervision/admin.	97.32	97.04	105.50	104.92	99.94	99.66
Miscellaneous	28.88	28.88	28.88	28.88	28.88	28.88
Total indirect	251.32	264.27	263.24	275.89	252.70	265.65
Total cost	339.78	364.73	415.81	442.96	368.51	384.66
Anticipated revenue	560.00	560.00	1 120.00	1 120.00	840.00	840.00
Third rotation *(coppice)*						
Establishment	19.63	32.77	23.90	39.97	13.05	17.93
Protection	18.00	18.00	18.00	18.00	18.00	18.00
Felling	59.36	59.36	118.72	118.72	89.04	89.04
Total direct	96.99	110.13	160.62	176.69	120.09	124.97
Roads	3.96	3.96	7.92	7.92	2.65	2.65
Buildings	31.52	31.52	31.52	31.52	31.52	31.52
Plant/vehicles	107.20	122.32	107.20	122.32	107.20	122.32
Supervision/admin.	110.82	110.12	119.23	120.06	113.02	112.67
Miscellaneous	33.00	33.00	33.00	33.00	33.00	33.00
Total indirect	286.50	300.92	298.87	314.82	287.39	302.16
Total cost	383.49	411.05	459.49	491.51	407.48	427.13
Anticipated revenue	560.00	560.00	1 120.00	1 120.00	840.00	840.00

Notes: (Costs in notes 1 to 5 are direct cost of labour, materials, and fuel oil and spares where machinery is used in place of hand work.) [1] Includes clearing. — [2] Includes polythene pots. — [3] Includes fertilizer and termicide where appropriate. — [4] Includes fire equipment other than plant and vehicle. — [5] Includes felling, snedding, debarking, crosscutting and extraction to roadside. — [6] Includes maintenance and capital charges. — [7] Includes water supplies, electricity and telephones. — [8] Includes all vehicle depreciation charges plus supervisory vehicles. — [9] Includes all salaries, wages for administrative staff, supervision, research, training, accounting and auditing. — [10] Includes cost of tools, materials and general expenses.

I. **Papua New Guinea** — PULPWOOD

Establishment cost estimates for *E. deglupta* in Papua New Guinea have been published (White, 1975). They are based on a planned planting rate of 2 000 ha per year, a spacing of 625 stems/ha and a 10-year rotation for production of pulpwood. The existing high forest is clear-felled for production of chips, hence clearing costs are almost nil. Cost estimates are shown for both the first and second rotations. Because of its poor coppicing characteristics, *E. deglupta* must be replanted. Costs used are those valid in 1974, and have been converted to $US at the 1974 rate of exchange of 1 kina = 1.44 $US.

Table 12.I. *E. deglupta* in Papua New Guinea: establishment costs per hectare

	1st rotation	*2nd rotation*	
	.... *US dollars*		*Percent*
Plants (less housing)	15.23	15.23	
Land preparation labour	72.00	36.00	50
Survey labour	5.76	2.88	50
Poison	0.43		Nil
Tools and equipment	2.30	1.61	70
Planting labour	23.04	13.82	60
Fertilizer	8.93	8.93	
Fertilizer labour	2.88	2.88	
Tending labour	69.12	34.56	50
Leave allocation labour	14.33	7.24	
Firebreak maintenance at US$1.656 per year	16.56	16.56	
Knapsacks and tools	0.72	0.72	
Fire tanker depreciated over 7 years	1.54	1.54	
Radios	1.38	1.38	
Radio maintenance	0.72	0.72	
Fire-towers depreciated over 7 years	0.62	0.62	
Labour compounds 17 at US$2 160 depreciated over 5 years	3.67	2.58	70
Road maintenance US$8 640 per year	43.20	43.20	
Vehicles depreciated over 3 years	21.57	21.57	
Staff housing depreciated over 10 years	8.93	6.25	70
Salaries	52.70	36.89	
Plant carrier depreciated over 10 years	0.12	0.12	
Medical	2.16	1.51	70
Office furniture and equipment	0.22	0.22	
Land rental at US$0.72/ha/yr	7.20	7.20	
Land survey at US$5.76 per hectare	5.76		Nil
TOTAL	381.09	264.23	
Plus 10 percent contingency	419.20	290.65	

13. Choice of species for planting

More than 175 years have passed since plant scientists started to take an interest in using eucalypts as exotics in Europe, the Indian subcontinent and adjacent countries, Africa and North and South America. During this considerable period of time a succession of new species has attracted attention for their ornamental and useful qualities, and some simply as curiosities. The stream of new species does not cease; the present edition of this book includes at least two "new" species which must be carefully tried out by countries of low latitudes of the world. It is unfortunate that there is not more land in the southern hemisphere with a latitude of 35-40°S, since there are some excellent species available for such conditions. There are further new species in northeastern Australia which have not yet been named but which will be of interest in fairly low latitudes.

In the wealth of experimentation that has occurred, at least three countries — Brazil, South Africa and the United States — have tested more than 200 species of eucalypt, and several other countries have tried out more than 100 species. Species have been used out of curiosity; because the distinctive aroma of their crushed leaves has suggested a potential for the use of essential oils for medical or industrial purposes; for ornamental purposes and for utilitarian purposes. Understandably, the recent explosion of eucalypt planting has been for utilitarian purposes, because a very large investment indeed has been necessary to establish the area of about 4 million ha already growing in the world. The investment in planting and maintenance, without the cost of land, must be between US$1-2 thousand million, and a much larger investment must be made to process the more than 40 million m^3 growing annually in these very large exotic plantations so that it benefits the communities which have established them.

It is of interest that out of the large number of species tried, most of the huge area of eucalypt plantations established to date as industrial forests has been planted with a certain few species which have proved themselves as excellent plantation species for commercial crops. These species include: *E. grandis, E. saligna, E. globulus, E. camaldulensis, E. tereticornis, E. urophylla* (*alba*), *E. robusta, E. maculata, E. paniculata* and *E. viminalis*. There would be another ten very good trees to take the place of these if any one should fail.

It will be seen that in 175 years the stream of species being tried has been reduced to 20 or perhaps 30 being used on a large or appreciable scale.

This is a sensible sorting out of the better trees in, say, five generations of human endeavour.

It should not be essential to repeat all the trials again, but it is most desirable that a continued stream of provenance trials of the better species be made by interested countries with the collaboration of FAO and the Australian authorities. These trials have already amply demonstrated their worth with *E. camaldulensis, E. tereticornis* and *E. viminalis*. Many more should be organized to maintain and improve the very large investment already made in the genus *Eucalyptus*.

Matching species to site and climate

In selecting good sites for eucalypt planting, one cannot do better than follow the Delphic maxim μηδὲν ἄγαν ("Nothing too much"). Unfortunately, most such sites are reserved for agriculture and the sites actually available may suffer from one or more limitations.

Limiting environmental factors are usually distinguished as: *edaphic* (e.g., soil depth, fertility, texture and structure; presence of excessive assimilable carbonates or chlorides); *climatic* (e.g., temperature, aridity, humidity); and *biotic* (e.g., pests, diseases, competition from vegetation).

The evolution of the eucalypts has produced species and provenances fitted to an enormous range of environmental conditions within the natural range of the genus. Except in the cold temperate and boreal regions and in the tropical rain forest, there should be no difficulty in finding one or more species of which the environmental conditions in Australasia match reasonably closely those in the country of introduction.

On the other hand, the outbreeding characteristics of the eucalypts result in a great deal of genetic variability, even within a local population, and this variability implies a capacity both for the individual phenotype to adjust to changes in the environment and for an introduced population to adapt over successive generations by natural selection. This variability permits changes in structure or function to conform with changed environmental conditions, which have given the eucalypts their reputation for adaptability or "plasticity."

Clearly the need for precise matching of homoclimes and of soils between the natural occurrence and the new sites for introduction varies inversely with the adaptability of the individual and of the seedlot. On the whole, experience over the last 20 years has confirmed the value of environmental matching and has somewhat reduced the emphasis on individual and population adaptability. Moderate and judicious displacement of a species to a different climate, on the lines described in the section on acclimatization, may yield excellent results. In the absence of evidence from comparable sites, however, individual adaptability should be regarded as an insurance against the inevitable annual fluctuations in climate rather than an excuse for the wilder excesses of "off-site planting."

On a poor site even the most suitable species cannot be expected to produce as high a yield as the most suitable (and usually a different) species on a good site.

For example, *E. grandis* on a fertile site in a moist tropical climate will always out-produce *E. camaldulensis* on the same site and *E. camaldulensis* on a dry site. But *E. camaldulensis* on a relatively infertile soil and with a severe dry season will out-produce *E. grandis* because of severe drought losses in the latter. In such cases high survival and a moderate yield in one species must be accepted as preferable to high mortality in another unsuited, though potentially faster growing, species.

Possibilities of acclimatization of species in climates differing somewhat from those within the natural range are considered further below. As a general rule too abrupt a movement of a species to a harsher climate than it is used to is likely to have a direct physiological effect expressed in reduced survival and growth. In some cases, secondary pests may appear, such as *Phoracantha* or termites attacking trees already weakened by drought. When species are moved to a climate which is much less harsh than they are used to (e.g., from a dry to a wet climate) initial growth may be even better, but there is a serious risk of an epidemic fungal disease appearing later; *Corticium salmonicolor* in Kerala, India, and *Diaporthe cubensis* in tropical America are examples of such epidemics.

Most species of eucalypt respond to planting on deep soils of moderate fertility and good texture and structure. Although the level of fertility acceptable is a good deal less than for agricultural crops, it is more than that required for many of the pines. The benefits to be gained from application of fertilizers depend very much on local soil conditions, but there are a number of well-authenticated cases where there was a big response to fertilization.

Intolerance of competition from other plants is a common feature of almost all eucalypts and clean weeding for the first year or two will always produce better plantations than less intensive methods of tending.

Where the limiting factors are fertility or plant competition, it is not only possible, but necessary to modify the environment. In other cases, modification of the environment is impossible or uneconomic, so it is necessary to search for species which have the greatest possible tolerance to the limiting factor in question.

Edaphic factors

TOLERANCE OF PERIODIC FLOODING

Poorly drained or waterlogged soils are unsuitable for most eucalypts. Waterlogged soils should be drained, and the drains maintained in effective condition. Several planting countries carefully do this and it permits an expansion of the land available for planting. Nevertheless, exceptional rains occasionally flood flattish land and it is necessary to know species which will tolerate periodic flooding. As more countries plant eucalypts, the list of tolerant species must be divided into groups which suit certain latitudes, as follows:

- Latitudes above 30°: *E. aggregata, E. camaldulensis* (southern provenances), *E. occidentalis, E. ovata, E. rudis.*

- Latitudes 20°-30°: *E. robusta, E. occidentalis, E. sargentii.*
- Latitudes below 20°: *E. alba, E. apodophylla, E. camaldulensis* (northern provenances), *E. microtheca, E. populnea.*

Tolerance of salinity

In arid and semi-arid conditions, where evapotranspiration greatly exceeds precipitation, and especially where there is no external drainage, an added limitation to tree growth may be the accumulation of salts in the soil. Few eucalypts tolerate high soil salinity.

Hall *et al.* (1972) list the following species as having relatively high tolerance (1), and some tolerance (2) of soil salinity:

(1) *E. dundasii, E. kondininensis, E. sargentii, E. torquata.*

(2) *E. brockwayi, E. campaspe, E. intertexta, E. longicornis, E. salubris, E. sideroxylon, E. stricklandii.*

Research in Western Australia summarized by Hart (1972) indicated that the most suitable species of those tested were *E. sargentii, E. platypus* var. *heterophylla, E. spathulata, E. camaldulensis, E. occidentalis, E. kondininensis* and *E. gracilis.* Salt conditions at one of the test sites: (*i*) pH 7.82 at surface, increasing to 8.60 at 1.4 m; (*ii*) total soluble salts 1.65% at surface, decreasing to 0.17% at 1.4 m; (*iii*) sodium as NaCl 1.47% at surface, decreasing to 0.09% at 1.4 m.

Chippendale (1973) lists *E. lehmannii* as tolerant of some soil salinity.

Species promising for saline soils in the Mediterranean are *E. gomphocephala, E. occidentalis, E. sargentii, E. rudis* and *E. microtheca* (Pryor, 1964). Israel, Italy and Morocco all report the tolerance of *E. occidentalis* to soil salinity and also to heavy clay soils.

Species listed as markedly tolerant (1) and somewhat tolerant (2) of saline soils in South Africa (Poynton, 1971) are: (1) *E. camaldulensis, E. cladocalyx, E. polyanthemos, E. robusta, E. viminalis*; (2) *E. botryoides, E. gomphocephala, E. sideroxylon, E. sieberi.*

Species which are resistant to salt spray and are recommended for coastal planting are *E. lehmannii* for dry areas and *E. botryoides* for moist areas.

Tolerance of calcareous soils

Soils derived from limestone which have a high pH and appreciable quantities of free calcium are unsuitable for many species of eucalypt. The outstanding example of a widely planted species which tolerates calcareous soils is *E. gomphocephala.* In Mediterranean countries, especially in North Africa, it remains healthy on soils where the local land races of *E. camaldulensis* suffer severely from lime-induced chlorosis. In extreme conditions, however, *E. gomphocephala* itself becomes chlorotic, e.g., on rendzina soils in Israel with 70 percent calcium carbonate and pH 7.7-7.8. Other species recommended for calcareous soils in the Mediterranean region are *E. albens, E. leucoxylon, E. melliodora, E. microtheca, E. rudis, E. sideroxylon, E. striaticalyx* and *E. tereticornis* (Pryor, 1964).

In trials on the Darling Downs of Queensland, where the poorly drained clay soils are somewhat alkaline, the most successful species of eucalypt tested were *E. camaldulensis, E. melliodora, E. ochrophloia, E. orgadophila, E. pilligaensis, E. populnea* and *E. sideroxylon* (Brown and Hall, 1968).

Certain calcicole provenances may occur within species which in general do not tolerate calcareous soils. Good examples are the Port Lincoln and Wiluna provenances of *E. camaldulensis* which have performed well on limestone soils in the Mediterranean (Lacaze, 1970). Differences in the degree of chlorosis on calcareous soils were also observed between provenances of *E. dalrympleana* in France (Lacaze, 1963).

Climatic factors

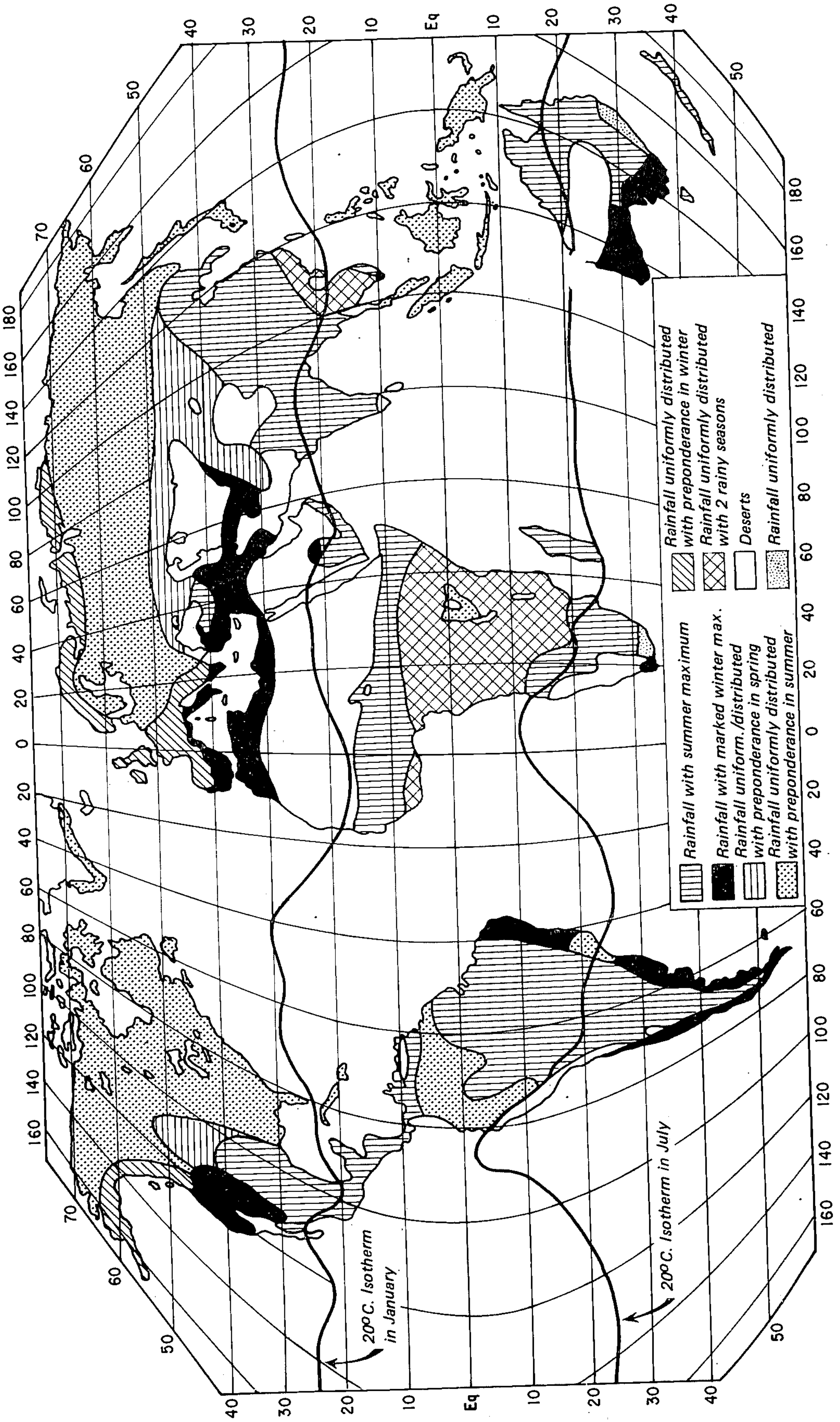
Drought resistance

E. camaldulensis and *E. gomphocephala* have usually given satisfactory performance on suitable soils in semi-arid regions with winter rainfall in excess of 400 mm. Below 400 mm they are less suited and it is necessary to consider inherently slower growing but more drought-resistant species. Pryor (1964) recommended *E. astringens, E. occidentalis, E. salubris, E. microtheca, E. leucoxylon* and *E. sideroxylon* for North Africa. Other species which have more recently been reported as growing well in rainfall between 200 and 400 mm in Morocco are *E. brockwayi, E. loxophleba, E. salmonophloia* and *E. striaticalyx* for fuelwood and protection and *E. salubris, E. stricklandii* and *E. torquata* which are too small for fuelwood but are good for protective planting.

The figure of 400 mm as a minimum for *E. camaldulensis* is only applicable to winter-rainfall areas. For summer-rainfall areas with a severe dry season in Africa south of the Sahara 700 mm are about the minimum unless subsoil moisture is available, e.g., on river levees (Jackson, 1976). The majority of the species listed by Hall *et al.* (1972) as growing in the driest conditions in Australia occur either in uniform or predominantly winter-rainfall conditions. Three species in which the rainfall varies from uniform to a summer peak and from 250 to 600 mm are *E. intertexta, E. ochrophloia* and *E. thozetiana.* Certain provenances of *E. microtheca* occur in similar dry conditions.

The possibilities of acclimatizing species to climatic conditions, whether seasonal rainfall distribution, severity of dry season or summer maximum temperature, somewhat different to those experienced within the natural range are tabulated in this section. It is taken, largely unaltered, from the discussion by Métro in the first edition of this book (Métro, 1955).

XXII Rainfall regions of the world
After Métro, 1955



The various species of eucalypt may be grouped into three classes according to the climatic zones from which they originate in Australia:

U - Uniformly distributed rainfall zone

W - Marked summer drought zone, winter rainfall, Mediterranean type

S - Marked winter drought zone, summer rainfall, type tending to tropical.

The following observations may be made:

1. Numerous species from group U can be acclimatized in zones with a marked dry season either in summer or winter.

Taking those species in this group which have been most often used in planting, it is found that the number of those which can be acclimatized in summer-drought zones, Mediterranean type (List UW), is approximately equal to the number of those which can be acclimatized in tropical zones with dry winters (List US).

List US has been arranged in tabular form, the species in question being placed approximately in the geographical order of their natural ranges, beginning with those farthest south at the top and those nearest the equator at the bottom. Moreover, although this corresponds to no precise criteria, the species have been divided into two groups: those which have proved comparatively unadaptable to arid conditions, and those which have shown considerable adaptability in this respect.

List US. Species originating in climatic zones with uniform rainfall and which in summer-rainfall zones have shown themselves adaptable to more severe drought conditions than those of their native range.

Comparatively little adaptability	Adaptable
	E. globulus ssp. *maidenii*
	E. bosistoana
	E. botryoides
E. propinqua	*E. punctata*
E. pilularis	*E. robusta*
E. acmenoides	*E. saligna*
	E. grandis
	E. maculata
	E. citriodora
E. microcorys	*E. paniculata*
	E. siderophloia
E. gummifera	*E. crebra*
E. resinifera	*E. tereticornis*

List UW has been drawn up on the same principle.

List UW. Species originating in uniform rainfall zones and which in winter-rainfall areas have shown themselves adaptable to more severe summer-drought conditions than those of their native range.

Comparatively little adaptability		Adaptable
		E. globulus ssp. *maidenii*
		E. bosistoana
		E. botryoides
E. propinqua		*E. punctata*
E. pilularis		*E. robusta*
		E. saligna
	E. acmenoides	*E. maculata*
		E. grandis
		E. citriodora
E. microcorys		
		E. paniculata
		E. siderophloia
		E. crebra
E. gummifera	*E. resinifera*	*E. tereticornis*

2. Numerous species from group W (Mediterranean type) can be acclimatized in winter-rainfall zones with a decidedly more severe summer drought, either with lower rainfall, or with higher temperatures, or dry for a longer period. These species are grouped together in List WW.

List WW. Species originating in climatic zones with winter rainfall, and which have proved adaptable to decidedly more severe summer droughts than those of their native range. (In ascending order of drought resistance)

Comparatively little adaptability			Adaptable
	E. amygdalina		
E. delegatensis			
E. regnans	*E. obliqua*	*E. viminalis*	
E. cypellocarpa			*E. globulus* ssp. *globulus*
		E. ovata	
		E. diversicolor	
		E. cladocalyx	
		E. moluccana	
		E. leucoxylon	
			E. melliodora
		E. woollsiana (ssp. *microcarpa*)	
			E. sideroxylon
		E. gomphocephala	
		E. astringens	
E. wandoo		*E. camaldulensis*	
	E. salmonophloia		
	E. salubris		
	E. brockwayi		

3. Several species in group W can equally be acclimatized in temperate zones which have uniform rainfall with or without a winter maximum. They are grouped in List WU.

List WU. Species originating from winter-rainfall zones which have proved adaptable to temperate conditions without a prolonged dry season and with uniform rainfall with either winter or summer maximum.[1]

Comparatively little adaptability		Adaptable
E. delegatensis		
E. obliqua		*E. globulus* ssp. *globulus*
	E. viminalis	
	E. ovata	
E. diversicolor		
E. melliodora		*E. cladocalyx*
	E. leucoxylon	
	E. gomphocephala	
		E. sideroxylon [2]
		E. camaldulensis [2]

[1] From top downward, approximately in ascending order of resistance to drought in native range. — [2] This species does not originate exclusively from W zones.

4. There are, however, no species exclusively originating from group W which have been reported as easy to acclimatize, or as giving good results, in low altitude, tropical summer-rainfall zones with marked drought. There is therefore no list WS.

5. On the contrary, many species originating from summer-rainfall zones with marked winter drought have been acclimatized in winter-rainfall zones (List SW).

List SW. Species originating in climatic zones with summer maximum rainfall which have proved adaptable to zones of summer drought.[1] *(All these species occur in the uniform rainfall zone and are included also in List UW.)*

Comparatively little adaptability		Adaptable
	E. acmenoides	*E. saligna*
		E. maculata
		E. citriodora
		E. grandis
E. microcorys		*E. paniculata*
E. gummifera		*E. siderophloia*
E. resinifera		*E. crebra*
		E. tereticornis

[1] From the top downward, approximately in ascending order of resistance to higher average temperature in their range.

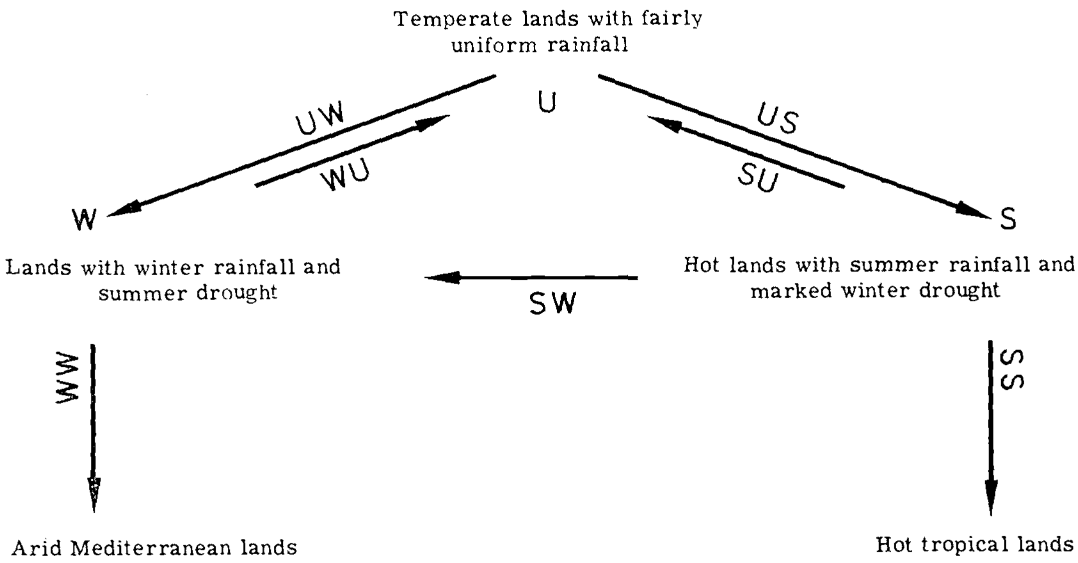
6. Finally, there is an SS adaptability which emerges from results obtained in several plantations, in which species originating from zone S (summer rainfall) have been successfully acclimatized in zones also of summer rainfall but with higher average temperatures.

List SS. Species originating in summer-rainfall zones which have proved adaptable to more severe drought conditions than those of their range.[1]

Comparatively little adaptability	Adaptable
	E. sideroxylon
	E. camaldulensis
	E. saligna
	E. maculata
	E. citriodora
	E. grandis
E. microcorys	*E. paniculata*
	E. siderophloia
E. gummifera	*E. crebra*
E. resinifera	*E. tereticornis*

[1] From the top downward, approximately in order of geographical distribution from the south toward the equator.

Figure XXIII, below, summarizes the course of adaptability in the various eucalypt species to different patterns of rainfall.



XXIII Eucalypt adaptability
After Métro, 1955

This general one-way adaptability which enables species originating from tropical summer-rainfall zones to become acclimatized in Mediterranean-type zones, while the reverse process is very rarely possible, has been observed by numerous foresters (Aubréville, 1948; Jacobs, 1962) in forest species other than the eucalypts. The phenomenon, however, is difficult to explain.

There are no exceptions to this phenomenon, save insofar as altitude compensates latitude entirely as regards temperature, atmospheric moisture and rainfall. It has been seen that at high altitudes, 1 500-3 000 m, it is possible to acclimatize in tropical zones and, even on the equator, certain eucalypt species which have originated from dissimilar zones, such as *E. camaldulensis* and *E. globulus*.

Few studies have been made on photoperiod in eucalypts. Karschon (1976) reported that growth of a tropical species, *E. papuana*, was depressed when moved to the longer summer day-length of Tel Aviv at latitude 32°N.

An attempt has been made to give a synopsis of the adaptability of the eucalypts to changes in climate (see Figure XXIV). The chief species used in planting are indicated in a vertical column. In the middle are those species the range of which corresponds to uniform rainfall zones. Reading upward are those species which grow in summer-rainfall zones with increasing temperature. Reading downward are those species growing in winter-rainfall regions with increasingly marked dry summers. These rainfall regions are indicated in the left-hand margin and it should be noted there is overlapping in the case of several species.

To either side of each species, lines of varying length indicate the extent to which they are acclimatizable, more or less marked in proportion to the length of the line, either toward the left, in zones of summer drought or, toward the right, in zones of higher average temperature.

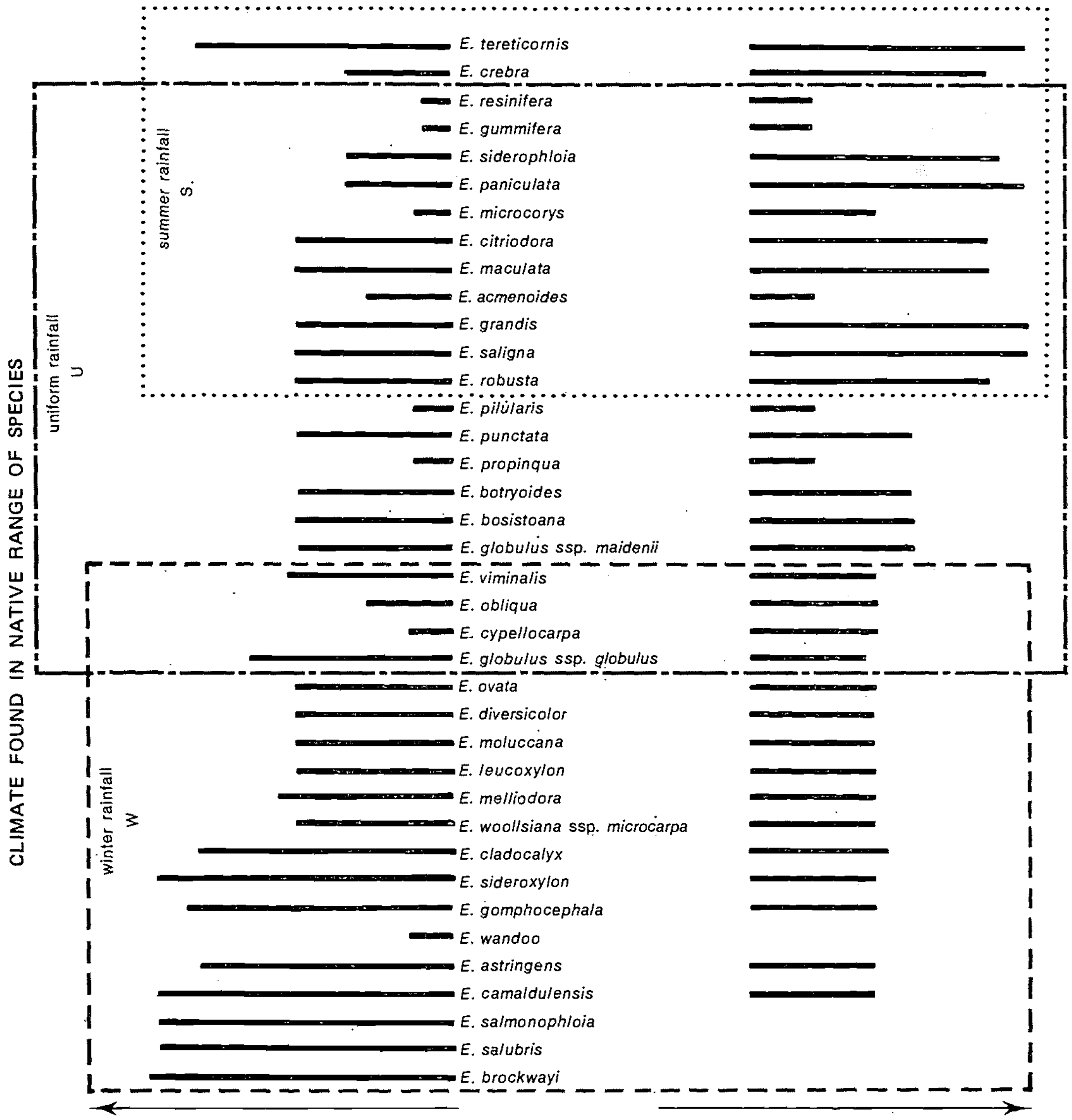
Resistance to cold

During the past century it was chiefly the Mediterranean and subtropical foresters who relied upon the eucalypts for their planting projects. Foresters in the cold temperate regions have, until now, looked to more valuable species which are better adapted to local conditions and capable of producing a more suitable quality of wood than the eucalypts. As a result most evidence on the relative resistance to frost and cold of different eucalypt species when planted as exotics has tended to come from observation rather than experimentation. In a number of cases, planting in cold climates has tended to favour ornamental rather than production species.

In extrapolating the tabulated information which follows, it is necessary to bear in mind the following general considerations:

- As with many other characteristics, seed origin or provenance within a species can be of decisive importance. In many assessments of relative resistance to cold, remarks such as "mountain variety" or "provenance from 1 000 m or higher in New South Wales" are commonly added. Seed collected from

XXIV Synopsis of adaptability of principal eucalypt species to drought and heat
After Metro, 1955



Possibilities of acclimatization in arid zones of climates with maximum winter rainfall.

Possibilities of acclimatization in climates with average temperature higher than that of native range, even in climates with uniform rainfall or summer maximum.

introduced stands or "land races" which have undergone one or more generations of selection in a new habitat may frequently produce better results than seed introduced for the first time from Australia.

- Local topography often has an important effect in modifying the severity of frost and cold. This applies both in the native range and on new sites where planting may be carried out. High exposed sites or frost hollows usually have considerably more severe cold than intermediate or partially sheltered slopes.

- Frost resistance is affected by age. Night temperatures are colder at ground level than some metres above it; for example, the minimum temperature recorded in a Stevenson screen is usually 2-3°C higher than the "grass minimum." The tender growing parts of the plant thus experience colder temperatures on an average in the first year or two after planting than when they reach a large size. At the same time, at a given height above ground, the cambial tissue of the stem will be protected by an increasingly thicker layer of bark as the trees grow older.

- The effect of cold depends on more than the lowest temperature reached. For example, a prolonged period of moderately cold weather below freezing may do more damage than a short spell at a considerably lower temperature. Another frequent cause of severe damage is a very sudden drop in temperature; in extreme cases there may be a drop of 20°C in 12 hours. A strong wind occurring at the same time as a moderately low temperature may do more damage than a much lower temperature with no wind (the "chill factor"). Damage is always less severe when the trees are in a dormant condition than when they are actively growing; spring and autumn frosts are more damaging than the same temperature in mid-winter.

- Many different degrees of damage may occur. In mild frosts damage may be confined to partial browning of the leaves. In more severe cases all the leaves and many of the branches may be killed back, but recovery may be rapid from epicormic shoots. In more severe cases still, the tree may die back to ground level and coppice vigorously. In the worst cases the roots as well as the shoots die. The capacity of the eucalypts to coppice vigorously means that seemingly catastrophic die-back may be made good in a relatively short time.

As a result of these very variable factors, it is often difficult to extrapolate results from one area to another. Nevertheless, the information available does give reasonably consistent evidence of those species which are most worthy of trial in new localities subject to intense cold and frost.

In the first instance a rough and ready guide to cold resistance may be obtained by extracting information on ground conditions in Australia from the monographs in this chapter. Table 13.1 lists species which are potentially resistant to fairly intense cold (List A) and to moderate cold (List B). Broadly speaking List A corresponds to species with a mean minimum temperature in the coldest month of 0°C or less, and of at least 50 frost days. List B corresponds to species with a mean minimum temperature in the coldest month of 0-2°C and 25-50 days of frost. The absolute minimum temperatures corresponding would be around −10°C or less for List A and −6 to −10°C for List B.

Table 13.1 Cold resistance in Australia

List A Mean minimum coldest month $\leqslant$ 0°C; number of frosts $\geqslant$ 50	**List B** Mean minimum coldest month 0-2°C; number of frosts 25-50
E. aggregata	*E. amygdalina*
E. camphora	*E. andrewsii*
E. coccifera	*E. bridgesiana*
E. delegatensis	*E. caleyi*
E. fraxinoides	*E. cinerea*
E. glaucescens	*E. consideniana*
E. gunnii	*E. cypellocarpa*
E. johnstonii	*E. dalrympleana*
E. laevopinea	*E. dives*
E. nitens	*E. fastigata*
E. pauciflora	*E. macarthurii*
E. perriniana	*E. nitida*
E. pulverulenta	*E. obliqua*
E. stellulata	*E. occidentalis*
E. urnigera	*E. oreades*
E. vernicosa	*E. ovata*
	E. pulchella
	E. radiata
	E. regnans
	E. robertsonii
	E. rossii
	E. rubida
	E. viminalis
	E. youmannii

In Ireland *E. johnstonii* and *E. urnigera* have proved the most frost-resistant species, followed by *E. coccifera, E. gunnii, E. subcrenulata, E. delegatensis, E. dalrympleana, E. ovata, E. viminalis, E. obliqua* and *E. globulus*. Temperatures experienced have been at least as low as −11°C (Mooney, 1960). Frost crack (vertical splitting of bark right through to the wood) has occurred on a number of the larger trees and *E. viminalis* appears particularly vulnerable to this form of damage. In Ireland *E. globulus* tends to survive lower temperatures (down to $-9°C$) than those indicated by Martin for the United Kingdom (see Table 13.2).

In France research has indicated the following rankings in resistance to cold for adult trees (Lacaze, 1963):

to $-20°C$: *E. niphophila*

to $-14°C$: *E. coccifera, E. dalrympleana, E. gunnii, E. parvifolia, E. pauciflora, E. rubida, E. stellulata*

to $-10°C$: *E. cinerea, E. johnstonii, E. macarthurii, E. ovata, E. urnigera*

to $-8°C$: *E. camaldulensis, E. globulus, E. melliodora*

The possibilities of replacing unthrifty stands of *Pinus pinaster* in the Maures massif east of Toulon by cold-resistant eucalypts have been investigated (Giordano, 1965). The most promising species for a combination of cold resistance, good growth and good form has been *E. dalrympleana*. Other species which have proved frost resistant on one or more sites are *E. ovata, E. gunnii, E. macarthurii, E. rubida, E. viminalis, E. stellulata* and *E. cinerea*. In most years the coldest temperatures to be expected are about $-6°C$ on the southern and $-10°C$ on the northern aspects. There is good evidence for variability of cold resistance with provenance in *E. gunnii* (Lacaze, 1962).

More recently extensive trials have been reported from the plain of Aube and the Pyrenean foothills in the south of France (Marquestaut *et al.*, 1978). Temperatures down to $-11°C$ were recorded on the colder sites during the 5 years of the trials, as well as some late spring frosts. Among the most promising species for a combination of frost resistance and good growth were *E. aggregata, E. bridgesiana, E. cordata, E. gunnii, E. johnstonii, E. macarthurii, E. nitens, E. ovata* and *E. urnigera*. *E. neglecta* proved very frost resistant but its growth and form were poor. *E. globulus* ssp. *globulus* and ssp. *bicostata* (syn. *E. stjohnii*) and *E. viminalis* grew very well on the lower and warmer sites but were susceptible to frost on the coldest sites.

In the USSR, on the Black Sea coast of the Caucasus between Sochi and Bathumi *E. dalrympleana* has proved the most cold-resistant species. It withstands short frosts of $-11°$ or $-12°$ without any damage. On the south coast of the Crimea 1-year-old plants have withstood temperatures down to $-14°C$ (Pilipenko, 1960, summarized in Linnard, 1969). On fertile sites it is capable of growing 3 m a year for the first five years. It and *E. cinerea* are recommended as the best species for comparatively long rotations for shelterbelts and for timber production, in areas with temperatures not expected to fall below $-12°C$. Somewhat less resistant to cold, but still worth cultivation on shorter coppice rotations for fuel, pulpwood, etc., are *E. delegatensis, E. urnigera* and, less resistant still, *E. viminalis* and *E. macarthurii*.

In Argentina, in La Pampa province in the vicinity of Santa Rosa, the most frost-resistant species of those tested have been *E. cinerea, E. viminalis, E. bridgesiana, E. crebra* and *E. rubida*. Absolute minimum temperatures encountered in this area, which is at about latitude 37°S, are $-10°$ to $-12°C$ (Poduje and Roic, 1972).

Table 13.2 Cold resistance in the United Kingdom

Martin (1948)	Barnard (1966)	Halliwell (1974)
Resistant to —18°C	For very cold localities (below —12°C for considerable periods)	Tolerates down to —18°C
E. vernicosa		
E. largiflorens		
E. pauciflora ssp. *niphophila* (resistant to —22°C at Charlotte Pass, Australia)	*E. niphophila*	*E. niphophila*
E. gunnii (very polymorphous, especially on moist soils)		*E. gunnii*
Resistant to —15°C		Tolerates down to —15°C
E. coccifera (not erect on better drained soils)		
E. vernicosa ssp. *subcrenulata* (more rapid growth than *E. coccifera*)		*E. vernicosa*
E. vernicosa ssp. *johnstonii* (resisted —22°C on Loch Hourn, Australia)		*E. johnstonii*
E. urnigera		*E. urnigera*
		E. perriniana
		E. pauciflora
		E. parvifolia
		E. glaucescens
		E. delegatensis
Resistant to —12°C	For cold localities (below —7°C for considerable periods. below —12°C only occasionally)	Tolerates down to —12°C
E. pauciflora (less resistant in England than in Australia)		*E. coccifera*
E. delegatensis (resisted —15°C on Mount Usher, Australia)	*E. perriniana*	
E. rubida	*E. glaucescens*	*E. rubida*
E. stellulata	*E. parvifolia*	
E. aggregata	*E. gunnii*	*E. aggregata*

Table 13.2 Cold resistance in the United Kingdom *(concluded)*

Martin (1948)	Barnard (1966)	Halliwell (1974)
E. cordata		
E. dalrympleana	*E. pauciflora* var. *nana*	*E. dalrympleana*
E. ovata		
Resistant to —9°C		Tolerates down to —9°C
E. viminalis		*E. viminalis*
E. macarthurii		
E. pulverulenta (more resistant in England, to —15°C, than in native New South Wales)		*E. cordata*
		E. gigantea
E. obliqua		
E. radiata ssp. *robertsonii*		
E. stjohnii		
E. melliodora		
E. blakelyi		
E. resinifera		
Resistant to —7°C	For mild localities (below —7°C for short periods only)	Tolerates down to —7°C
E. globulus	*E. dalrympleana*	*E. globulus*
E. regnans	*E. pauciflora*	*E. regnans*
E. perriniana	*E. pulverulenta*	*E. ovata*
E. goniocalyx	*E. urnigera* var. *glauca*	*E. obliqua*
E. pulchella		*E. leucoxylon*
E. amygdalina		*E. amygdalina*
E. camaldulensis		
E. saligna		
E. risdonii		
E. tenuiramis		
E. sieberi		
Resistant to —4°C	Very mild localities (rarely below —5°C)	
E. leucoxylon	*E. cordata*	
E. lehmanii	*E. cordieri*	
E. sideroxylon	*E. rubida*	

In South Africa a number of species are classed as suitable for planting in areas having severe frosts. These have absolute minimum temperatures of between −10 and −12°C and an average of 60 to 90 frosty nights per year. Species considered suitable for planting in these conditions are *E. bridgesiana, E. cinerea, E. dalrympleana, E. dives, E. macarthurii, E. maidenii, E. melliodora, E. nitens, E. pauciflora, E. rubida* and *E. viminalis*. Of the above species, *E. maidenii, E. melliodora, E. nitens, E. rubida* and *E. viminalis* are considered suitable species for the production of sawlogs (Poynton, 1971).

In parts of southern Brazil abnormally severe cold weather was experienced in the winter of 1975, with minimum temperatures as low as −9°C. In these areas frost is experienced annually. Fishwick (1976) has reported that in these conditions results from trial plantings indicate clearly that, compared with the widely planted *E. viminalis*, there are five species which show equal or better frost resistance, equal early growth rates, and which will produce acceptable pulp material. They are *E. dalrympleana, E. dunnii, E. nova-anglica, E. nitens* and *E. stjohnii*. All except *E. dalrympleana* were of excellent form, better than *E. viminalis*. The trials also indicated considerable differences in frost resistance between different provenances of the same species.

Trials have been under way since 1972 to identify species of eucalypt suitable for planting in the southeastern coastal plain of the United States where both mild freezing and large, rapid temperature fluctuations occur. After five years, *E. viminalis* grew the best, but cold-hardiness varied greatly among individuals. *E. macarthurii* showed good cold resistance and, although slightly smaller in volume production than *E. viminalis*, also has excellent potential. *E. nova-anglica* and *E. camphora* also rated high in cold resistance but will need improvement in growth and form. Other species which grew slower but demonstrated good cold-hardiness and merit further testing are *E. rubida, E. dalrympleana* and *E. nitens*. During the period of the trials, over 100 nights below freezing were recorded, with the lowest temperature being −8°C. Rapid and extreme temperature fluctuations, such as from 27°C in the daytime down to −4°C at night, caused most severe damage to the eucalypts. Absolute low temperatures appeared to be less critical than large, rapid fluctuations (Hunt and Zobel, 1978).

Quick reference tables

Tabulated information on a limited number of the more important species provides a quick and convenient aid to the selection of species for trial in a given climate. In addition to listing the species which are suited to various climatic types, the tables may provide information on the uses of the species. An example of a table showing the bioclimatic regions of Brazil and potentially suitable species for them are shown in Chapter 4 under Brazil. Further examples, from Australian and South African experience, are in Appendix 4. The tables should assist in identifying potentially suitable species, on which more detailed information may be obtained from the monographs in Chapter 14.

14. Species monographs

Hundreds of species or varieties of eucalypts have been tested in many of the countries of the world, for production forestry, protection against wind or erosion, possible medicinal values, as street trees or for ornamental purposes. Their potential is discussed in this chapter and some buds and fruits are illustrated in Appendix 7. The species which seem to justify most interest are discussed first in monographs; then follow brief notes on about 50 species which have not been successful in planting trials to date or which, in a few cases, have scarcely been tested but could be of interest for special sites.

Both the monographs and the brief notes give species in alphabetical order. The monographs give the following information:

1. The botanical name and the author or authors. Names and authors are those used by Chippendale (1976).

2. References to the number of the species in the second edition (1955) of Blakely's *A key to the eucalypts*; the code letters of the species in Pryor and Johnson's (1971) *A classification of the eucalypts*; if applicable, the page number where the species is described and illustrated in the third edition (1970) of *Forest trees of Australia*" (FTA, p. ....); if applicable, the number of the descriptive sheet on the species in the Forest Tree Series issued by the Division of Forest Research, CSIRO, Canberra (FTS No....); and, if applicable, the page number where the species is described in Chippendale's (1973) *Eucalypts of the Western Australian goldfields*" (Chipp., p.....). The Blakely number is the same as the number under the illustration of the buds and fruits in Appendix 7.

3. The common name used in Australia.

4. Regions of natural occurrence; the tree in Australia; soils.

5. Latitudinal range.

6. Altitudinal range.

7. Rainfall type and amount; the length of the dry season (number of consecutive "dry" months, with less than 30 mm in a month).

8. Temperature in the regions of natural occurrence; number of frosts. In the longer monographs temperature and rainfall of some places where the species has been outstandingly successful are also given.
9. Botanical characteristics:
   - Tree height in Australia; tree form
   - Bark type
   - Juvenile leaves
   - Adult leaves
   - Wood (density figures refer to "air-dry" — 12° moisture content)
   - Buds and fruits (reference in parentheses following sequence number to the number of the figure in Appendix 7 which is the same as the Blakely number; thus, a7-1 (125) is read as Appendix 7, Figure 1, Blakely number 125).
   - Viable seeds per gram [1]
10. Uses of the wood, bark or leaves.
11. Prospects for planting.
12. Success outside Australia.

Eucalyptus accedens W.V. Fitzg.

Refs. Blakely No. 125 Code SII:C FTS No. 82

Common name in Australia. Powder bark wandoo

Regions of natural occurrence. In savanna woodland on sandy or gravelly soils both north and south of Perth, Western Australia, in scattered association with *E. wandoo* and sometimes brown mallet (*E. astringens*). An attractive tree with a smooth white bark.

Latitudinal range. 31°-34°S

Altitudinal range. Up to 300 m

Rainfall

Type: winter-rainfall zone
Total: 300-600 mm
Dry season: in the warmer months, rather severe

Temperature

Mean maximum of hottest month: 35-36°C
Mean minimum of coldest month: 2-4°C
Frosts: 5-20

---

[1] *Note:* When eucalypt seed is extracted from the capsules, it is mixed with a large number of unfertilized ovules called "chaff." The seed is sold commercially mixed with the chaff. The figure given for viable seeds per gram is taken from the 1975 *FAO Forest Tree Seed Directory*. The number of viable seeds per gram of seed and chaff varies greatly. Unless otherwise indicated, the number given in the monographs is the Australian average shown in the FAO Seed Directory.

Characteristics

Tree height in Australia: up to 20 m; usually of good form
Bark type: smooth throughout, white
Juvenile leaves: opposite first, then alternate
Adult leaves: alternate, stalked, narrow-lanceolate
Wood: hard and tough
Buds and fruits: Figure a7-1 (125)
Viable seeds per gram: 71

Uses. The tree has a high tannin content in both bark and wood

Prospects for planting. Limited. There is little reason to prefer it ahead of the more vigorous species *E. astringens* and *E. wandoo.*

Success outside Australia. FTS No. 82 reports "when planted overseas growth has been slow." South Africa (Poynton, 1957) reports a mean height of 11 m and a mean DBH of 20 cm at age 22 at Tokai on a deep sandy loam in silvicultural Zone A. The altitude was 61 m and the rainfall 965 mm. Tokai is in a suitable climate for the species. It was tried in Brazil in an unsuitable climate and failed.

Refs. Blakely No. 313 Code MAG:C FTA p. 156

E. acmenoides Schau.

Common name in Australia. White mahogany

Regions of natural occurrence. In coastal forests from Sydney, New South Wales, to Rockhampton, Queensland, and also on the Atherton Tableland. On ridges and hills and in Queensland on plateaus and hills. It grows on a wide variety of well-drained soils.

Latitudinal range. 14°-35°S

Altitudinal range. From near sea-level to 300 m in the southern part of the range and to 1 000 m in the far northern part.

Rainfall

Type: uniform rainfall in the south to summer rainfall in the north
Total: 625-1 500 mm
Dry season: in the cooler months, not severe

Temperature

Mean maximum of hottest month: 27-33°C
Mean minimum of coldest month: 10-14°C
Frosts: few

Characteristics

Tree height in Australia: up to 40 m; usually of good form
Bark type: fibrous and stringy throughout

Juvenile leaves: opposite and sessile
Adult leaves: stalked and lanceolate
Wood: a valuable polewood and sawtimber
Buds and fruits: Figure a7-2 (313)
Viable seeds per gram: 97

Uses. A high-quality timber, used in pole form, sawn or hewn

Prospects for planting. A good tree but there are other better species from the eastern Australian forests. It is likely to hybridize with *E. pilularis.*

Success outside Australia. It has made fair plantations in Brazil, South Africa, North Africa and Kenya

E. alba Reinw. ex Bl.

Refs. Blakely No. 207 Code SNABAA FTA p. 104

Common name in Australia. Poplar gum, Khaki gum

Regions of natural occurrence. Tropical regions in both northeastern and northwestern Australia; the Papuan portion of Papua New Guinea; Timor and several other islands in the far eastern part of the Indonesian archipelago. It grows on flats, slopes and ridges; the soils are usually heavy and maybe waterlogged in the rainy season.

Latitudinal range. 17.5°-6°S

Altitudinal range. Sea-level to 500 m or even higher

Rainfall

Type: summer rainfall
Total: 750-2 000 mm
Dry season: up to eight months, can be severe

Temperature

Mean maximum of hottest month: 32-35°C
Mean minimum of coldest month: 5-10°C
Frosts: nil or very few

Characteristics

Tree height in Australia: 15-25 m; usually not of good form in Australia
Bark type: smooth, with white, cream or pink patches; surface covered with a powdery bloom; bark contains 30-32 percent tannin
Juvenile leaves: alternate, stalked, ovate to deltoid
Adult leaves: alternate usually, stalked, deltoid to lanceolate
Wood: light reddish brown; moderately durable to very durable
Buds and fruits: Figure a7-3 (207)
Viable seeds per gram: 412

Uses. Used locally in Australia, but frequently hollowed out by termites, particularly on ridges.

Prospects for planting. This is a widespread low-latitude species in its own right, quite apart from earlier confusion with *E. urophylla.* There are few eucalypts growing naturally in a latitude lower than 10°. If this species is considered for future planting, careful provenance testing should be carried out because it covers a very wide range. Many of the occurrences have been isolated for a long time. Stands on the south coast of Timor are good, also some provenances in the Kimberley ranges in Australia. Other good provenances are the taxa earlier known as *E. alba* var. *australasica,* in the far northern part of the Northern Territory, which has lanceolate leaves, and *E. pastoralis* (Blakely No. 209) from Stapleton in the Northern Territory which has long petioles and large, thick, poplar-like leaves and makes a good shade tree.

A disadvantage of the species is that it has a long flowering period and this appears to be extended when it is planted overseas, causing it to hybridize with many other species of the subgenus *Symphyomyrtus.*

Success outside Australia. There are excellent individual trees of true *E. alba* in Sri Lanka, Brazil, India and Africa. The successful plantations in Brazil earlier known as *E. alba* are hybrids of *E. urophylla* or true *E. urophylla.*

E. andrewsii Maid. (incl. E. campanulata)

Refs. Blakely No. 422 Code MATHDA FTA p. 212 under *E. campanulata* FTS No. 140

Common name in Australia. New England blackbutt

Regions of natural occurrence. Tableland areas of northern New South Wales and Queensland, to coastal ranges near Mackay (latitude 21.1°S) in Queensland. In New South Wales it grows mainly on the warmer and drier western side of the tablelands. The soils vary from moderately deep loamy sands of good fertility to skeletals.

Latitudinal range. 21°-32°S

Altitudinal range. 600-1 200 m

Rainfall

Type: uniform or summer rainfall
Total: 625-1 000 mm
Dry season: up to three months, not usually severe

Temperature

Mean maximum of hottest month: 27-32°C
Mean minimum of coldest month: 0°C

Characteristics

Tree height in Australia: up to 35 m; usually of good form
Bark type: fibrous and persistent on trunk and larger branches
Juvenile leaves: sub-opposite to alternate, broadly lanceolate to ovoid
Adult leaves: alternate, stalked, lanceolate, tendency to be falcate, oblique at base
Wood: a useful general building timber
Buds and fruits: Figure a7-4 (422)
Viable seeds per gram: 116

Uses. A good forest tree. General purpose sawnwood. Grown on podsolic skeletal soils, usually moderately deep sandy loams; parent material granite or some quartz porphyry.

Prospects for planting. This species was relatively inaccessible until after the Second World War and was not common in overseas trials. It should adapt readily to plantation practice and would not hybridize with *E. grandis* and other members of the subgenus *Symphyomyrtus*; a promising prospect.

Success outside Australia. Moderate in Brazil

E. astringens (Maid.) Maid.

Refs. Blakely No. 112 Code SIDAB FTA p. 78

Common name in Australia. Brown mallet

Regions of natural occurrence. Southwest Western Australia, inland from the Darling Range, the principal area extending from 60 km north to 120 km south of the town of Narrogin (latitude 32.9°S). It occurred naturally, mainly on country of low relief on the sides of low stony hills, but the best trees were found on the sides of the low flat-topped hills on soils which were sandy or clay loams. Most of the region of natural occurrence has been used for wheat farming. The parent material of the soils was weathered laterite.

Latitudinal range. 32°-34°S

Altitudinal range. 300-400 m

Rainfall

Type: winter rainfall
Total: 350-550 mm

Narrogin, lat. 32.9°S

J	F	M	A	M	Jn	Jl	A	S	O	N	D	Total
10	16	22	30	65	92	93	71	48	34	14	13	508

Extremes recorded: highest 741, lowest 268
Dry season: 6-7 months, can be severe

50. 38-year-old plantation of *E. astringens* at Dryandra, Western Australia
Forests Department of Western Australia

Temperature

Mean maximum of hottest month: 35°C
Mean minimum of coldest month: 2-4°C
Frosts: 7-10
Extremes recorded: highest 43.9°C, lowest −3.5°C

Characteristics

Tree height in Australia: up to 25 m; a rather short trunk but a well-developed crown
Bark type: smooth throughout shedding by curled flakes; thin with many kino vessels; bark contains 40-57 percent tannin
Juvenile leaves: opposite first then alternate, stalked ovate to broadly lanceolate
Adult leaves: alternate, stalked, lanceolate, slightly curved
Wood: light red-brown to dark grey-brown, fine textured, very hard, strong and very tough; moderately durable; weight 980 kg/m^3; it machines readily
Buds and fruits: Figure a7-5 (112)

Uses. The wood is used for axe handles and hammer handles, also as a mine-timber; it is an excellent fuelwood

Prospects for planting. The high quality of the wood and the tanning content of the bark are attractive features; the rate of growth is fair for the rainfall to which it is suited, but it is a non-lignotuberous eucalypt and a weak coppicing species, which makes it unattractive for coppice plantations

Success outside Australia. It was introduced and successfully established in southern Africa, Kenya and North Africa but has not been widely used; it was not a success where tried in Brazil because it was not suited to the climatic pattern. In Tunisia it has proved to be one of the most resistant species to *Phoracantha,* owing to its ability to maintain a relatively high osmotic pressure without damage in the dry season (Chararas, 1971) and is considered among the most promising species in the arid and semi-arid southern half of the country (Stone, 1973). Tolerant of clay soils, but susceptible to frost and to highly calcareous soils (Schoenenberger, 1971).

E. blakelyi Maid. var. blakelyi

Refs. Blakely No. 186 Code SNEEFA FTA p. 94

Common name in Australia. Blakely's red gum

Regions of natural occurrence. The inland side of the Great Dividing Range from southern Queensland to northern Victoria, growing mainly on compact loams of moderately good quality.

Latitudinal range. 28°5′-37°S

Altitudinal range. 150-1 000 m

Rainfall

Type: uniform to summer rainfall
Total: 450-750 mm
Dry season: fairly long droughts occur periodically

Temperature

Mean maximum of hottest month: 26.5-32°C
Mean minimum of coldest month: 3-4°C
Frosts: 5-50

Characteristics

Tree height in Australia: 15-25 m; with a good lower bole and the depth of the crown at least half the height of the tree
Bark type: smooth, red-gum type
Juvenile leaves: opposite first then shortly petiolate, ovate to nearly orbicular
Adult leaves: alternate, lanceolate and usually curved
Wood: pinkish to reddish brown; interlocked grain; durable; density 980 kg/m^3
Buds and fruits: Figure a7-6 (186)
Viable seeds per gram: 635

Uses. Farm purposes and fuel; rarely milled but frequently split for posts

Prospects for planting. Selected provenances of *E. tereticornis* would be preferable, except possibly on higher sites. *E. blakelyi* is more suited to inland sites than *E. tereticornis.*

Success outside Australia. Rather poor in Brazil

E. bosistoana F. Muell.

Refs. Blakely No. 479 Code SUNCA FTA p. 230

Common name in Australia. Gippsland grey box

Regions of natural occurrence. Coastal areas of southern New South Wales and Victoria, on the better soils. The only member of the box group of eucalypts that grows in a closed forest.

Latitudinal range. 33.5°-38.5°S

Altitudinal range. 0-300 m

Rainfall

Type: uniform to winter rainfall
Total: 625-1 000 mm
Dry season: not severe, usually in the cooler months

Temperature

Mean maximum of hottest month: 22-28°C
Mean minimum of coldest month: 3-9°C
Frosts: 5-30, not severe

Characteristics

Tree height in Australia: 30-35 m; of good form, with the bole usually longer than half the height of the tree
Bark type: typical box; brown
Juvenile leaves: opposite at first, then alternate, stalked, orbicular
Adult leaves: alternate, stalked, lanceolate
Wood: hard, interlocked grain, durable, density 990-1 200 kg/m^3
Buds and fruits: Figure a7-7 (479)
Viable seeds per gram (France): 844

Uses. Sawnwood of best strength class. Hewn timbers, sleepers and poles.

Prospects for planting. The most vigorous of the box group of eucalypts. It could find a useful place if wood of its type is required.

Success outside Australia. Fairly successful as one of the slower growing eucalypts in southern and northern Africa in Mediterranean-type countries

E. botryoides Sm.

Refs. Blakely No. 64 Code SECAD FTA p. 60

Common name in Australia. Southern mahogany

Regions of natural occurrence. Coastal areas of southern New South Wales and Victoria; as a good forest tree in sheltered lowland valleys with fertile soils and also as a smaller tree on exposed coastal hills.

Latitudinal range. 32°-39.5°S

Altitudinal range. 0-300 m

Rainfall

Type: uniform rainfall
Total: 625-1 000 mm
Dry season: usually 2-3 months, not severe

Temperature

Mean maximum of hottest month: 23-28°C
Mean minimum of coldest month: 2-9°C
Frosts: 0-20, not severe

Characteristics

Tree height in Australia: 40 m, with a good trunk and a fairly dense crown
Bark type: persistent on lower trunk, smooth above

Juvenile leaves: alternate, broadly ovate, petiolate, wavy edges
Adult leaves: stalked, lanceolate, strong midrib
Wood: reddish brown, interlocked, hard and durable; density 910 kg/m^3
Buds and fruits: Figure a7-8 (64)
Viable seeds per gram: 406

Uses. Excellent coastal eucalypt; withstands strong winds off the sea; good for shade and shelterbelts

Prospects for planting. Useful for coastal plantings in its latitude. It can tolerate sea winds. The favourable reports from several countries make this a species worth closer attention and a series of provenance trials.

Success outside Australia. An excellent timber tree and watershed cover on the island of Maui in Hawaii; a useful windbreak tree in California; a very good forest tree in the far south of Brazil; successful in southern Italy and North Africa. It hybridized with *E. camaldulensis* in Algeria to form the successful hybrid known as *E. trabutii.* It has been successful in South Africa but is reported as being one of the poorer coppicing species. It grows well in New Zealand. Good reports come from Kenya and Malawi; Malawi has found the Victorian provenance better than their provenance from New South Wales and growing as well as *E. grandis* in some areas.

Refs. Code SNEET FTS No. 213

E. brassiana S.T. Blake

Common name in Australia. Cape York red gum

Regions of natural occurrence. Cape York Peninsula, Queensland; the western district of Papua in Papua New Guinea

Latitudinal range. 6°-18°S

Altitudinal range. Not known

Rainfall

Type: summer rainfall
Total: 1 000-1 500 mm
Dry season: 2-3 months, not severe

Temperature

Mean maximum of hottest month: 30°C
Mean minimum of coldest month: 10°C
Frosts: nil

Characteristics

Tree height in Australia: 30 m
Bark type: rough on lower trunk, red-gum type above
Juvenile leaves: tend to be orbicular

Adult leaves: stalked and lanceolate
Wood: heavy, strong and durable, grain interlocked; probably like *E. tereticornis*
Buds and fruits: like Figure a7-101 (178) but much larger
Viable seeds per gram: 341

Uses. Probably similar to *E. tereticornis*

Prospects for planting. This is a newly separated red gum from the low latitudes of northern Queensland and Papua New Guinea. It should be treated like a low-latitude provenance of *E. tereticornis* and tried in low-latitude countries wishing to grow eucalypts.

Success outside Australia. Not known at present: it could have been planted as *E. tereticornis*

E. bridgesiana R.T. Bak. (syn. E. stuartiana F. Muell. ex Miq.)

Refs. Blakely No. 225 Code SPIDCA FTA p. 116

Common name in Australia. Apple box

Regions of natural occurrence. The natural occurrence of *E. bridgesiana* covers a wide area along the Great Dividing Range in New South Wales and northeastern Victoria, mainly on the inland slopes of the range. There is a small extension into southern Queensland. The soils are usually fairly heavy over a moderately heavy clay. It is typically a species of open woodland rather than closed forest.

Latitudinal range. 29°-38°S

Altitudinal range. Near sea-level in the south to 1 300 m in the north

Rainfall

Type: winter to summer rainfall
Total: 625-1 100 mm
Dry season: up to 4 months, irregular droughts

Temperature

Mean maximum of hottest month: 28-30°C, warm to hot summers
Mean minimum of coldest month: 0-2°C, cool to cold winters
Frosts: 15-60

Characteristics

Tree height in Australia: 15-40 m; the bole is usually short but the crown is large and heavily branched; it is a good shade tree
Bark type: box type
Juvenile leaves: sub-opposite, heart shaped and sessile, glaucous
Adult leaves: stalked and long-lanceolate
Wood: not liked by sawmillers; used to line wells in early settlement days

as it does not colour the water; very few gum veins.
Buds and fruits: Figure a7-9 (225)
Viable seeds per gram: 205

Uses. Good shade tree; planted for ornamental purposes; good honey tree

Prospects for planting. Not a prospect for wood producers but valuable as a shelterbelt tree on high cold treeless plains

Success outside Australia. Successful as a shelterbelt tree in South Africa and several other winter or uniform rainfall countries. Not used for wood production.

E. brockwayi C.A. Gardn.

Refs. Blakely No. 584 Code SIS:C Chipp. p. 97 FTA p. 264

Common name in Australia. Dundas mahogany

Regions of natural occurrence. Inland southwest Western Australia, occurring on sandy soils or sandy loams derived from basic rocks. A tree of open woodlands.

Latitudinal range. 31°-33°S

Altitudinal range. 180-420 m

Rainfall

Type: winter rainfall
Total: 225-375 mm
Dry season: in the warmer months up to 8 or 9 months

Temperature

Mean maximum of hottest month: 30°C
Mean minimum of coldest month: 4°C
Frosts: up to 15

Characteristics

Tree height in Australia: up to 15-25 m, with a relatively short but straight trunk
Bark type: smooth and white to salmon pink
Juvenile leaves: very narrow, crowded on stem
Adult leaves: stalked and lanceolate
Wood: straight grained; hard and tough but not termite resistant
Buds and fruits: Figure a7-10 (584a)
Viable seeds per gram: 383

Uses. Used locally for mining purposes, firewood and tool handles; the bark contains more than 40 percent tannin; it is an attractive ornamental

Prospects for planting. A possibility for arid Mediterranean-type climates where wood is urgently needed

Success outside Australia. Promising results are reported from northern Africa

E. calophylla R. Br.

Refs. Blakely No. 32 Code CAFUA FTA p. 30

Common name in Australia. Marri

Regions of natural occurrence. Widespread in the better forests of the southwest corner of Western Australia. It occurs on the plateau of the Darling Range, down the westward slopes and in the forests of the sand-plains to near sea-level. It will grow on poor soils but makes a better tree on the alluvial soils between laterite-capped ridges. It occurs in mixture with karri (*E. diversicolor*) and Red Tingle (*E. jacksonii*) in the very tall forest of the southern part of its occurrence, and throughout the jarrah (*E. marginata*) forest.

Latitudinal range. 31.5°-35°S

Altitudinal range. 0-300 m

Rainfall

Type: winter rainfall
Total: 625-1 200 mm
Dry season: 4-6 months, not severe

Temperature

Mean maximum of hottest month: 24-29°C
Mean minimum of coldest month: 4-7°C
Frosts: 1-15

Characteristics

Tree height in Australia: 30-35 m; normally producing a good trunk with a deep, heavy crown

Bark type: bloodwood type

Juvenile leaves: opposite to alternate, with glandular hairs on surface

Adult leaves: stalked, alternate, lanceolate

Wood: pale yellow, hard, strong and durable; spoiled as a commercial saw-timber by frequent kino pockets; valuable as a woodchip timber.

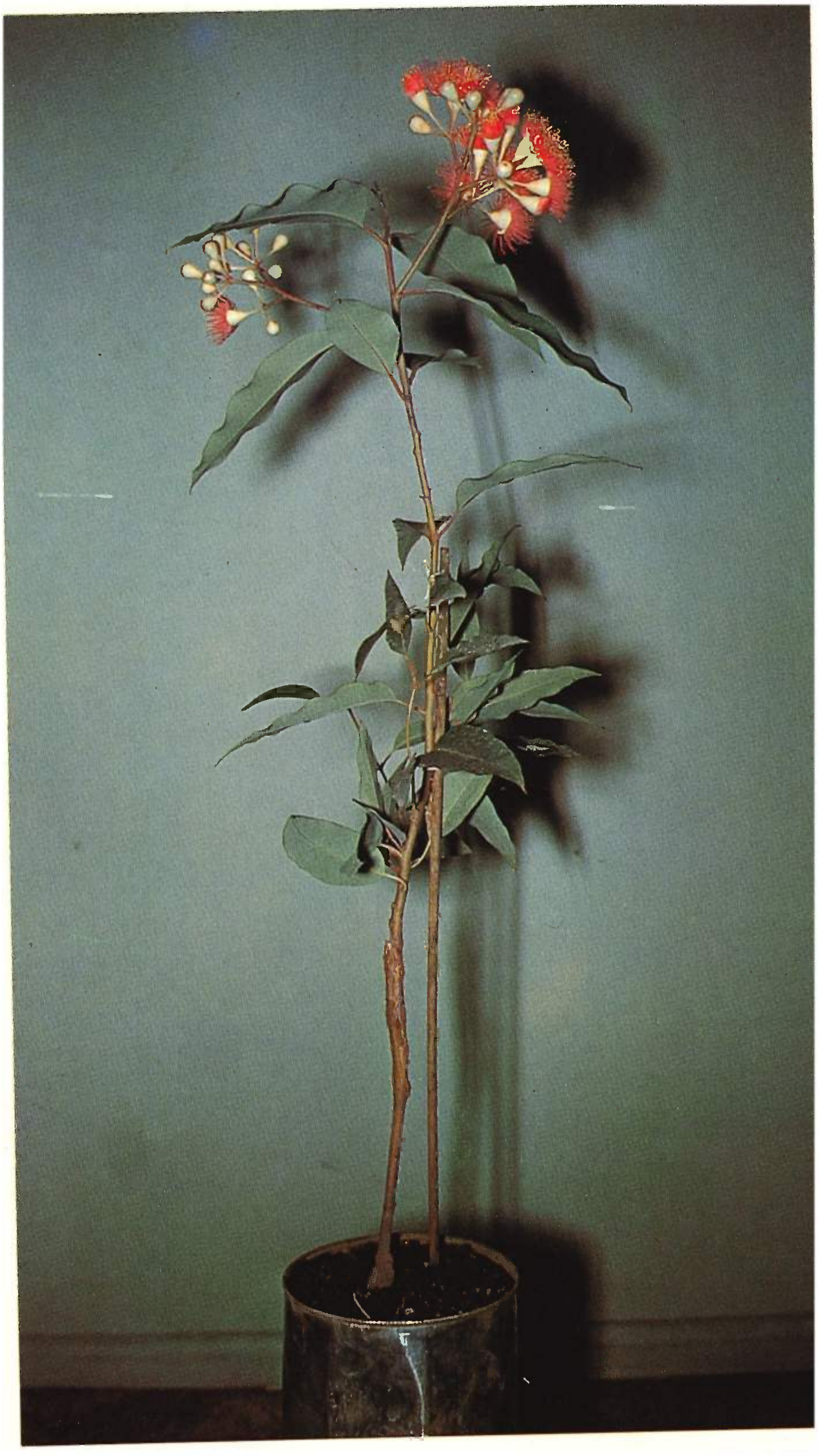
Buds and fruits: Figure a7-11 (32)

Viable seeds per gram: 9

Uses. In the jarrah forest marri is a valuable component because it is resistant to the insidious pathogen *Phytophthora cinnamoni* which is proving so damaging to jarrah. Marri regenerates well and ensures continuity of forest

Eucalyptus regnans, Maydena, Tasmania

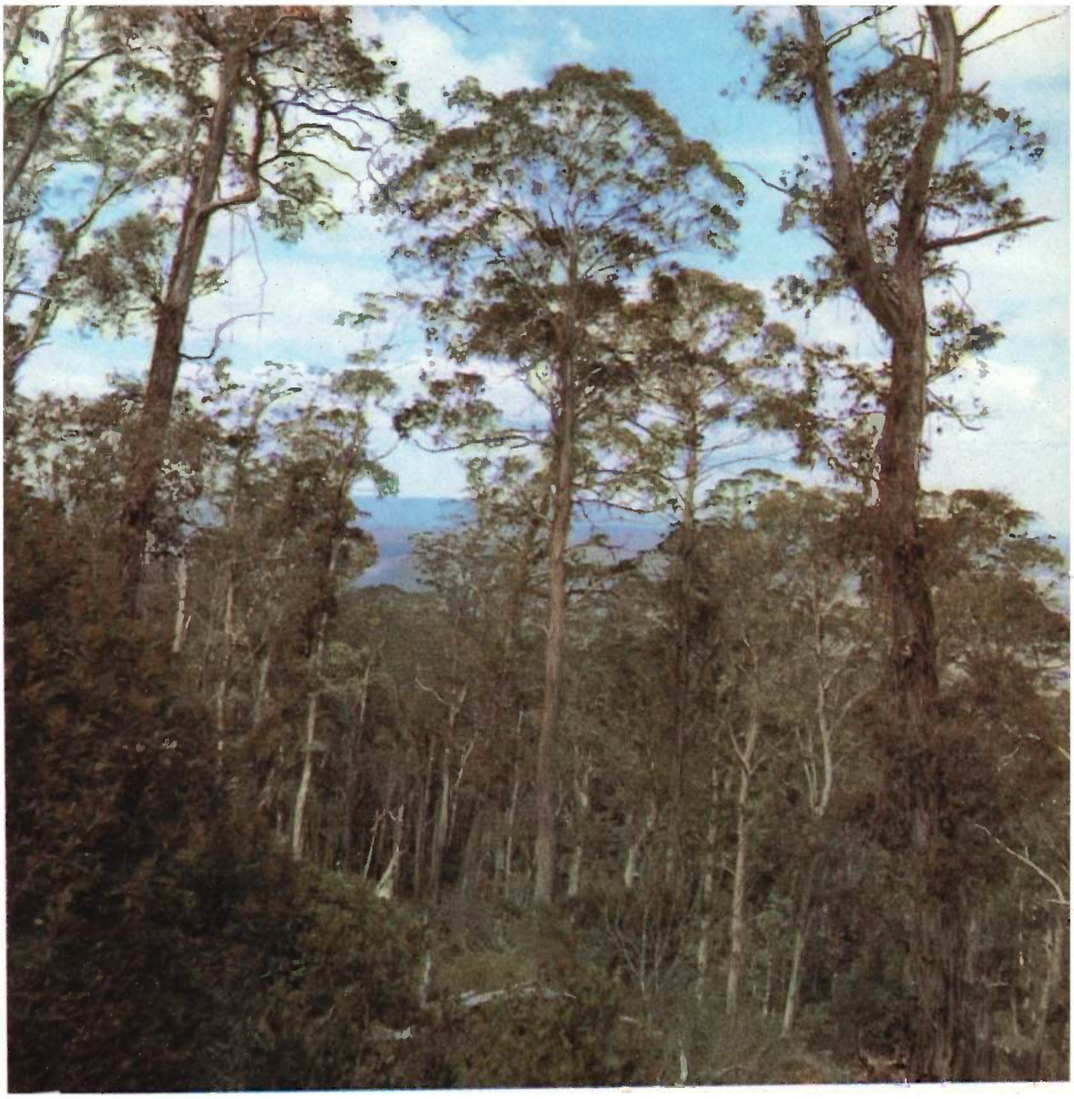
L.D. Pryor



E. ficifolia, grafted adult scion

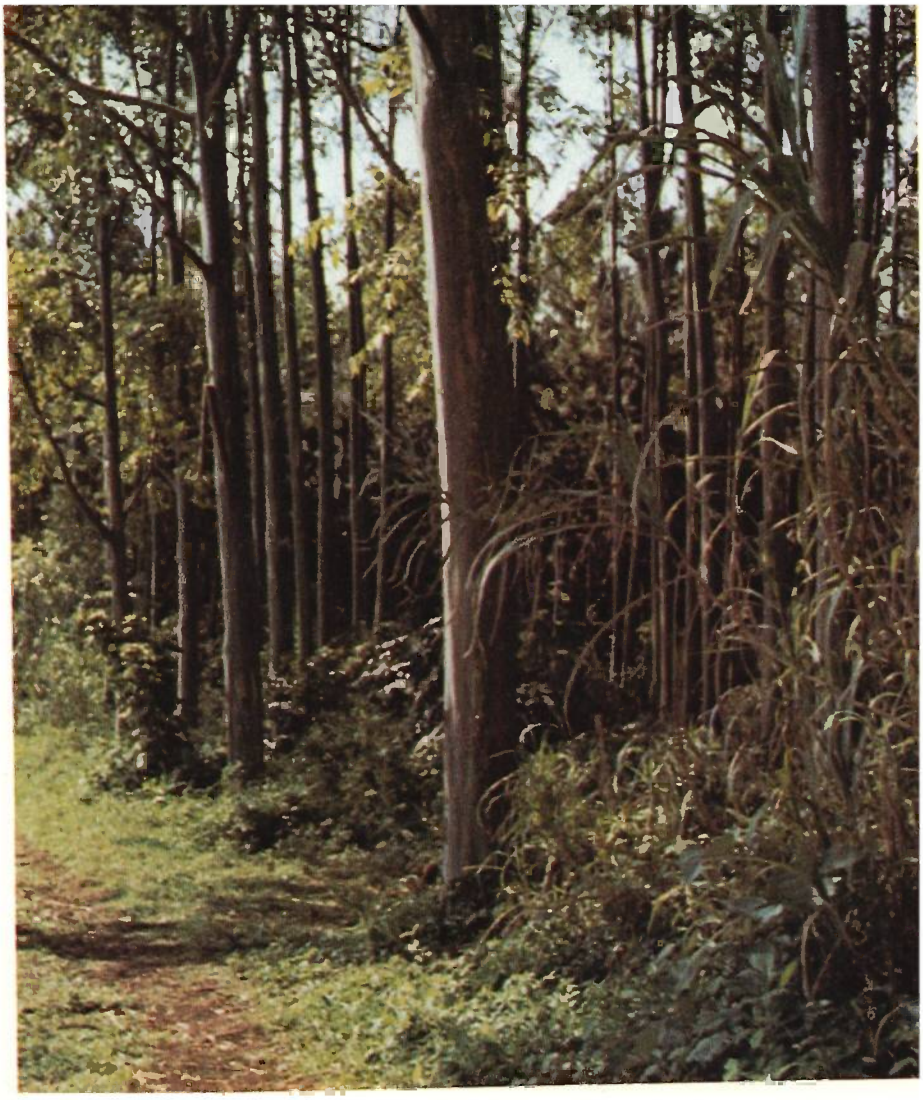
L.D. Pryor

E. ficifolia, flower in bloom
C. Palmberg



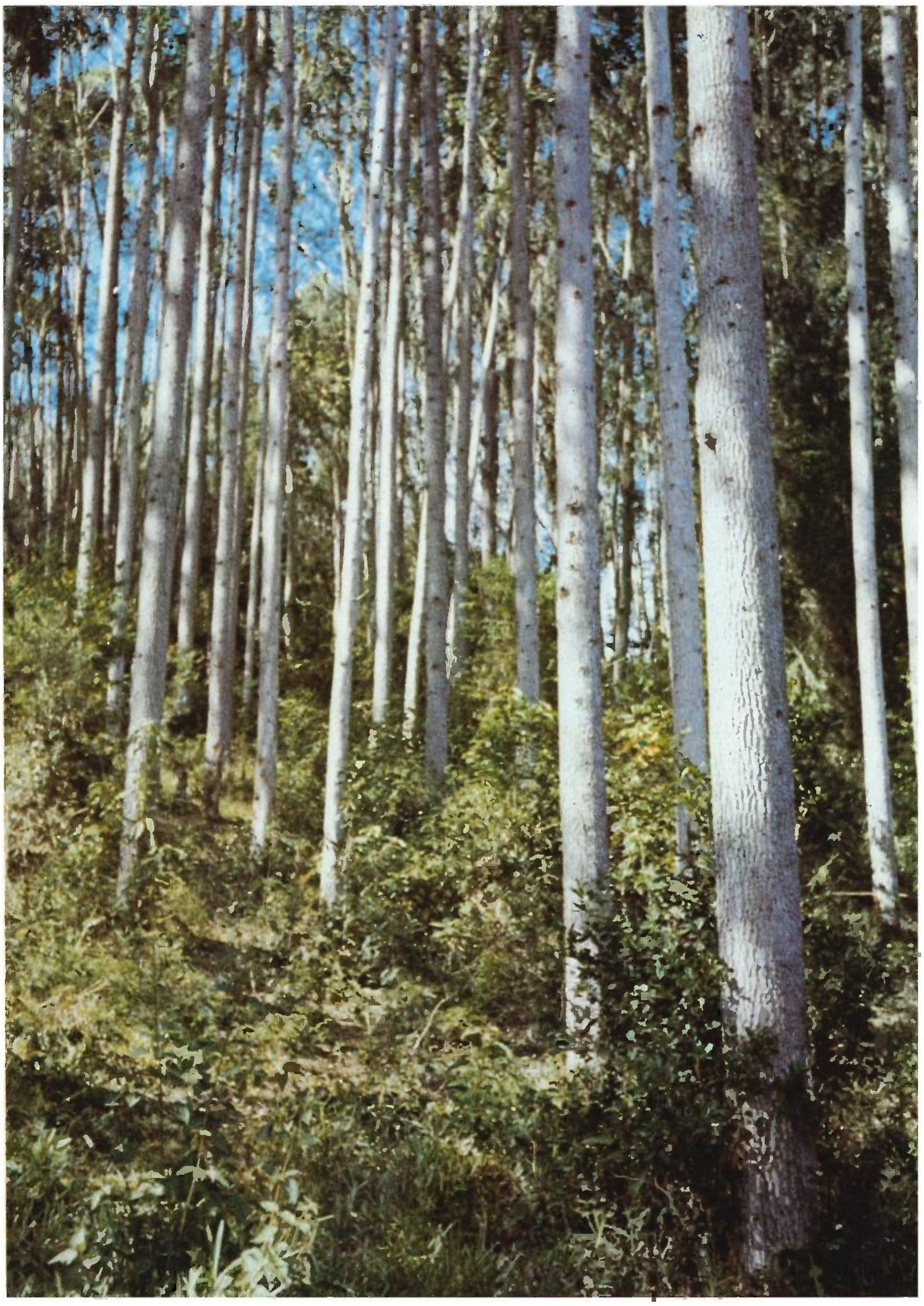
E. nitens, tree form
CSIRO
Division of Forest Research,
Canberra, ACT, Australia

E. nitens, bark, upper portion
CSIRO
Division of Forest Research,
Canberra, ACT, Australia



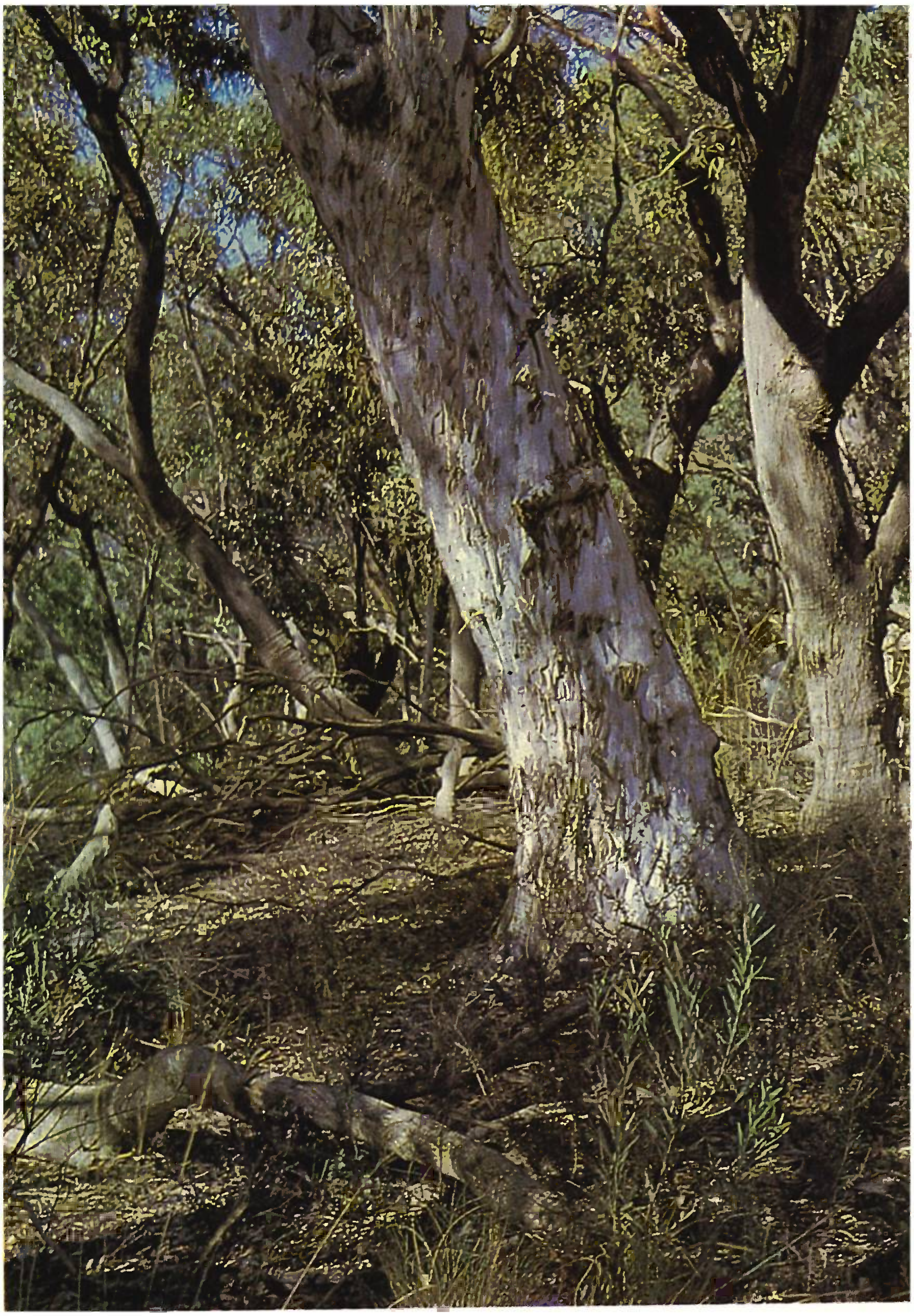
E. deglupta, Malunga, Zaire, 9-year-old plantation

P.J. Wood
Unit of Tropical Silviculture
Commonwealth Forestry Institute
University of Oxford



E. cloeziana, Périnet, Madagascar,
16-year-old plantation

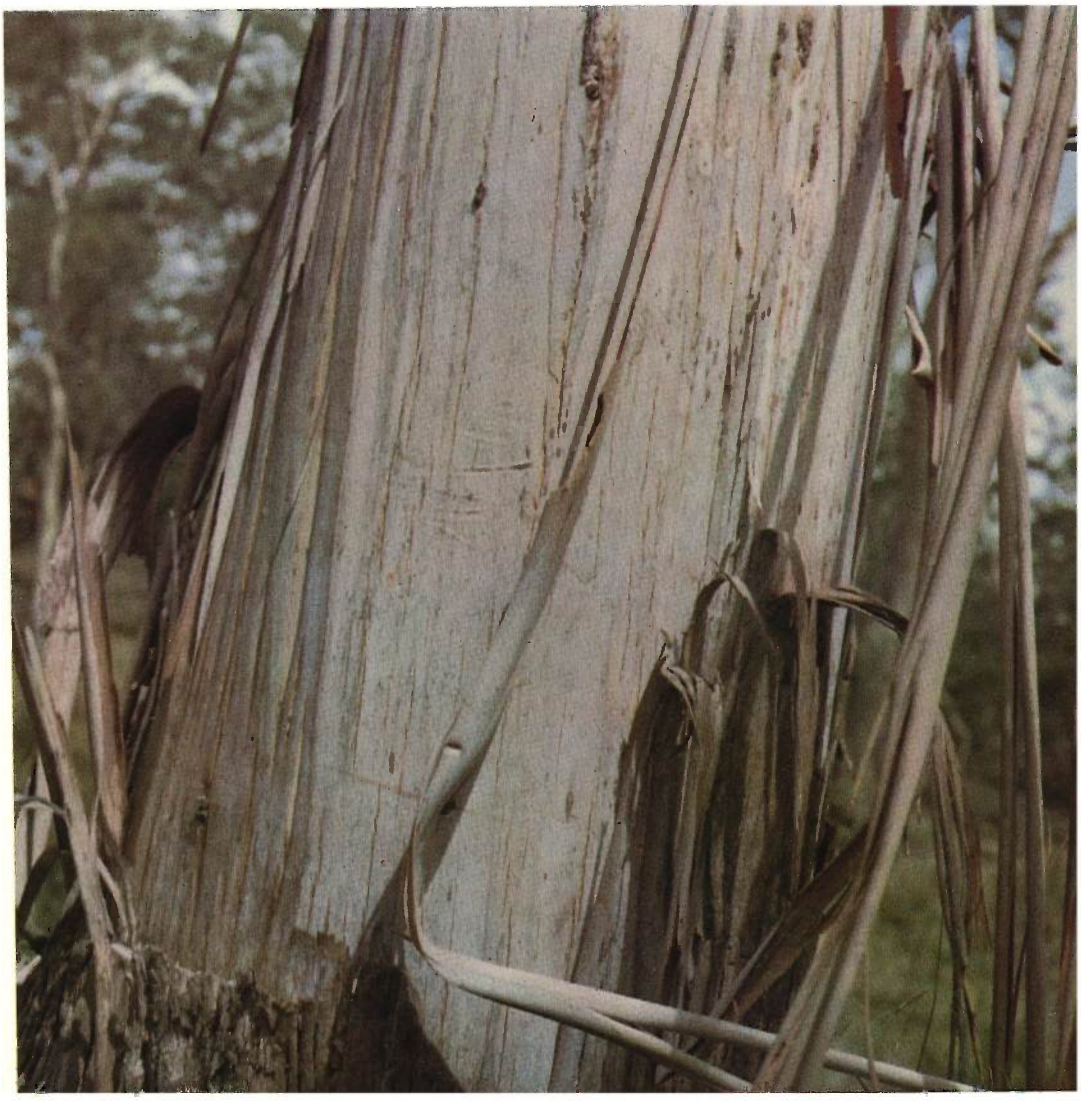
P.J. Wood
Unit of Tropical Silviculture
Commonwealth Forestry Institute
University of Oxford



8c

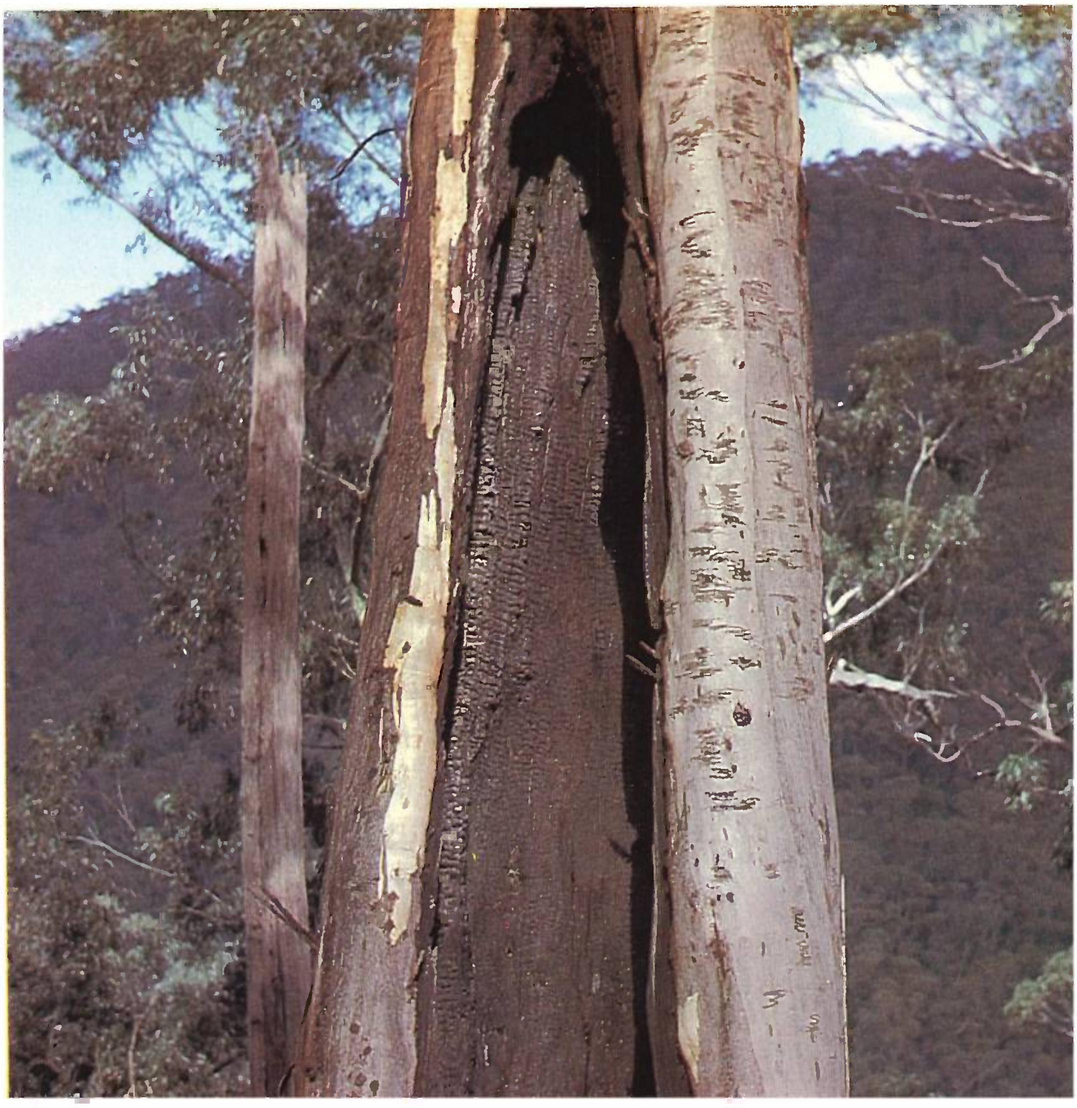
E. mannifera, ssp. *maculosa (left)* and *E. dives (centre)*: natural mixed eucalypt stand, Tasmania

L.D. Pryor



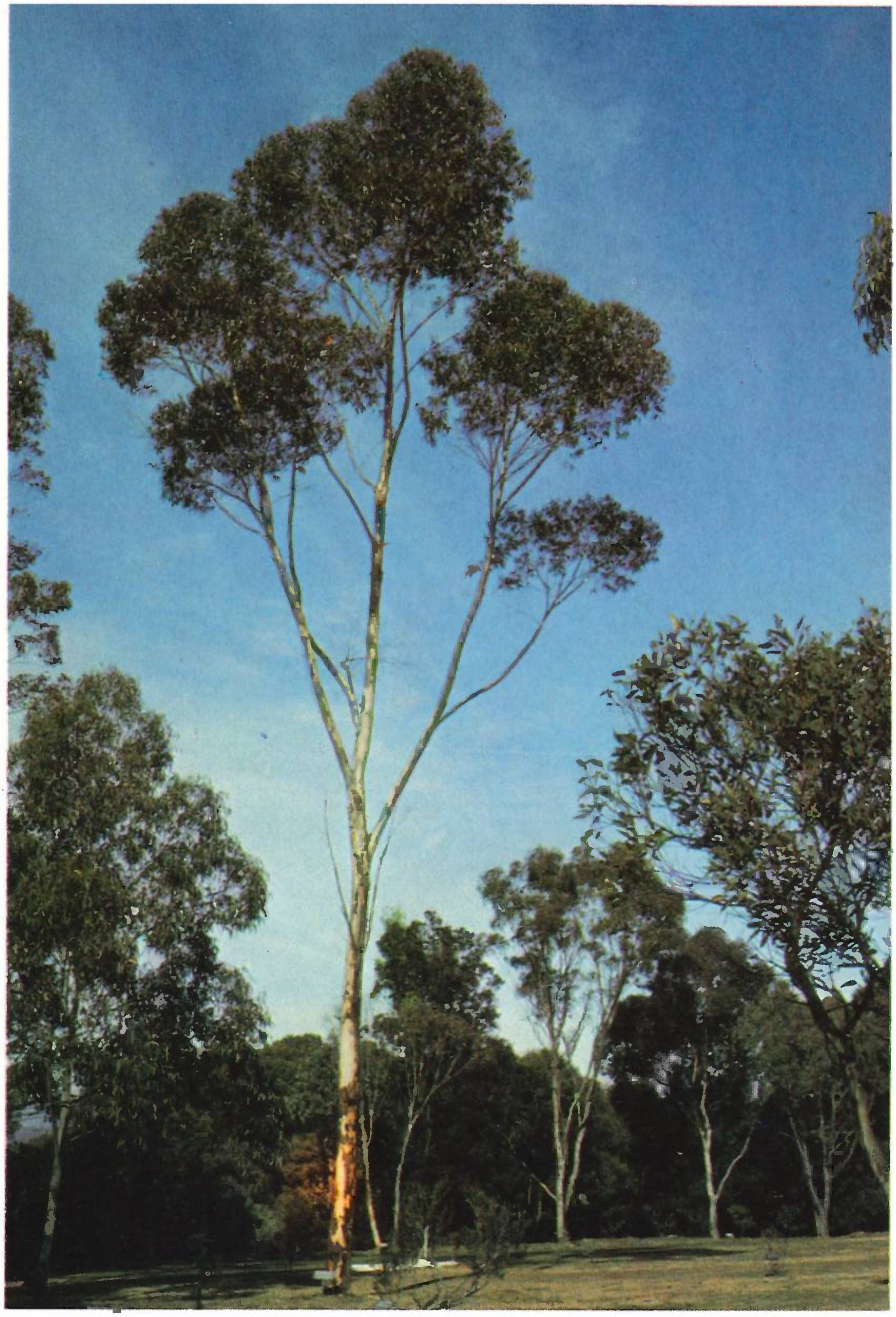
E. viminalis, bark form
CSIRO
Division of Forest Research,
Canberra, ACT, Australia

E. viminalis, tree form
CSIRO
Division of Forest Research,
Canberra, ACT, Australia

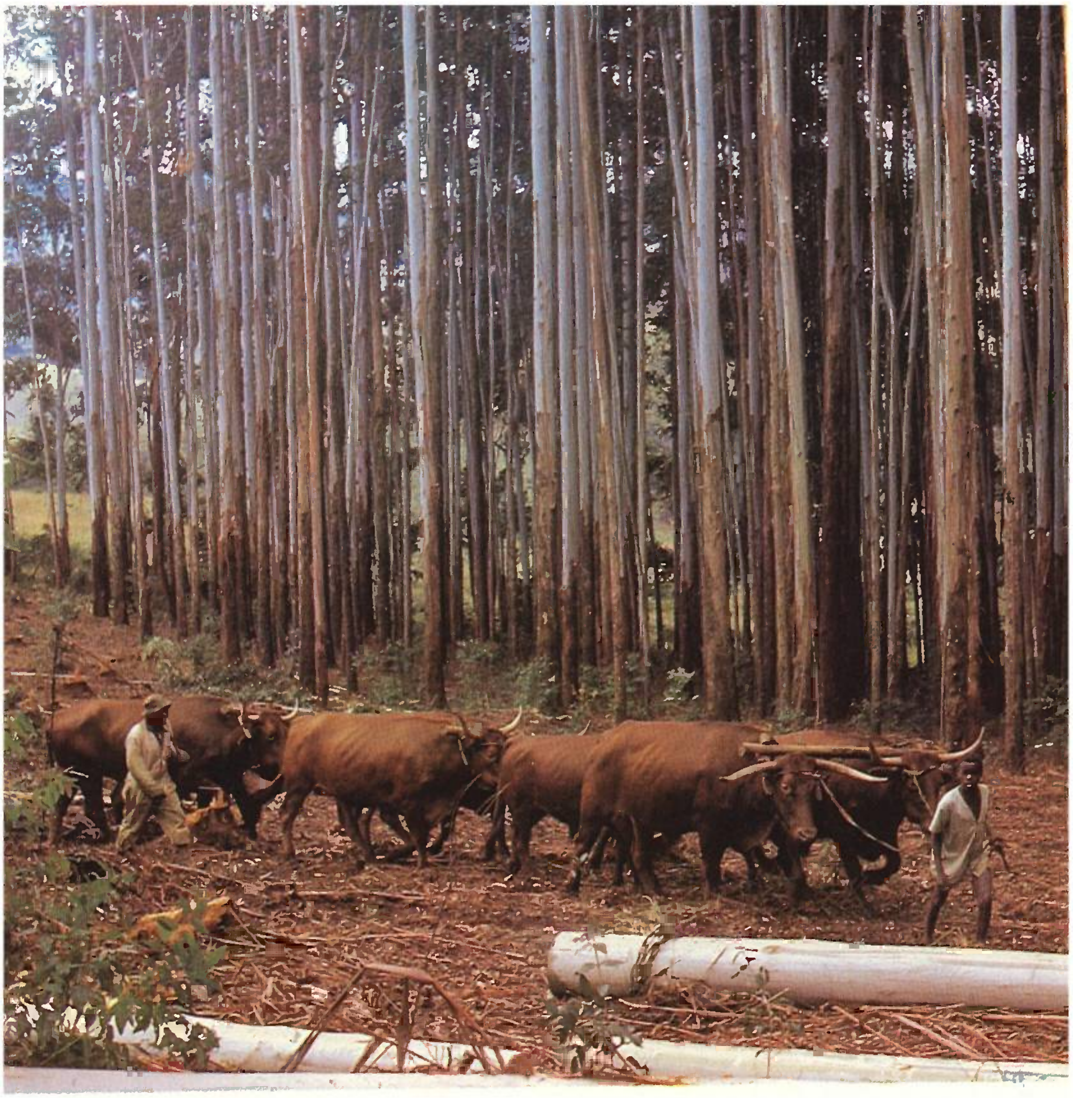


E. fraxinoides, natural tree, showing scribbles on bark and large fire scar.
Braidwood, New South Wales

L.D. Pryor



E. cladocalyx, Canberra Botanical Gardens
C. Palmberg

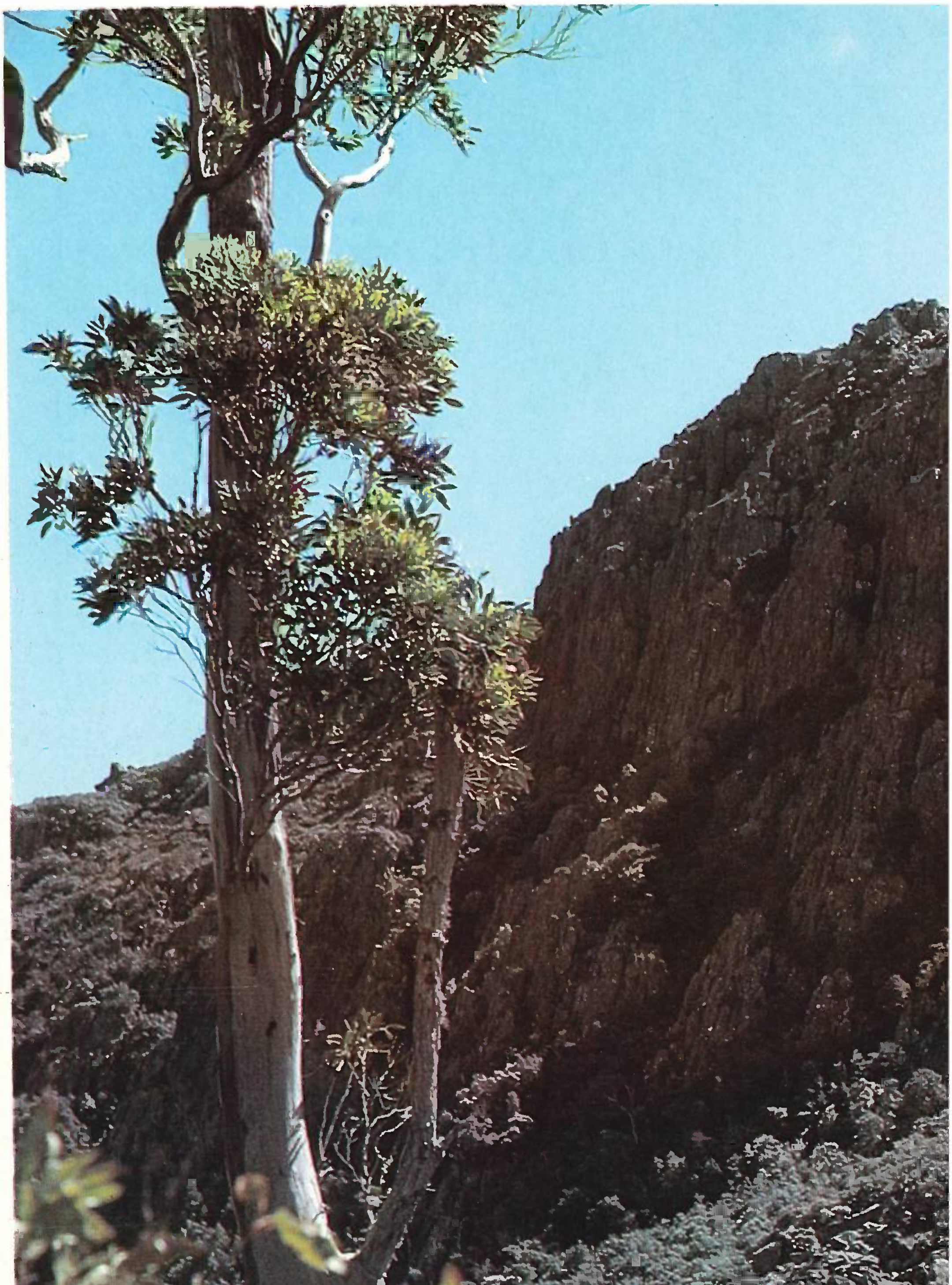


E. grandis, 30-year-old plantation near Umtali, Zimbabwe

L.D. Pryor

E. microcorys, 40 years old, Port Durnford, South Africa

L.D. Pryor



Natural eucalypt forest
near Mt Barrow,
Tasmania

L.D. Pryor

cover. Marri is now the basis of an export woodchip industry in Western Australia.

Prospects for planting. There is a pink-flowered form which is attractive, but the related *E. ficifolia* is a better ornamental, particularly as a street tree.

Success outside Australia. Excellent growth is reported in Hawaii where the species has few gum veins and does not give serious growth stress problems as a sawtimber. It has been successfully established in many countries but is rarely used commercially.

E. camaldulensis Dehnh. var. camaldulensis (syn. E. rostrata Schlecht.)

Refs. Blakely No. 197 Code SNEEPA FTA p. 100

Common name in Australia. River red gum

Regions of natural occurrence. The most widespread eucalypt on the mainland of Australia; found in all states except Tasmania; there is a southern (temperate zone) form and a tropical form.

Latitudinal range. 15.5°-38°S

Altitudinal range. 30-600 m: mainly a riverain species

Rainfall

Type: winter to summer rainfall
Total: 250-625 mm
Dry season: 4-8 months or more, frequently severe

Temperature

Mean maximum of hottest month: 29-35°C
Mean minimum of coldest month: 11-20°C
Frosts: 0-50

Characteristics

Tree height in Australia: 25-50 m; the trunk of many provenances is rather crooked; the crown tends to be thin
Bark type: red-gum type, smooth, patchy
Juvenile leaves: ovate to broadly lanceolate, stalked; stems square
Adult leaves: stalked, lanceolate, thin and pendant
Wood: red, close textured, interlocked or wavy grain; hard, durable, resistant to termites; tends to warp on drying; very useful when plain bulk is needed in large dimensions; density 980 kg/m^3
Buds and fruits: Figure a7-12 (197)
Viable seeds per gram: 773

Uses. The most important inland hardwood in Australia; valuable for purposes varying from honey, through shelterbelts, to sawnwood. A good charcoal; an important sleeper timber.

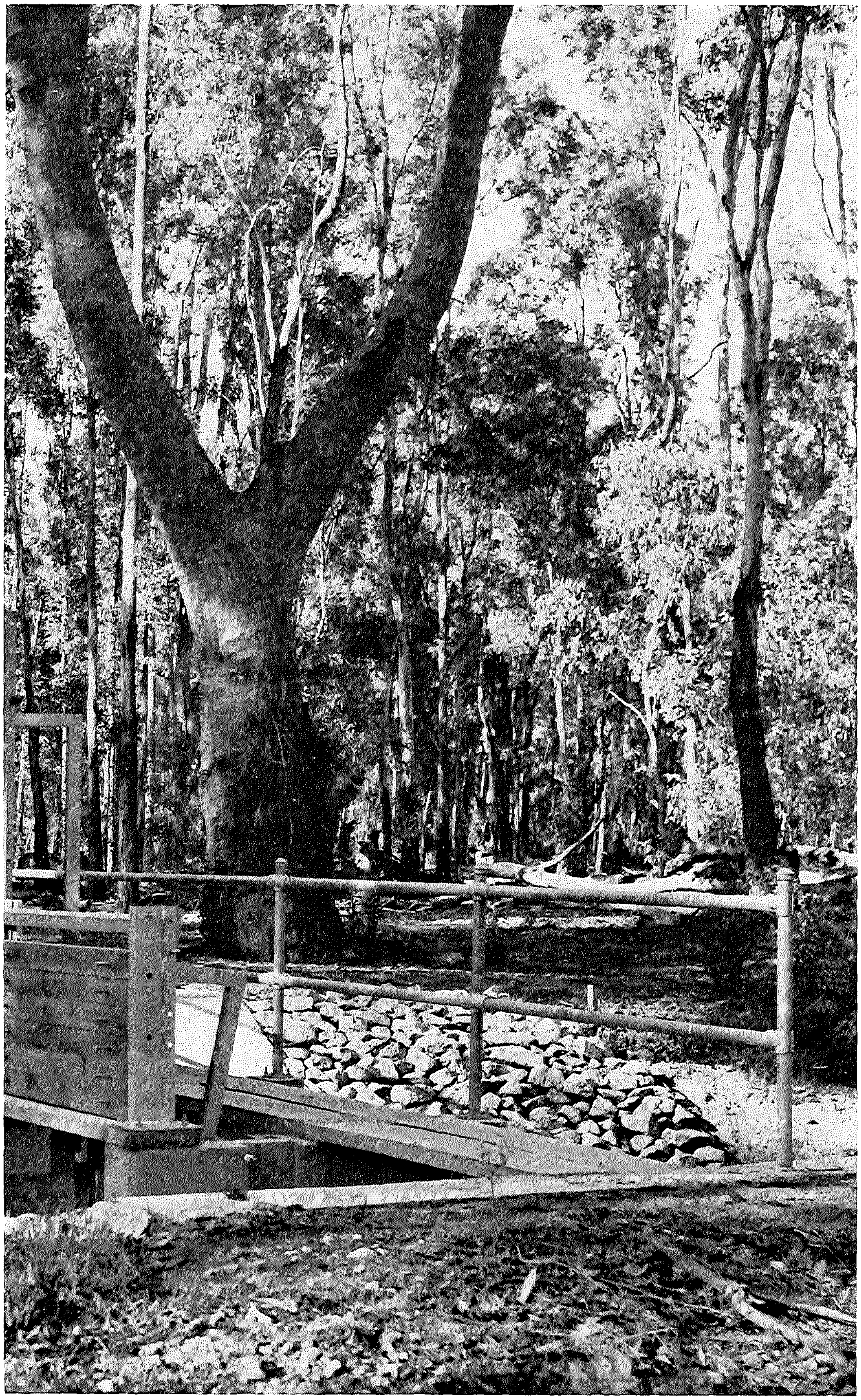
Prospects for planting. Already widely planted. Recent work on provenances shows that provenance is most important when *E. camaldulensis* is used as an exotic (Eldridge, 1975b). The results of some provenance trials are discussed below.

Success outside Australia. E. camaldulensis was one of the first species of eucalypts to be planted overseas. It was recorded planted as specimen trees in Naples in 1803 and was probably introduced to Italy before that; the first forest plantations in Italy were established in 1870. Its introduction into Pakistan was in 1867, and it was introduced into Uruguay and Argentina at about the same time. In Turkey and in Israel it was introduced in about 1884. It was introduced into a number of African countries toward the end of the nineteenth century or the beginning of the twentieth. In Kenya it was one of the first species to be introduced and was recorded in 1903. The world plantation area at present is of the order of half a million hectares. It is the dominant species around the Mediterranean. Spain has reported over 114 000 hectares, mainly in the southwestern provinces, and Morocco over 87 000 hectares.

As might be expected with a species having such a vast distribution, there are considerable differences in performance and adaptability between different provenances. These are discussed later. The provenance differences make it difficult to summarize the characteristics of the species as a whole. However, practically all the seed for the older introductions of *E. camaldulensis* into other countries came from the forests along the Murray river, or from inland areas in New South Wales. "Even now almost all bulk seed of this species collected in Australia comes from the Murray-Darling system" (Turnbull, 1973). Thus, the general characteristics and site requirements of the species reported by countries and summarized below may be assumed to apply mainly to the provenances from the Murray-Darling system. The main characteristics are:

(*i*) Ability to thrive and produce acceptable yields on relatively poor soils with a prolonged dry season.
(*ii*) Ability to tolerate periodic waterlogging.
(*iii*) Some resistance to frost.
(*iv*) A vigorous coppicer.
(*v*) Usually crooked or at least considerably more crooked than preferred species such as *E. grandis* or *E. globulus.*
(*vi*) Thin-crowned and thus less able to suppress weed growth rapidly than a dense-crowned species such as *E. grandis.*
(*vii*) Becomes chlorotic on highly calcareous soils.
(*viii*) Produces a harder, heavier and more deeply coloured wood than species such as *E. grandis* or *E. globulus.* This makes it somewhat less suitable for pulp.

Most Mediterranean countries specify a minimum rainfall of about 400 mm if acceptable yields are to be obtained, but the exact amount at any given location is closely related to depth and texture of soil. Most countries indi-



51. *E. camaldulensis* growing in regularly flooded area of Cohuna, north central Victoria

Forestry Commission, Victoria

cate that the species is moderately frost resistant, but it is difficult to quantify this precisely. In Morocco a minimum temperature of −5°C is specified. In Turkey frosts of −7°C for a single day are considered as usually fatal to young trees. In Iran the species is considered suitable for planting in the temperate winter zone, with less than 10 days' frost and a mean minimum temperature during the coolest month of 3-7°C (Webb, 1974). Outside the Mediterranean region, somewhat higher minimum rainfall figures have been suggested. In Zimbabwe it is planted on sites in Zone 3 (rainfall 700-900 mm, altitude 1 065-1 525 m) which are too dry for *E. grandis*. In South Africa it is more widely grown in the subhumid and semi-arid zones than in the humid zone, where faster- and straighter-growing alternatives are available. In Argentina planting is done in rainfall varying between 400 and 1 000 mm.

The species is adapted to a wide variety of soils. It becomes chlorotic if planted on calcareous soils. In Israel it has been found that growth and health are affected if there is more than 4 percent of free active lime. In the same country it has been found fairly tolerant of saline soils, and in Pakistan it has given promising initial results on waterlogged and saline soils with a high pH (Sheikh, 1974). In Morocco, on the other hand, it is stated to be unsuitable both for saline and for calcareous soils, while in Italy it is considered inadvisable to plant it on saline clays. On clays or calcareous clays in both countries it is usually outgrown by *E. occidentalis*.

There is probably more evidence for variation between provenances in *E. camaldulensis* than there is in any other species. The following proposals for provenance groups are quoted from Turnbull 1973:

"The selection of seed from different drainage systems within a broad climatic classification offers the best overall guide for the choice of material for initial provenance trials. Within the interior a more intensive representation may be necessary to sample the variation pattern. The following provenance groups will assist in the sampling.

1. MURRAY-DARLING SYSTEM

   (*a*) Approximate location: Southeast Australia, 25°S-37°S, 140°E-150°E.
   (*b*) Climatic zones: Temperate inland, temperate interior, subtropical inland. The typical southern form of *E. camaldulensis* is in this region.

2. WIMMERA BASIN

   (*a*) Victoria, 35°S-37°S, 142°E-144°E.
   (*b*) Temperate inland. This is a small internal drainage system which includes several salt lakes, e.g. Lake Albacutya.

3. NORTHEAST SLOPES

   (*a*) Eastern Queensland, 16°S-26°S, 145°E-150°E.
   (*b*) Subtropical highlands, tropical highlands.

There is a well-defined form, intermediate between *E. camaldulensis* and *E. tereticornis*, occupying this region. It follows the western slopes of the

Great Dividing Range but extends across it in the Charters Towers area and on Cape York Peninsula. It is a zone of gradual change from *E. camaldulensis* in the west to *E. tereticornis* in the east but the cline may be disturbed by introgression of *E. alba.* The well-known Petford provenance is in this region.

4. Gulf of Carpentaria

   (*a*) Northwest Queensland, eastern Northern Territory, 17°S-22°S, 136°E-145°E.
   (*b*) Tropical inland.

   The *E. camaldulensis* in this region has the typical appearance of the northern form.

5. Timor Sea Drainage

   (*a*) Kimberley area of northern Western Australia, northwest Northern Territory, 14°S-18°S, 124°E-133°E.
   (*b*) Tropical inland.

The typical northern form of *E. camaldulensis,* usually with a well-defined axis, occurs in this region. In the Kimberley area there is evidence of some hybridization with *E. alba.* The Katherine provenance has been the main representative of this region in provenance trials.

6. Indian Ocean Drainage

   (*a*) Coastal Western Australia, 20°S-29°S, 114°E-120°E.
   (*b*) Tropical dry west coast, tropical interior, subtropical interior.

In the southern part of this region there is introgression with *E. rudis.*

7. Western Interior

   (*a*) Central Australia, 17°S-35°S. 119°E-136°E.
   (*b*) Tropical interior, subtropical interior, temperate interior, temperate inland, dry continental interior.

This is an area of uncoordinated drainage with isolated populations. Some of the more drought-resistant provenances probably occur in this region.

8. Lake Eyre Basin

   (*a*) Northern South Australia, southeastern Queensland, 20°S-32°S, 133°E-145°E.
   (*b*) Tropical interior, subtropical interior, dry continental interior.

This region covers a large area with a small and unreliable rainfall, and provenances adapted to drought conditions probably occur in the area. It is a region of internal drainage."

The most extensive series of international provenance trials is that initiated by FAO's Mediterranean Forestry Research Committee under its project No. 6. Early results were reported by Lacaze (1970) and the following gives a condensed version of his findings.

Seed was collected during 1964 and the collection covered a large part of the natural distribution, comprising over 30 provenances. These were planted on 24 sites (16 in the Mediterranean) in 10 countries (8 Mediterranean). Most of the trials were planted between 1966 and 1968 and were up to 3 years old at assessment.

The early results produced clear and consistent evidence of the superior survival and/or growth of certain provenances. These were:

(1) 6845 Lake Albacutya, Victoria. Temperate inland zone. Rainfall 350 mm, well distributed, with slightly more in winter than summer (41 percent in the six summer months November-April). Has proved consistently superior throughout the Mediterranean region.

(2) 6953 Petford, northern Queensland. Tropical highlands zone. Rainfall 720 mm summer, with pronounced winter drought (total 54 mm in five months May-September). Consistently superior in moister tropical savanna conditions in Nigeria and the Congo.

(3) 6869 Katherine, Northern Territory. Tropical inland zone. Rainfall 960 mm summer. Though total rainfall is higher than at Petford, the winter drought at Katherine is even more severe (total 15 mm in five months May-September), and temperatures are higher throughout the year. Consistently superior in more arid tropical savanna conditions. The only provenance with satisfactory survival at Yambawa, Nigeria, where conditions are extremely harsh (an infertile free-draining sand with a total rainfall of 830 mm, and six completely rainless winter months).

(4) 7029 Murchison River, Western Australia. Temperate inland zone. Rainfall 470 mm winter. Though total rainfall is higher than at Lake Albacutya, it is more seasonal (only 16 percent falling in the six summer months November-April). Temperatures are higher throughout the year than at Lake Albacutya. Performed well in the more arid types of Mediterranean climate, with severe summer drought.

(5) 6975/79 Port Lincoln, South Australia; 7046 Wiluna, Western Australia. Both provenances performed well on a calcareous soil in southern Italy. Both are from areas in Australia with a high soil pH.

More recent assessments at ages of up to 10 years have confirmed the early results and are summarized by Lacaze (1978). 6845 Lake Albacutya has maintained its superiority on most Mediterranean sites and, even in summer-rainfall conditions (Zambia, Nigeria, Madagascar), is still among the best performers. The magnitude of provenance differences is indicated by the fact that at Afaka (Nigeria) volume yields in the best and worst provenances are in the ratio 3 to 1 at age 6, while at Gan Hadar (Israel) they are 8 to 1 at age 10.

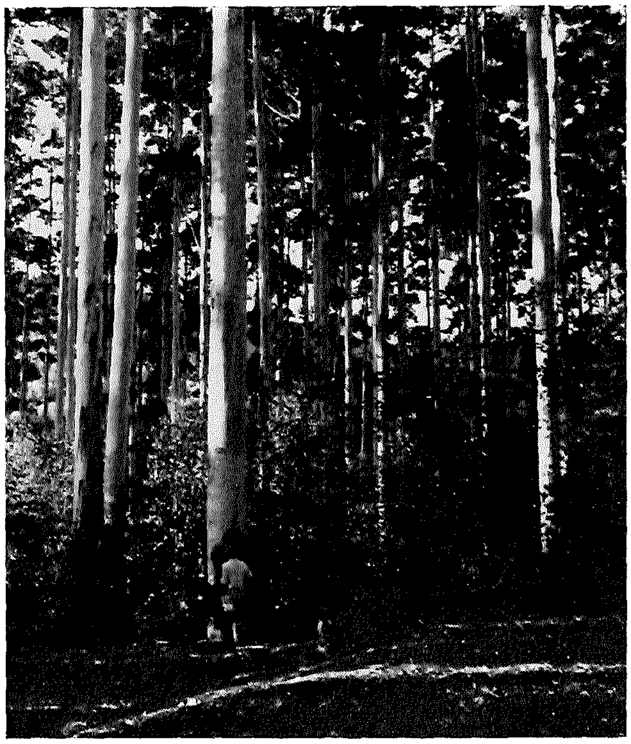
Table 14.1 Production from the Afaka plots to March 1972

Australian data				Growth at Afaka		
Seed origin	Rainfall (mm)	Altitude (m)	Latitude	1972 Mean height (m)	1972 Total volume produced (m³/ha)	1972 MAI (m³/ha)
Petford, Q.	716	518	17°20′S	17.8	83.1	17.3
Bullock Creek, Q.	463	327	20°49′S	14.8	78.4	15.3
Katherine, N.T.	958	110	14°20′S	15.1	67.6	14.1
Lake Albacutya, V.	347	180	35°50′S	14.6	60.0	12.5
Wiluna, W.A.	249	490	26°38′S	14.2	54.4	11.3
Newcastle Waters, N.T.	483	210	17°30′S	14.0	51.3	10.7
Mundiwindi, W.A.	269	300	23°05′S	14.1	49.5	10.3
Alice Springs, N.T.	252	580	23°8′S	14.8	45.2	9.4
Darlington Point, N.S.W.	385	90	34°34′S	13.2	42.1	8.8
Tennant Creek, N.T.	422	340	19°30′S	12.7	41.1	8.6
Bourke, N.S.W.	343	110	30°13′S	13.6	40.5	8.4
Silverton, N.S.W.	234	210	31°54′S	11.4	40.0	8.3
Eulo R., Q.	320	190	28°04′S	14.2	38.3	8.0
Wohlpooer, V.	606	300	37°0′S	13.2	36.6	7.6
Menger's Hill, S.A.	1 182	610	34°30′S	10.4	25.7	5.4
Walpole, N.S.W.	247	90	34°10′S	12.4	24.7	5.1

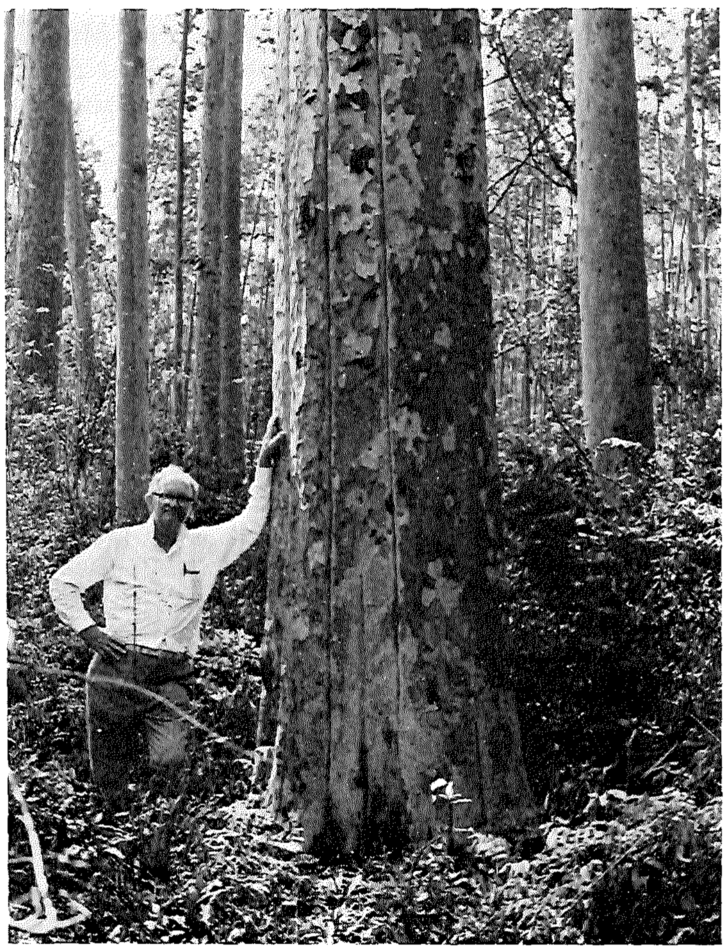
A detailed account of Nigerian provenance trials has been published (Jackson and Ojo, 1973). The above table shows the seed sources in Australia and the production figures for one site in Nigeria (Afaka, total rainfall 1 283 mm, 5 successive dry months with less than 30 mm rainfall, ferruginous tropical soil). The provenances were planted out in July 1967 and given an application of 56 g of borate per tree in 1968 to correct boron deficiency, but no other fertilizer treatment was given. The plots were thinned in 1971 and fully measured in March 1972.

It is clear that there was a great difference in the growth of the different provenances. The best provenance at Afaka had yielded over three times the volume of timber produced by the worst. The most productive provenances were from the tropical part of Australia with a pronounced summer rainfall. At Afaka the Petford provenance had yielded the most, but it has a very

52. Young plantation of *E. camaldulensis* with wide firebreak, Upper Volta
FAO



53. 35-year-old plantation of *E. grandis* at Louw's Creek, South Africa
Wattle Research Institute, Pietermaritzburg



54. 56-year-old plot of *E. maculata,* height 70 m, in Rio Claro arboretum, Brazil
L. Golfari

narrow crown and in older plantations invasion by savanna grasses may be a problem. It was followed by the Bullock Creek and Katherine provenances; the former tended to outyield the latter slightly but was of poorer form. In contrast to Afaka the only provenance with reasonable survival in the extremely harsh conditions at Yambaya in the Sudan zone was that from Katherine. In an irrigated trial at Malam Fatori, the Silverton provenance from New South Wales performed best, although it was one of the worst on all unirrigated sites. Somewhat similar results were obtained in Zimbabwe (Barrett and Carter, 1970). Of 36 provenances tested on five different sites, Petford gave consistently the best results, followed by Katherine, followed by the local land race. At Mortagello on piedmont ash soils on Djebel Marra mountain in the western Sudan, with 800-mm rainfall and a 6-month dry season, the best provenance of eight tested at 11 years was Alice Springs 391. The local plantation seed (origin unknown) was found to be among the worst.

In Pakistan, Newcastle Waters gave the best results out of 22 provenances tested, with Katherine second and Fortescue river (Western Australia) third (Hafeez and Sheikh, 1972); the trials were conducted on three sites, two with less than 250 mm and the third with less than 350 mm rainfall, all irrigated. In Iran the Wiluna provenance from Western Australia proved the best of three tried in the temperate winter zone on calcareous soils, confirming the suitability of this provenance for this type of soil. In Israel additional provenances which did well on calcareous soils in the drier areas were Silverton from New South Wales and Mundiwindi from Western Australia. At Ilanot the Petford provenance, at 6.5 years, had grown the best and coppiced the most vigorously of four north Australian provenances.

In Brazil provenance trials are in progress in subtropical and tropical areas with a pronounced dry season. So far Gibb River (Western Australia) is the most promising. In Argentina, on the other hand, the more southerly provenances in Australia are doing best.

In addition to growth rate and resistance to drought, variation in resistance to frost has been demonstrated. In Israel it was found that Alice Springs was more resistant than either Katherine or Ashmurton River (Western Australia). The treatment applied in this case was 3 hours at a temperature between -4.5 and $-7^{\circ}C$. In Australia it has been shown that some of the interior dry provenances such as Katherine and Agnew are more resistant than the more southerly and easterly provenances to sudden, but not excessive radiation frosts. On the other hand, the more southerly provenances respond better to a gradual hardening to low temperatures (Awe and Shepherd, 1975).

Climatic data for some representative stations are given on the following page. No. 1 (Rainbow) is close to Lake Albacutya, No. 2 (Chapman) is close to Murchison river and No. 3 (Mount Surprise) is close to Petford. Nos. 5 and 6 are representative stations for the Mediterranean region, where the Lake Albacutya provenance has proved outstanding. No. 7 has a lower total rainfall and hotter summer temperatures; Murchison River has performed well here, in addition to Lake Albacutya. Nos. 8 and 9 represent summer-rainfall conditions in which the Petford provenance has been outstanding, while No. 10 represents summer rainfall with a more severe dry season, in which Katherine is the best performer. Stations 5, 6, 7, 8 and 10 are in the northern hemisphere (cool season December-January), the remainder in the southern hemisphere (cool season June-July).

Vegetative propagation of *E. camaldulensis* by cuttings is comparatively easy from young trees, but not from old trees. In older trees air-layering may be promising (Franclet, 1970). *E. camaldulensis* hybridizes freely with a number of species. The hybrid *E. camaldulensis* × *E. botryoides* is common and has been given the name *E.* × *trabutii.* In Portugal a hybrid, *E. camaldulensis* × *E. maidenii*, has been reported and in both Australia and Pakistan the hybrid *E. camaldulensis* × *E. rudis.* Growth varies greatly according to climate and soil. On good sites a MAI of 2 m in height and 2 cm in diameter may be maintained for the first 10 years, but on the poorer and drier sites this is reduced to between 1 and 1.5 m height and 1 to 1.5 cm diameter a year. Volume yields of 20 to 25 m^3 per hectare per year are reported from Argentina and on the very best sites in Israel as much as 30 m^3 may be obtained. In Turkey 17-20 m^3 can be obtained on good sites in the initial seedling rotation and 25-30 m^3 in subsequent coppice rotations. However, on the poorer and drier sites much lower yields can be expected. Morocco records a range between 3 and 11 m^3 according to site quality, Portugal between 2 and 10 m^3 and Uruguay a range between 4 and 18 m^3. In Italy an average of 6.5 m^3 is expected. On the driest sites in Israel only 2 m^3 are obtainable. In southern Africa the average is between 7 and 14 m^3.

Most *E. camaldulensis* plantations are managed on coppice rotations; 7-10 years is common on the better sites, but on poor sites this is prolonged, e.g., in Spain to 14-15 years. The first coppice rotation is expected to produce a higher yield than the initial seedling rotation and the length of the rotation may be adjusted accordingly. For example, Morocco recommends 12 years for the initial seedling rotation, 7 years for the first coppice rotation and 10 years for the second coppice rotation.

Response to fertilization has been noted on some sites in Israel, but only where soil moisture is not a limiting factor. Yields may be greatly increased by irrigation. In Israel irrigated plantations produced 14.6-16 m^3 while unirrigated plantations in the same area produced only 7.7 m^3. Irrigation was carried out during the winter between September and May and a total amount of 500-700 mm was applied during the season. It was found that irrigation in the summer was ineffective because of summer dormancy in the trees.

Like most eucalypts, *E. camaldulensis* is susceptible to termite damage during its early years. Control may be effected by a suitable insecticide. In South Africa it is considered as not being very susceptible to attack by the snout beetle *Gonipterus.* It has however been attacked at Muguga in Kenya and also in Uruguay, where the parasite has been imported to combat the pest. *Phoracantha semipunctata* has attacked trees in Israel, mainly those weakened by drought. Additional pests recorded in Uruguay are species of *Platypus, Pantomorus* and *Atta.* In Portugal the species has

Table 14.2 *E. camaldulensis* climatic stations

Station	Location		
	Latitude	Longitude	Altitude (m)
1. Rainbow (Victoria)	35°54′S	142°00′E	90
2. Chapman (W. Australia)	28°30′S	114°49′E	15
3. Mt Surprise (Queensland)	18°09′S	144°17′E	454
4. Katherine (N. Territory)	14°06′S	132°42′E	112
5. Crotone (Italy)	39°05′N	17°09′E	6
6. Natanya (Israel)	32°20′N	34°51′E	25
7. Sidi Slimane (Morocco)	34°15′N	6°06′W	33
8. Afaka (Nigeria)	10°37′N	7°17′E	600
9. Mtao (Zimbabwe)	19°22′S	30°38′E	1 477
10. Yambawa (Nigeria)	12°10′N	9°00′E	400

Station	Temperature (°C)					
	Hottest			Coolest		
	Month	Mean temp	Mean max.	Month	Mean temp.	Mean min.
1. Rainbow (Victoria)	Feb.		31°	July		4°
2. Chapman (W. Australia)	Feb.		34°	July		7°
3. Mt Surprise (Queensland)	Dec.		35°	July		9°
4. Katherine (N. Territory)	Jan.		38°	July		13°
5. Crotone (Italy)	Aug.		32°	Jan.		6.5°
6. Natanya (Israel)	Aug.	26°		Jan.	13°	
7. Sidi Slimane (Morocco)	Aug.	27°	37°	Jan.	11°	4°
8. Afaka (Nigeria)	Apr./May		35°	Dec.		14°
9. Mtao (Zimbabwe)	Oct.		29°	June		6°
10. Yambawa (Nigeria)	Apr.		38°	Jan.		13°

Station	RAINFALL (mm)												
	J	F	M	A	M	Jn	Jl	A	S	O	N	D	Total
1. Rainbow (Victoria)	16	30	16	22	33	34	35	34	37	30	26	32	347
2. Chapman (W. Australia)	8	10	21	19	58	109	99	68	38	25	10	8	473
3. Mt Surprise (Queensland)	192	192	93	23	17	21	8	4	4	20	41	101	716
4. Katherine (N. Territory)	229	203	161	30	5	2	1	1	6	30	84	206	958
5. Crotone (Italy)	104	53	60	28	20	10	3	13	41	122	116	114	684
6. Natanya (Israel)	136	71	49	14	3	0	0	0	1	18	90	147	529
7. Sidi Slimane (Morocco)	59	53	52	44	26	7	1	1	8	45	65	84	445
8. Afaka (Nigeria)	0	2	12	69	157	178	203	300	272	86	5	0	1 283
9. Mtao (Zimbabwe)	175	146	82	26	7	9	2	2	6	36	102	180	773
10. Yambawa (Nigeria)	0	0	0	0	66	81	206	302	160	13	0	0	833

been very susceptible to the fungus *Oidium* in the nursery, especially during the early autumn rains. *E. camaldulensis* is considered fairly fire resistant in a number of countries, e.g., Spain and Turkey. Younger trees are most susceptible, but old ones usually recover and even severely damaged trees, if felled immediately, will coppice successfully.

E. camaldulensis has been used in many countries for the production of fuelwood, charcoal, posts and poles. It is also commonly used for shelterbelts, shade and amenity planting in dry areas. Actual or proposed use for flooring blocks has been reported by Spain, Portugal and Uruguay. Its main use in Argentina is for production of hardboard, including some for export. It is also used in Argentina for charcoal for the iron industry. It is also largely used in Israel and Spain for fibre- and particle board. It has been used for production of sawtimber on a comparatively small scale, and the quality of sawnwood is not high. It is used for pulp, and is the main pulpwood species for the factory in Sidi-Yahia in Morocco. In Portugal and Spain it is also used for pulp, but is reported to produce a lower grade of pulp and to need more intensive and more costly bleaching than either *E. globulus* or *E. maidenii*, due to the darker colour of its wood.

Great variation in wood properties has been reported between different provenances of *E. camaldulensis*. An investigation, based on 2 400 4- or 5-mm Pressler wood cores taken at breast height, was undertaken in 10-year-old plots on two Italian sites (Sicily and Calabria) within the international provenance trial mentioned above (Sesbou and Nepveu, 1978). Of the 24 provenances included in the trial, it was found that basic density varied from 443 kg/m^3 in the lightest provenance to 593 in the heaviest, while volumetric shrinkage varied from 18 to 58 percent. In general the fastest-growing provenances had the lowest density and the highest shrinkage. The Lake Albacutya and other provenances from the Murray River System in southeast Australia, which were among the fastest-growing, had low density and high shrinkage, while the slowest-growing provenance (Tennant Creek, Northern Territory) had the highest density and the lowest volumetric shrinkage.

E. cinerea F. Muell. ex Benth.

Refs. Blakely No. 283 Code SPINUA FTA p. 144

Common name in Australia. Argyle apple; mealy stringybark

Regions of natural occurrence. Tablelands of southern New South Wales and northern Victoria.

Latitudinal range. 33°-38°S

Altitudinal range. 500-800 m

Rainfall

Type: winter to uniform rainfall
Total: 500-700 mm
Dry season: 3-4 months, usually in the warmer months

Temperature

Mean maximum of hottest month: 26-29°C
Mean minimum of coldest month: 0-4°C
Frosts: 15-45

Characteristics

Tree height in Australia: 8-15 m
Bark type: stringy bark when mature
Juvenile leaves: opposite, sessile, usually amplexicaul, orbicular, glaucous
Adult leaves: usually in Australia the juvenile foliage is retained, but overseas lanceolate shortly stalked mature leaves develop but retain the glaucous leaf surface.
Wood: rather soft, weak, not much used except as fuel
Buds and fruits: Figure a7-13 (283)
Viable seeds per gram: 327

Uses. Widely used as an ornamental for the glaucous foliage and convenient tree height for a suburban garden. Most eucalypts grow too tall.

Prospects for planting. Ornamental plantings are rapidly extending; the foliage is widely used for floral arrangements

Success outside Australia. A favourite in many countries. It is grown in commercial nurseries and glasshouses.

E. citriodora Hook f.

Refs. Blakely No. 53 Code CCCA FTA p. 44

Common name in Australia. Lemon-scented gum

Regions of natural occurrence. Central and northern areas of eastern Queensland. There are two main occurrences, with several minor ones between them. The larger and more southerly extends from the coast inland for more than 300 km. The main northern occurrence is in higher and rather dry country some distance from the coast.

The species occurs on undulating country, including plateaus and dry ridges. It is usually found on rather poor gravelly soils, podzols and residual podzols of lateritic origin. It prefers well-drained and gravelly soils, where it usually grows with other useful eucalypts such as *E. acmenoides*, *E. propinqua* and *E. crebra.*

Latitudinal range. 22°-26°S (southern occurrence), 17°-19.5°S (northern)

Altitudinal range. 80-300 m (southern occurrence), 600-800 m (northern)

Rainfall

Type: summer rainfall
Total: 625-1 250 mm
Dry season: 5-7 months in the cooler months, may be severe

Both the southern and the northern occurrences are found over a fairly wide range of rainfall.

Temperature

Mean maximum of hottest month: 29°C (southern occurrence), 35°C (northern)
Mean minimum of coldest month: 5°C (southern occurrence), 10°C (northern)
Frosts: 0-few (light). Has tolerated moderate frosts when planted outside natural range.

Characteristics

Tree height in Australia: 30-40 m. A handsome tree of excellent form, with a well-shaped but sparsely foliaged crown
Bark type: Smooth, white or faintly bluish
Juvenile leaves: Opposite then alternate, narrowly to broadly lanceolate, with wavy margins, hairy, many peltate
Adult leaves: Alternate, narrowly lanceolate. Both juvenile and adult leaves smell strongly of citronellal when crushed.
Wood: Strong and hard, fairly durable
Buds and fruits: Figure a7-14 (53)
Viable seed per gram: 118

Uses. Sawtimber, poles and tool handles. Can be turned easily. Produces straight poles which can be pressure impregnated for many industrial purposes.

Prospects for planting. *E. citriodora* is already planted in many countries. Métro (1955) noted "Despite its good qualities, this species has rarely been planted commercially". One reason for this may be the relatively large seed which may be expensive to obtain in the quantity required for commercial eucalypt plantations. Against this, the germination percentage is usually reported as "good".

In general it is considered that the potential value of *E. citriodora* as a plantation species has been underestimated. It is not a eucalypt of spectacular growth but one of the better ones for regions in the lower latitudes of the subtropics and tropical latitudes down to about 10°. It is unsuitable for equatorial regions. *E. citriodora* will hybridize with other members of the Pryor & Johnston subgenus *Corymbia.* To some of these hybrids *E. citriodora* may bring useful properties, but in other cases it may be a disadvantage. Several countries could develop a useful minor industry by distilling the citronellal from the leaves. For this latter purpose the species should be kept pure.

Success outside Australia. In Mediterranean countries it has been introduced mainly as occasional plantings in North Africa and Portugal. In South Africa and Zimbabwe it has been planted for several decades on a limited scale and has been fairly resistant to drought and termites. In Tanzania it has been direct-seeded, which is unusual for eucalypts. It is reported as difficult to raise in the nursery in Morocco. In Malawi it is planted in zones where *E. grandis* is affected by high temperatures and is reported as growing well, reaching a height of 5 m in 21 months and closing canopy after 12 months. In South Africa it is reported as being a good coppicing species and moderately easy to debark. At Muguga in Kenya the experimental plantation had a height of 19 m in 19 years. In Rwanda fine results have been obtained on various soils. Good reports of the success of the northern Queensland provenance are given for the subhumid/dry tropical region of Brazil where it is said to be fairly resistant to the *Diaporthe cubensis* canker, but it is susceptible at latitude 2°-6°N in Suriname.

In Thailand it is reported to be the best eucalypt introduced (at age 7) with a "remarkable" rate of growth. It is reported as promising at both high and low altitudes in Malaysia. It has failed at low altitudes in Indonesia. India reports variable results but it is listed among the four most suitable species for Pakistan. It grows excellently in Hawaii from sea-level to 300 m. It is one of the main species planted in Kwantong province of China (20°-25°N), where a MAI of about 16 m^3/ha/yr is obtained; the leaves are distilled for oil and yield 1.2 to 1.7 percent.

E. cladocalyx F. Muell. (syn. E. corynocalyx F. Muell.)

Refs. Blakely No. 121 Code SIS:A FTA p. 82

Common name in Australia. Sugar gum

Regions of natural occurrence. The southern Flinders Range, Eyre Peninsula and Kangaroo Island in South Australia. It is found as a dominant in dry sclerophyll forest in the wetter parts of its range and as a component of the savanna woodland in the drier part. The soils are mainly skeletal or podzolic and rather shallow.

Latitudinal range. 32°-36°S

Altitudinal range. 0-600 m

Rainfall

Type: winter rainfall
Total: 375-625 mm
Dry season: 4-5 months in the warmer months

Temperature

Mean maximum of hottest month: 23-30°C
Mean minimum of coldest month: 4-8°C
Frosts: 0-20

Characteristics

Tree height in Australia: up to 30 m; with a good trunk and a thin crown
Bark type: smooth, pale grey and yellow-brown patches
Juvenile leaves: stalked, elliptical to circular
Adult leaves: alternate, stalked, narrow to broad-lanceolate
Wood: pale yellow-brown with fine uniform texture; grain frequently interlocked; hard, moderately strong, moderately durable; density 1 100 kg/m^3
Buds and fruits: Figure a7-15 (121)
Viable seeds per gram: 108

Uses. It is much used in southern Australia for the production of poles and as a windbreak. In the plains of western Victoria, which had few trees, farmers planted several rows of sugar gum as windbreaks. The trees have high thin crowns and, to maintain their value as windbreaks, individual rows of trees were felled at intervals of a few years. The sugar gum coppices well and the low coppice crowns block the winds blowing under the crowns of the older trees. The rows felled yield poles and fuelwood.

Prospects for planting. Widely used in fairly dry situations in winter-rainfall climates

Success outside Australia. Thousands of hectares of successful coppice forest have been planted in the western and eastern conservancies of the Cape Province in South Africa. It has been successfully used in fairly dry winter-rainfall zones of several countries. In Morocco, where over 4 000 ha have been planted, it is considered somewhat more tolerant of aridity and infertile soils than *E. camaldulensis*, although more slow-growing.

Refs. Blakely No. 295 Code IAA:A FTA p. 146

E. cloeziana F. Muell.

Common name in Australia. Gympie messmate

Regions of natural occurrence. Scattered occurrences in central and north Queensland, sometimes near the coast, at other times well inland. Its best development is on the moist soils of the lower slopes of valleys, but in the northern occurrences it may grow on tablelands and upper slopes.

Latitudinal range 16°-26.5°

Altitudinal range. The main occurrence is in the Gympie district at latitude 26°S and at a low altitude of about 60 m. This occurrence includes most of the best forest. Other occurrences are in the ranges inland from Mackay at latitude 21°S and as far north as Atherton, latitude 17°S, where the species occurs at an altitude of 900 m.

Rainfall

Type: summer rainfall
Total: 1 000-1 600 mm
Dry season: 3-4 months, not severe

Table 14.3 Distribution of rainfall (in mm)

Locality	Lat. (S)	Alt (m)	J	F	M	A	M	Jn	Jl	A	S	O	N	D	Total	Frosts per year
			Rainfall													
Gympie	26.2°	94	163	171	161	86	71	62	52	40	50	71	86	135	1 148	3.5
Mackay	21.1°	14	360	335	304	156	95	66	38	28	36	47	74	163	1 702	0
Atherton	17.3°	752	297	313	249	108	60	46	29	24	23	27	75	174	1 425	1.4

Temperature

Mean maximum of the hottest month: 29°C
Mean minimum of the coldest month: 8-12°C
Frosts: few and light

Characteristics

Tree height in Australia: 35-45 m. In Australia the species has strong apical dominance and sheds its young branches very well. These growth habits lead to splendid pole stands. The mature trees have a dense crown for a eucalypt and enable it to control a site effectively.
Bark type: flaky, dark brown, fibrous, a little soft
Juvenile leaves: sub-opposite, stalked, ovate-lanceolate
Adult leaves: alternate, stalked, lanceolate, often curved
Wood: yellow-brown, heavy, strong and very durable
Buds and fruits: Figure a7-16 (295)
Viable seeds per gram: 141

Uses. A good sawtimber, used for a wide range of construction purposes; one of the best pole timbers

Prospects for planting. It is a vigorous grower in seedling and pole stages when on site. It requires care in the nursery and in planting out. In its natural habitat it is not subject to many fires but, after reaching the pole stage, it is fire resistant. The dense shade cast by fully stocked young plantations will prevent grass invasion and so reduce the risk of fire. It is listed as a poor coppicing species and difficult to debark in South Africa, but there are many excellently managed coppice forests of it in that country. In the native forests in Australia it seems to coppice well.

Success outside Australia. During the past 30 years, it has been tried in many countries, usually with favourable results. The many excellently managed coppice plantations in South Africa have already been referred to. It was tried in the well-known eucalypt plots at the research station at Muguga, Kenya, where the mean diameter at 17 years was 34.0 cm and the height 30 m. The seed was from Gympie. The last two sentences in the plot summary reflect the potential value of this species — "It has been fairly free from pests and disease. All in all this is a superb crop". In Hawaii it has given excellent results from sea-level up to 300 m elevation. The species is reported as promising by Brazil, the Congo, Madagascar, Nigeria, Sri Lanka and Zambia. Zambia has 500 ha of plantation. Trials have been reported as failing in Ethiopia and the Ivory Coast, both of which countries have localities that should suit it. *E. cloeziana* is sometimes difficult to handle in the nursery and at planting out. In several countries there are indications that the northern provenances have not performed as well as the Gympie provenance.

E. cornuta Labill.

Refs. Blakely No. 96 Code SICBA FTA p. 74

Common name in Australia. Yate

Regions of natural occurrence. Yate is found along the coastal belt of far southwest Western Australia from Busselton to Albany, occurring as scattered individuals among other local species such as *E. gomphocephala* and *E. rudis.* It usually grows in fertile moist valleys.

Latitudinal range. 33.5°-35°S

Altitudinal range. 0-300 m

Rainfall

Type: winter rainfall
Total: 750-1 400 mm
Dry season: 3-5 months in the warm season

Temperature

Mean maximum of hottest month: 25°C
Mean minimum of coldest month: 7.5°C
Frosts: few and light

Characteristics

Tree height in Australia: 16-20 m; of moderate stem form and a substantial crown
Bark type: persistent on trunk and larger branches, dark grey or almost black, furrowed
Juvenile leaves: stalked, alternate, circular to broadly lanceolate
Adult leaves: alternate, stalked, lanceolate
Wood: pale yellow-brown; very heavy; interlocked grain; hard and one of the strongest timbers; durable
Buds and fruits: Figure a7-17 (96)
Viable seeds per gram (France): 60

Uses. Formerly in wheelwright work but now in short supply in Australia

Prospects for planting. Limited, unless a wood with outstanding strength qualities is required

Success outside Australia. A plot at Concordia, South Africa, in silvicultural Zone D grew to a height of 30 m and a mean diameter of 23 cm in 32 years on deep sands, but the trees were reported as being branchy and crooked. The species was grown in Cyprus and other Mediterranean countries for many years, but hybridized with other species and is now largely superseded. It was vigorous in winter-rainfall conditions in Chile, but is not a preferred species there. Specimens are healthy in California. It was not successful in Brazil where the climate is very different from that in its natural range.

Refs. Blakely No. 514 Code SUP:S FTA p. 248

E. crebra F. Muell. (syn. E. racemosa Cac.)

Common name in Australia. Narrow-leaved red ironbark

Regions of natural occurrence. Much of eastern Queensland, mainly inland northern New South Wales, but occasionally approaching coastal areas in New South Wales, growing on undulating plains and low plateaus. The soils are varied but mainly acid sandy soils, sometimes overlying alkaline clayey subsoils.

Latitudinal range. 11°-33°S, the widest distribution of any ironbark

Altitudinal range. 0-500 m

Rainfall

Type: mainly summer rainfall; uniform in the southernmost occurrences
Total: 500-1 500 mm
Dry season: 4-6 months in the cooler season; can be severe

Temperature

Mean maximum of hottest month: 32°C or more, hot, tropical
Mean minimum of coldest month: 3-5°C
Frosts: 5-15

Characteristics

Tree height in Australia: 20-30 m; the trunk is usually of good form and up to 2/3 tree height
Bark type: ironbark type; persistent to smaller branches
Juvenile leaves: alternate, stalked, narrowly lanceolate
Adult leaves: alternate, stalked, narrowly lanceolate
Wood: Dark red, very hard and strong, very durable, density 1 070 kg/m^3
Buds and fruits: Figure a7-18 (514)
Viable seeds per gram: 119-666

Uses. An important Australian tree, particularly inland; a valuable pole; an excellent fuelwood and charcoal timber

Prospects for planting. Questionable. It has done quite well but is somewhat slow-growing. The wide latitudinal range gives opportunities for provenance testing if an ironbark-type eucalypt is required. If an ironbark-type wood is required the more vigorous *E. paniculata* from latitude 30°S or higher, or *E. drepanophylla* from latitude 30° or lower should be tried.

Success outside Australia. Reasonable success in South and North Africa, India and Latin America. It does well in Hawaii at a rainfall of 1 000-2 500 mm. It is slow-growing and of poor form in Uganda.

E. cypellocarpa L. Johnson (planted overseas as E. goniocalyx)

Refs. Blakely No. 262 Code SPIFE FTA p. 134

Common name in Australia. Mountain grey gum

Regions of natural occurrence. Much of Victoria; scattered occurrences in New South Wales. It grows on a wide range of sites, mainly in closed forest and associated with a wide range of the better eucalypt species of eastern Australia.

Latitudinal range. 35.5°-39°S

Altitudinal range. 0-1 300 m

Rainfall

Type: winter to uniform rainfall
Total: 1 000-1 200 mm
Dry season: 3-4 months, not usually severe

Temperature

Mean maximum of hottest month: 23-28°C
Mean minimum of coldest month: 0-5°C
Frosts: 10-110

Characteristics

Tree height in Australia: 30-45 m; in closed forest a tree of good form
Bark type: smooth, shed in large irregular plates leaving a mottled yellow, grey and white surface
Juvenile leaves: opposite, sessile, broadly lanceolate, glaucous
Adult leaves: alternate, stalked, narrowly lanceolate and tapering to a long point
Wood: pale yellow to brown, hard, heavy; density 700-960 kg/m^3; moderately strong and durable; frequently defective; has a high shrinkage
Buds and fruits: Figure a7-19 (262)
Viable seeds per gram: 160

Uses. Used in Australia when good logs are available. The paper-makers do not like it.

Prospects for planting. Limited because of doubtful qualities

Success outside Australia. Not very successful; recorded as growing in several countries

Refs. Blakely No. 236 Code SPINCA FTA p. 122

E. dalrympleana Maid. subsp. delrympleana

Common name in Australia. Mountain gum

Regions of natural occurrence. Higher country in New South Wales, Victoria and Tasmania; a tree of upper plateaus and slopes of the southern part of the Great Dividing Range. It is not exacting as to soil type but is not suited to dry soils.

Latitudinal range. 32.5°-42.5°S

Altitudinal range. 600-1 450 m

Rainfall

Type: winter to uniform rainfall
Total: 875-1 400 mm
Dry season: 3 months, irregular, not usually severe

Temperature

Mean maximum of hottest month: 27°C
Mean minimum of coldest month: 0°C
Frosts: 20-100

Characteristics

Tree height in Australia: 30-40 m; with a large crown over a usually well-formed and straight trunk.
Bark type: smooth, irregular blotches of light and dark grey, white and salmon pink
Juvenile leaves: opposite, sessile, ovate or cordate, glaucous
Adult leaves: stalked, narrowly lanceolate
Wood: white to pale pink; straight grain; moderate strength, hardness and durability; density 610 kg/m^3
Buds and fruits: Figure a7-20 (236)
Viable seeds per gram: 210

Uses. A useful high-country tree. When maintained in farm parks in Tasmania for a long period is very handsome.

Prospects for planting. Not fast-growing species, but useful for cold sites. The wide natural range gives opportunities for provenance testing.

Success outside Australia. Moderate in several countries. Not a preferred species in extensive plantings but very useful in special cases, where resistance to cold is desirable. Has been among the most successful frost-resistant species in South Africa, Brazil, the USSR, France and Ireland. In India it shows promise at 1 200-2 000 m elevation on deep soils.

E. deanei Maid.

Refs. Blakely No. 62 Code SECAA FTA p. 58

Common name in Australia. Deane's gum, Mountain Blue gum

Regions of natural occurrence. Central and northern New South Wales; southeastern Queensland. A tree of fertile and well-watered valleys in its best form but occurring on upper slopes and tablelands of the Great Dividing Range in its northern occurrence. Essentially a tree of the closed wet sclerophyll forest mixed with several of the better eucalypts.

Latitudinal range. 28°-34.5°S (in two widely separated occurrences)

Altitudinal range. 30-1 000 m

Rainfall

Type: uniform to summer rainfall
Total: 900-1 500 mm
Dry season: 3 months, not usually severe

Temperature

Mean maximum of hottest month: 26-27°C
Mean minimum of coldest month: 1-10°C
Frosts: few to 50

Characteristics

Tree height in Australia: 40-55 m: with a long straight bole and a large straggling crown
Bark type: smooth, decorticating to close to ground level
Juvenile leaves: shortly stalked, alternate, orbicular to broadly ovate
Adult leaves: alternate, stalked, lanceolate, sometimes broadly lanceolate, hence one common name "round-leaved gum" on the New South Wales coast
Wood: hard, strong, tough, moderately durable
Buds and fruits: Figure a7-21 (62)
Viable seeds per gram: 682

Uses. Similar to *E. saligna*

Prospects for planting. Quite a good planting species. More work needed on provenances.

Success outside Australia. Successful in southern Brazil; excellent in Hawaii at 700-m elevation and 2 500-mm rainfall; moderate success in South Africa

Refs. Blakely No. 437 Code SBA:A FTS No. 175

E. deglupta Bl. (syn. E. naudiniana F. Muell.)

Common name. Kamarere (Papua New Guinea), Bagras (Philippines). It is not an Australian tree.

Regions of natural occurrence. New Britain, Papua New Guinea, Ceram, Celebes, Mindanao

Latitudinal range. 9°N-11°S

Altitudinal range. 0-1 800 m

Rainfall

Type: summer rainfall
Total: 3 750-5 000 mm
Dry season: nil

Temperature

Mean maximum of hottest month: 24-32°C
Mean minimum of coldest month: 20-22°C
Frosts: nil

Characteristics

Tree height: 35-75 m; usually of very good form
Bark type: smooth, decorticating in long strips; sometimes a basal stocking of 1-2 m of compact bark
Often multi-coloured, ornamental
Juvenile leaves: opposite, shortly stalked, ovate-lanceolate
Adult leaves: opposite or sub-opposite, shortly stalked, ovate to ovate-lanceolate

Wood: light to dark red-brown, more like a coarse-grained rain-forest wood than a eucalypt; moderate strength but not durable; density 560-800 kg/m³
Buds and fruits: Figure a7-22 (437)
Viable seeds per gram: 4 210

Uses. Useful for building and joinery, wood pulp, wood-based panels

Prospects for planting. Possibly very valuable in high-rainfall equatorial localities with no pronounced dry season. Provenance testing is necessary because of the wide discontinuous natural occurrences. These are proceeding and it is apparent that there are variations in the species.

Success outside natural range. E. deglupta is a comparative newcomer as a plantation species and planting has until recently been experimental or on a pilot scale. The earliest introductions of seed were from the indigenous stands which occur in the Cotabato area of Mindanao to other islands in the Philippines, e.g., to Baguio in northwest Luzon in 1918 and 1926. The first introduction into Cebu island was in 1954 (Lizardo, 1956). Similarly, the first major plantings on the main island of Papua New Guinea were made in 1948 from seed collected at Keravat on the neighbouring island of New Britain. Outside Southeast Asia, the first small-scale introductions were made in the late 1950s or in the 1960s, e.g., the Ivory Coast and Solomon Islands 1958, the Congo 1961, Sri Lanka 1967.

The total area of plantations is still small, compared with other species. The Philippines had about 7 000 ha planted by 1974, mainly by the Paper Industries Corporation of the Philippines (PICOP). Papua New Guinea recorded 736 ha planted to 1973 and plans for a rapid increase in planting rate. The Congo reported 170 ha planted mainly between 1961 and 1966. The Ivory Coast reported 50 ha of trials and plans for large-scale industrial plantations. British Solomon Islands plan to plant 32 000 ha by 1985. Many other tropical countries have introduced the species in arboreta and trial plots.

E. deglupta is the only species of eucalypt occurring naturally north as well as south of the equator and is adapted to thrive in conditions of uniformly high rainfall and temperature throughout the year, in which other species may be susceptible to disease. In these conditions it is fast growing and of reasonably good form. It is very susceptible to fire. It flowers and sets seed at an early age and cuttings from young trees can be rooted readily, but coppicing ability is so poor that this is not a practicable method of regenerating plantations.

Most of the plantations which are reported as successful or promising have been planted in areas where there is either no dry season, e.g., total annual rainfall over 3 000 mm, driest month over 100 mm (Philippines, Papua New Guinea, Fiji, British Solomon Islands), or only a mild one, e.g., total annual rainfall 1 900-2 600 mm, 1-4 consecutive months with less than 100 mm but none less than 30 mm (Sri Lanka, Uganda, Western Samoa, the Ivory Coast). In Hawaii it has grown excellently below 700 m in 2 500 mm or more rainfall, if on sites protected from wind. In Kampala, Uganda, it grew better on ridge sites than in seasonally flooded valley bottoms and coppiced adequately.

In the Congo, where there are four consecutive months with less than 20 mm and a total of 1 300 mm rainfall, it is reported as notably inferior to the eucalypts known as 12ABL (a form of *E. tereticornis*) and "*E. platyphylla* F." (a hybrid close to *E. urophylla*). Other countries which have reported poor results from trials on sites too dry and/or too high are Ethiopia, Kenya, Nigeria and Zambia. Suitable temperature conditions are a mean daily minimum of 22°C in the coolest month and a mean daily maximum of up to 30°C in the warmest.

E. deglupta has been planted on a wide variety of soils. Papua New Guinea reports that it can grow successfully on coarse-textured sands and loamy soils, volcanic ash and on limestone-derived soils (pH 6 to 7.5) but that best growth occurs on deep, well-drained sandy alluvial loams. In the Congo it is reported to grow better on the heavy clays of Loudima than on the infertile, free-draining ochraceous sands at Pointe-Noire. In British Solomon Islands the main soils to be planted are deep weathered volcanic clay soils of low nutrient status, but good performance has also been shown on shallower clay soils of moderate nutrient status overlying coral and limestone.

With an altitudinal range from sea-level to 1 800 m (Turnbull, 1974) and a geographical distribution which covers a number of widely separated islands between 9°N and 11°S, *E. deglupta* is likely to exhibit considerable differences between provenances. Provenance trials are still in their early stages, but Papua New Guinea has reported that in trials on the main island early performance of provenances from New Britain (Keravat), Mindanao and Sulawesi has in general been superior to provenances from mainland Papua New Guinea. There are, however, significant site × provenance interactions. In eastern Mindanao (Philippines), the majority of trees planted of a Papua New Guinea provenance have been attacked by a borer, whereas the local indigenous provenance is not affected. Most early introductions outside Southeast Asia have been of the New Britain provenance. Since the species is an early and profuse seeder, many introducing countries can already produce their own seed.

At Turrialba in Costa Rica two apparently distinct provenances have been introduced but the seed origins are not known. They are known locally as "red" or "green" from the general appearance of both foliage and bark. Hybrid offspring have been produced which are of superior form to either parent and of rapid growth. The F_1 generation produces fertile seed and the resulting F_2 generation shows surprising uniformity.

In the Philippines the spacing most commonly used is 4 × 4 m and the rotation 12 years, with no thinning. The purpose is pulpwood production (Tagudar, 1974). In Papua New Guinea spacing varies from 3 × 3 m to 4 × 4 m, for a rotation of 7 to 10 years, also for pulpwood production. In Fiji, the spacing is 11 × 2.75 m for line planting and varies from 3.6 × 3.6 m to 5.4 × 5.4 m for block planting and a rotation of 10 years is foreseen. In the Congo a spacing of 2.8 × 2.8 m for a rotation of 5-7 years is considered suitable. Although pulpwood production is the most common object of management and short rotations with no thinning are therefore the rule, Papua New Guinea has reported a suitable regime for sawlog production

— 25-year rotation, with thinnings at ages 5, 10 and 15, of which the last reduced the stocking to 99 stems/ha.

The following measurements from sample plots and trial plantings give an indication of the range of growth rates in *E. deglupta*:

Table 14.4 Growth data for *E. deglupta*

Place	Age (years)	Trees per ha	Mean height (m)	Mean DBHOB (cm)	Basal area (m^2/ha)	Standing vol. OB (m^3/ha)
Keravat, New Britain	5	300	[1] 21.6	18.7	9.3	90.1
	10	260	[1] 32.3	23.6	12.9	172.8
	15	128	[1] 43.0	40.8	22.9	300.8
	20	133	[1] 54.5	49.5	25.8	520.0
[1] Dominant height = mean height of 50 tallest trees per ha.						
Nukurua, Fiji (all line-planted at 11 × 2.75 m)						
PSP 138	10	203	[2] 32.2	[2] 38.0	15	163
PSP 139	10	134	[2] 17.1	[2] 17.5	3	17
PSP 140	10	60	[3] 27.4	[3] 28.4	4	37
[2] Dominant height and diameter = mean height and diameter of 100 largest diameter trees per ha. [3] Dominant height and diameter = mean height and diameter of 50 largest diameter trees per ha.						
British Solomon Islands	6		19	25		
	9		25	35		
	12		[2] 30	43		
	15		[2] 30	48		
Western Samoa (Asau)	2½			17.4	53.5	
Congo (Loudima)	8½		20	13.5		
Peninsular Malaysia	15		34	67		

On good sites *E. deglupta* is evidently capable of maintaining a mean annual increment of 2-3 m in height and 2-3 cm in diameter over the first 10 years. It is sensitive to variations in site quality, as shown above by PSP 138 and PSP 139 at Nukurua, and Fiji has also reported that growth is uneven within a single plot, i.e., while some trees appear remarkable in growth, others are stunted.

Volume yield figures from larger areas are sparse. In the Philippines a yield of 200-300 m^3/ha is expected at age 12, a MAI of 17-25 m^3 (Tagudar, 1974), while in the Ivory Coast a MAI of about 30 m³ is expected on a rotation of 6 or 7 years.

Periodic damage from the following pests and diseases has been reported, but serious epidemics have not occurred:

INSECTS AND LOWER ANIMALS

Achatina fulica (PNG)	*Lycteus brunneus* (Fiji)
Agrilus opulentus (PNG)	*Nasutitermes novarumhebridarum* (PNG)
Ambleypelta cocophaga (BSI)	*Paratella errudita* (PNG)
Arsipoda sp. (PNG)	*Rhyparida coriacea* (PNG)
Capaxa janetta (PNG)	*Xyleborus Fijianus* (Fiji)
Ceresium sp. (Fiji)	*Zeuzera coffeae* (PNG)
Leptoglossus australis (PNG)	*Austromalaya* sp. (PNG)

FUNGI

Phellinus noxius (PNG)	*Rhizoctonia solani* and other damping-off fungi (PNG, Malaysia, Western Samoa)

The most important potential use for the wood of *E. deglupta* is for pulp (proposed industrial plantations in British Solomon Islands, the Ivory Coast, Papua New Guinea and Philippines).

Other possible uses are for sawlogs, poles (Ghana, Philippines, Sri Lanka) and wood-based panels including rotary veneer (Philippines).

E. delegatensis R.T. Bak. (syn. E. gigantea Hook.)

Refs. Blakely No. 370 Code MAKBE FTA p. 184

Common name in Australia. Alpine ash

Regions of natural occurrence. Mountainous parts of southern New South Wales, Victoria and Tasmania. In southern Tasmania it may descend to sea-level. It tends to be a shelf species in hilly areas, growing on southern and eastern aspects where there is air drainage to lower frost hollows. It is frequently the dominant species in the areas suited to it, though it has several associated species of eucalypts and other genera, e.g., *Nothofagus* which may play a part in the succession of vegetation types on the site. The soils of the better forests are moist but well-drained loams, especially those derived from granites or dolerites, but the mother rock may be a variety of sedimentary deposits in some places.

E. delegatensis occurs at a higher altitude than any other important timber species in Australia. The natural occurrences of the species are likely to have snow on the ground for several weeks each year. Range-wide provenance seed collections have recently been made (Boland and Morgan, 1979).

Latitudinal range. 35°-42.5°S

Altitudinal range. Usually 300-1 500 m, occasionally to sea-level in Tasmania

Rainfall

Type: winter rainfall
Total: 2 500-3 700 mm
Dry season: may be 3 months, not severe

Temperature

Mean maximum of hottest month: 21°C
Mean minimum of coldest month: 0°C
Frosts: 70-100; frequent snowfalls

Characteristics

Tree height in Australia: 40-70 m; of very good form and attractive appearance in all growth stages. Quick-growing, easy to regenerate.
Bark type: persistent in lower part of trunk, smooth blue-grey or white above, decorticating in long strips
Juvenile leaves: alternate, stalked, broadly lanceolate or oblong
Adult leaves: alternate, stalked, lanceolate, often curved, venation at a low angle with midrib
Wood: pale brown or pinkish, open texture, straight grain, with conspicuous growth rings
Buds and fruits: Figure a7-23 (370)
Viable seeds per gram: 108

Uses. One of the most important sawtimbers and pulpwood timbers in Australia. Widely used for construction.

Prospects for planting. Good in cool areas with a fairly high winter rainfall. One of the eucalypts resistant to frosts at least as severe as −9°C at time of planting.

Success outside Australia. It was introduced into South Africa in Zones E and G on a relatively small scale and showed good height and diameter growth, but did not become a preferred species. Several countries have good specimens but the main commercial plantations are in New Zealand. In New Zealand it is planted both in containers and as bare-rooted planting stock. With adequate root-pruning good seedlings are prepared and planted either by hand or by machine. The trees grow vigorously but the leading shoot is attacked each autumn by the fungus *Mycosphaerella nubilosa*, which results in multiple leaders. One of these becomes the mainstem early in the next growing season, but successive attacks of the fungus cause a series of large branches to develop on the trunk. This is not of great significance if the crop is being grown for pulpwood, but is more serious in the case of sawtimber.

Refs. Blakely No. 57 Code SEB:A FTA p. 50 **E. diversicolor F. Muell.**

Common name in Australia. Karri

Regions of natural occurrence. Southwest Western Australia; a limited but magnificent high-quality closed forest growing on undulating country with sandy and sandy loam soils low in nutritive value and deficient in trace elements such as zinc, copper and cobalt.

Latitudinal range. 34°-35°S

Altitudinal range. 0-300 m

Rainfall

Type: winter rainfall
Total: 1 100-1 500 mm
Dry season: up to 3 months, not severe

Temperature

Mean maximum of hottest month: 27°C
Mean minimum of coldest month: 8°C
Frosts: few and light

Characteristics

Tree height in Australia: 50-60 m; a very good bole and a wide-spreading heavy crown
Bark type: smooth; shed in irregular plates; surface yellowish white to blue-grey
Juvenile leaves: alternate, stalked, ovate to broadly lanceolate
Adult leaves: alternate, stalked, lanceolate
Wood: red, hard, heavy, density 900 kg/m^3; strong, tough, moderately durable
Buds and fruits: Figure a7-24 (57)
Viable seeds per gram: 71

Uses. An important Western Australian sawnwood for local use and export to other Australian States and overseas; acceptable as a pulpwood

Prospects for planting. It requires a winter rainfall and a nearly frost-free locality to do well. There are few places in the world with planting land with these qualities.

Success outside Australia. Excellent in the Knysna area of South Africa as a plantation species used largely for tool handles. Very good park trees in the North Island of New Zealand.

Refs. Blakely No. 417 Code MATEP FTA p. 210 **E. dives Schau.**

Common name in Australia. Broad-leaved peppermint

Regions of natural occurrence. Hilly localities in southern New South Wales and Victoria

Latitudinal range. 34°-39°S

Altitudinal range. 160-1 300 m

Rainfall

Type: winter rainfall
Total: 625-1 250 mm
Dry season: 3-4 months, not usually severe

Temperature

Mean maximum of hottest month: 23°C
Mean minimum of coldest month: 0-5°C
Frosts: 15-80

Characteristics

Tree height in Australia: 15-25 m; of rather poor form, much branched
Bark type: peppermint type
Juvenile leaves: opposite, sessile, broadly lanceolate
Adult leaves: alternate, stalked, broadly lanceolate
Wood: light brown, fairly hard and tough, gum veins frequent, fissile but not durable
Buds and fruits: Figure a7-25 (417)
Viable seeds per gram: 75

Uses. Sometimes the leaves of certain provenances are used for essential oils. The wood is little used.

Prospects for planting. Limited unless a particular provenance is required for essential oils

Success outside Australia. Growth is good in many countries but the species is not popular for wood production. It is grown for production of essential oils on a short rotation in several countries, e.g., the USSR and South Africa.

E. drepanophylla F. Muell. ex Benth.

Refs. Blakely No. 533 Code SUP FTA p. 254

Common name in Australia. Queensland grey ironbark

Regions of natural occurrence. Queensland, from New South Wales coastal border up to Cairns, growing on a wide variety of sites and soils. It occurs as a component of a mixed forest or sometimes as the principal species.

Latitudinal range. 17°-28°S

Altitudinal range. 0-800 m

Rainfall

Type: summer rainfall
Total: 625-1 250 mm
Dry season: 4-5 months in the cooler season

Temperature

Mean maximum of hottest month: 29-35°C
Mean minimum of coldest month: mild
Frosts: up to 10

Characteristics

Tree height in Australia: 25-30 m; usually of good form
Bark type: ironbark type
Juvenile leaves: alternate, stalked, narrow to broadly lanceolate
Adult leaves: alternate, stalked, narrow to broadly lanceolate
Wood: hard, heavy, tough, durable
Buds and fruits: Figure a7-26 (533)
Viable seeds per gram: 184

Uses. An important ironbark wood in Queensland; very high strength properties; highly valued as a pole and for bridge construction or general sawnwood use; one of the best fuelwoods and charcoal timbers

Prospects for planting. If an ironbark type is required in a summer-rainfall locality it could be very useful. Much more provenance testing and, indeed, species determination are needed in the ironbark group.

Success outside Australia. Successful in Brazil

Refs. Blakely No. 134 Code SLUBA FTA p. 86 Chipp. p. 182

E. dundasii Maid. (earlier spelt E. dundasi)

Common name in Australia. Dundas blackbutt

Regions of natural occurrence. Restricted scattered occurrences near Norseman in south-central Western Australia. It grows on gravelly soils which may be alkaline but not salty.

Latitudinal range. 31°-33°S

Altitudinal range. 250-400 m

Rainfall

Type: winter rainfall
Total: 400-500 mm
Dry season: 4-5 months in the warm season; can be severe

Temperature

Mean maximum of hottest month: 30-33°C
Mean minimum of coldest month: 4°C
Frosts: 1-12

Characteristics

Tree height in Australia: 10-20 m; frequently with a good trunk somewhat less than half the height of the tree
Bark type: rough, scaly or deeply fissured or tessellated
Juvenile leaves: alternate, stalked, ovate or lanceolate
Adult leaves: alternate, stalked, narrowly lanceolate, tapering to a long point with a hooked tip
Wood: dark brown, hard, dense and durable
Buds and fruits: Figure a7-27 (134)
Viable seeds per gram: 396

Uses. Particularly drought resistant; one of the most promising species for street planting in dry inland towns; valuable as a fuelwood

Prospects for planting. Limited but of possible value for environmental purposes and fuel

Success outside Australia. Failed in Brazil in a climate not suited to it, but there are successful experimental plantings in California. South African plantings were not promising.

E. dunnii Maid.

Refs. Blakely No. 223 Code SPIDA FTA p. 114

Common name in Australia. Dunn's White Gum

Regions of natural occurrence. A restricted occurrence on optimum sites in closed forests in the northeast corner of New South Wales and the adjacent southeast corner of Queensland just west of the McPherson Range. It is found mainly on the lower slopes of hills and valley bottoms, but also grows on ridges in basaltic soils around the edge of rain forest. Another interesting site is along streams in frost hollows believed to have been kept open as campsites by the aboriginal inhabitants of the district. It forms an important part of mixtures with such valuable species as *E. saligna, E. microcorys* and *E. grandis.*

Latitudinal range. 28°-30°S

Altitudinal range. 150-800 m

Rainfall

Type: summer rainfall
Total: 1 000-1 500 mm
Dry season: 3 months in the cooler season

Temperature

Mean maximum of hottest month: 27-29°C
Mean minimum of coldest month: 8°C
Frosts: few and light

Characteristics

Tree height in Australia: 40-50 m; long straight trunks and heavily branched crowns. It is a very shy seeding species.
Bark type: smooth, whitish, with short stocking of rough bark at the base of large trees
Juvenile leaves: sub-opposite to alternate, stalked, broadly ovate to subcordate
Adult leaves: alternate, stalked, lanceolate, tending to be undulate
Wood: whitish in colour, coarse grained, fissile, tough, non-durable
Buds and fruits: Figure a7-28 (223)
Viable seeds per gram: 296

Uses. The wood is used for general sawnwood purposes. There is no paper-making industry close to its natural occurrence, but it has been planted in Australia with the aim of making pulpwood plantations. Australian manufacturers do not like it for paper at present, but some Brazilian manufacturers consider it acceptable.

Prospects for planting. E. dunnii is one of the fastest growing trees in Australia, possibly the fastest. If papermakers will accept it and if seed supplies can be developed, it should be one of the most popular plantation species for summer-rainfall areas with a rainfall of 1 200 mm or more. An additional advantage of the species is its resistance to cold, which has only been tested in the last decade.

Success outside Australia. A recent introduction to South Africa and Brazil, *E. dunnii* shows remarkable height and volume growth in plantations in summer-rainfall regions. At the present stage it promises a higher volume yield than *E. grandis.* In tests in the United States it has been found to be one of the most cold-resistant eucalypts. In a recent bout of freezing weather in Brazil which damaged the coffee crop and some eucalypt plantations, *E. dunnii* was not injured.

E. elata Dehnh. (syn. E. andreana Naudin.)

Refs. Blakely No. 406 Code MATEN FTA p. 202

Common name in Australia. River peppermint

Regions of natural occurrence. Central tablelands and south coastal areas of New South Wales and eastern Victoria. It is characteristically seen along the banks of small streams or the edges of river flats. The situations in which it grows have fertile soils which maintain a moist subsoil but do not get waterlogged. *E. elata* is not a tree of the closed forests even though it is a good plantation species. Along streams it may be associated with other good eucalypts such as *E. longifolia, E. sieberi, E. globulus* subsp. *maidenii, E. muellerana* and *E. globoidea.*

Latitudinal range. 34°-38°S

Altitudinal range. 0-700 m

Rainfall

Type: winter to uniform rainfall
Total: 1 000-1 500 mm
Dry season: 3-4 months, not usually severe

Temperature

Mean maximum of hottest month: 28°C
Mean minimum of coldest month: 3-4°C
Frosts: up to 50

Characteristics

Tree height in Australia: 20-30 m; with a long straight trunk and a deep crown with light drooping foliage
Bark type: smooth, decorticating in long strips, leaving a smooth white surface
Juvenile leaves: opposite, sessile, lanceolate
Adult leaves: stalked, lanceolate to linear-lanceolate
Wood: pale, subject to gum veins, fissile, not durable
Buds and fruits: Figure a7-29 (406)
Viable seeds per gram: 148

Uses. It can be used as a rather inferior sawtimber. Fast-growing.

Prospects for planting. Rather limited prospects as a timber species. It could be very useful as a pulpwood species.

Success outside Australia. E. elata has been planted on a substantial scale in South Africa in recent decades. It is classed as a good coppicing species which debarks well. It does well in winter- or uniform rainfall conditions which are similar to the climate of its native habitat, but it also makes good plantations on suitable soils in summer-rainfall areas, which suggests it is a species of great plasticity, since in general it is difficult to move species from a winter-rainfall to a summer-rainfall situation. *E. elata* has done fairly well in summer-rainfall regions in Brazil. It would appear that the species has been underestimated regarding its potential for production forestry. Because of its plasticity it should be tried in more countries.

E. erythrocorys F. Muell.

Refs. Blakely No. 1 Code EAAAC Chipp. p. 30

Common name in Australia. Illyarrie

Regions of natural occurrence. Coast of southern Western Australia

Latitudinal range. 29°-32°S

Altitudinal range. Up to 100 m

Rainfall

Type: winter rainfall
Total: 470 mm
Dry season: 6-7 months in the warmer season, can be severe

Temperature

Mean maximum of hottest month: more than 30°C
Mean minimum of coldest month: below 10°C
Frosts: rare

Characteristics

Tree height in Australia: 6-8 m; with an open-branched crown
Bark type: smooth, grey to white
Juvenile leaves: stalked, opposite and ovate with a slightly sinuous margin
Adult leaves: opposite, stalked, narrowly lanceolate
Wood: pale, soft, brittle
Buds and fruits: Figure a7-30 (1). The flower buds are large and have a brilliant scarlet operculum. The stamens are bright yellow.
Viable seeds per gram: 16

Uses. A popular ornamental

Prospects for planting. Only as an ornamental

Success outside Australia. Successful as an ornamental in California

Refs. Blakely No. 318 Code MAHEA FTS No. 93

E. eugenioides Sieb. ex Spreng.

There are several "stringybarks" in the better forests of the southeast coastal tableland region of Australia and there has been some confusion about the correct nomenclature in Australian literature. The species described as *E. eugenioides* is Blakely No. 318 described in Forest Tree Series No. 93.

Common name in Australia. Thin-leaved stringybark

Regions of natural occurrence. Coastal New South Wales and southern Queensland in closed mixed good-quality forest on a wide variety of soils

Latitudinal range. 27°-37°S

Altitudinal range. Up to 1 000 m (only to 300 m in south)

Rainfall

Type: uniform and summer-rainfall regions
Total: 600-1 000 mm
Dry season: 4 months, usually in the cool season

Temperature

Mean maximum of hottest month: 24-32°C
Mean minimum of coldest month: 0-7°C
Frosts: up to 20

Characteristics

Tree height in Australia: 25-30 m; with a low crown and persistent branches
Bark type: stringy-bark type
Juvenile leaves: opposite or sub-opposite, sessile or shortly stalked; elliptical to broadly lanceolate; softly tomentose with minute stellate hairs
Adult leaves: alternate, stalked, broadly lanceolate, may be slightly oblique at base
Wood: light brown to pale pink, hard, strong, tough, moderately durable; generally straight-grained and easy to split
Buds and fruits: Figure a7-31 (318); the fruits of this species are slightly pedicellate while those of *E. globoidea*, No. 346, are tightly sessile
Viable seeds per gram (France): 100-196

Uses. A useful hardwood sawtimber

Prospects for planting. Restricted. There are better choices.

Success outside Australia. Fairly successful in Brazil. The nomenclature in some plantings is understandably confused.

E. exserta F. Muell.

Refs. Blakely No. 173 Code SNEEX FTA p. 90

Common name in Australia. Queensland peppermint; named "peppermint" because of its bark, but it is a relative of *E. camaldulensis* and *E. tereticornis.*

Regions of natural occurrence. A wide occurrence usually 300 km or more wide in east Queensland from near Cairns to the New South Wales border occurring on many topographical and soil types.

Latitudinal range. 17°-28°S

Altitudinal range. Near sea-level to 400 m

Rainfall

Type: summer rainfall
Total: 450-1 100 mm
Dry season: 2-3 months with less than 25 mm, not severe

Temperature

Mean maximum of hottest month: 35°C
Mean minimum of coldest month: 5°C
Frosts: few

Characteristics

Tree height in Australia: 15-25 m; frequently with a straight bole and an attractive crown
Bark type: bark like a peppermint

Juvenile leaves: linear to linear-lanceolate
Adult leaves: alternate, stalked, lanceolate to narrow-lanceolate
Wood: pale pinkish brown, heavy, hard and durable, interlocked grain, somewhat brittle
Buds and fruits: Figure a7-32 (173)
Viable seeds per gram (France): 362

Uses. Used locally for general construction. In spite of the wide area of natural occurrence the wood is in limited supply.

Prospects for planting. Suggested in Métro 1955 as a relative of *E. camaldulensis,* which is so successful, and in which the importance of provenance is being demonstrated. *E. exserta* has attracted further attention from visitors to Australia and provenance trials of it could prove valuable to tropical planting countries.

Success outside Australia. Not very successful in Brazil at first but interest in the species is growing; it did not perform well in South Africa but it was off site. It is one of the main species planted in Kwantong province of China (20°-25°N) where a MAI of about 16 m^3/ha/yr is obtained. The leaves are distilled for oil and yield 0.7 percent.

E. fastigata Deane & Maid.

Refs. Blakely No. 368 Code MAKCB FTA p. 180

Common name in Australia. Brown barrel

Regions of natural occurrence. An important occurrence in northeastern Victoria and southeastern New South Wales, with scattered occurrences along the tablelands and ranges of the Great Dividing Range up to latitude 30°S. In the main occurrence it occurs with *E. nitens* in a wet sclerophyll forest of very high quality, which would be an excellent seed source for both species. It may also be associated with *E. delegatensis, E. dalrympleana, E. viminalis, E. obliqua* and *E. robertsonii* in high-quality forest types. A very close relative of *E. regnans,* it rarely touches the range of that species, but near the forest town of Bendoc in northeast Victoria, close to the New South Wales border, the two species mix in association with *E. nitens.* The two relatives, *E. regnans* and *E. fastigata,* can be readily recognized in this area.

Further up the Great Dividing Range in New South Wales, *E. fastigata* continues to be a very good forest tree, but it does not attain the size found around the border with Victoria. There are more than seven degrees of latitude over which the species occurs as a good tree available for provenance testing. The species occurs on a wide range of fertile soils derived from the assorted rock strata of the Great Dividing Range. On spurs from the Great Dividing Range west of Canberra, A.C.T. (lat. 35°S), *E. fastigata* is a tall tree of the frosty valleys, while above it on slopes with southern and eastern aspects are good forests of *E. delegatensis.* On the exposed rocky ridges at an elevation of 1 200 m or more, above the *E. delegatensis,* may be found a hardy small form of *E. fastigata* up to 20 m high mixed with snow gum, *E. pauciflora.* This ridge form of *E. fastigata*, although hardy, could not be recommended as a seed source for production forestry.

Latitudinal range. 30°-37.5°S

Altitudinal range. 170-1 200 m

Rainfall

Type: winter through uniform to some summer rainfall
Total: 750-1 200 mm
Dry season: occasional dry periods, rarely severe

Temperature

Mean maximum of hottest month: 27°C
Mean minimum of coldest month: 0-2°C
Frosts: 50-100; snow is common. The species has not scored well in overseas frost tests but is one of the most frost hardy in the forests of its natural occurrence.

Characteristics

Tree height in Australia: 30-50 m for the closed forest type, up to 20 m for the ridge type; of good form with a straight bole
Bark type: persistent over the trunk and larger branches, smooth above
Juvenile leaves: first opposite then alternate, stalked, broadly lanceolate
Adult leaves: alternate, stalked, obliquely lanceolate; rather oblique venation with a distinct marginal vein
Wood: pale brown, straight grained, open-textured; hardness, strength and durability moderate
Buds and fruits: Figure a7-33 (368)
Viable seeds per gram: 94

Uses. A very useful sawnwood species in Australia

Prospects for planting. Promising in suitable localities. The species is hardy and handles well in nurseries and at planting out.

Success outside Australia. It was planted on a small scale in New Zealand in plantations of *Pinus radiata.* Each grew at approximately the same rate and the resulting mixed forest is very attractive. There are also much more extensive successful pure plantations of *E. fastigata* in New Zealand and excellent single-tree or line-plantings. It is planted bare-rooted after careful root-pruning in regions of high rainfall and succeeds well; it is not preferred over *E. regnans* but is recognized as hardier.

In South Africa *E. fastigata* has been widely planted as a production species. It has succeeded well in the cooler humid regions of summer rainfall, but tended to die off in the summer mist belt region of the Transvaal. An advantage of the species for South Africa is that it is immune to the attacks of

Gonipterus scutellatus. Some thousands of hectares have been planted and the volume MAI has been up to 25 m^3/ha or more. It has behaved better than most eucalypts as a sawtimber. It is classed as a good coppicing species in South Africa (Wattle Research Institute, 1972) and many plantations have been successfully coppiced there. *E. fastigata* regrowth destroyed by fire in Australia nearly always recovers with the aid of coppice shoots if the old burnt trunks are cut near the ground.

E. ficifolia F. Muell.

Refs. Blakely No. 36 Code CAFOA FTA p. 32

Common name in Australia. Red-flowering gum

Regions of natural occurrence. Extreme south of Western Australia

Latitudinal range. 34.5°-35°S

Altitudinal range. Sea-level to 150 m

Rainfall

Type: winter rainfall
Total: 900-1 400 mm
Dry season: 5 months with 25 mm, not severe

Temperature

Mean maximum of hottest month: 24°C
Mean minimum of coldest month: 8°C
Frosts: nil

Characteristics

Tree height in Australia: 10-12 m; with a short trunk and widely spreading branches
Bark type: bloodwood type, rough bark throughout
Juvenile leaves: opposite then alternate, ovate to circular, stalked with leaf blade sometimes peltate
Adult leaves: stalked, ovate or broadly lanceolate, petiolate
Wood: pale — not used
Buds and fruits: Figure a7-34 (36)
Viable seeds per gram: 42

Uses. Red flowers make it a valuable ornamental and the tree size is suitable as a street tree

Prospects for planting. Good prospects as an ornamental in mild climates with little or no frost

Success outside Australia. Widely planted in California, South Africa, Latin America and New Zealand. The budded tub-plantings at the F.R.I. at Rotorua, New Zealand, are spectacular.

E. flocktoniae (Maid.) Maid.

Refs. Blakely No. 584 Code SIT:T Chipp. p. 108

Common name in Australia. Merrit

Regions of natural occurrence. Southwest Western Australia; Eyre Peninsula in South Australia

Latitudinal range. 30°-35°S

Altitudinal range. Up to 100 m

Rainfall

Type: winter rainfall
Total: 220-450 mm
Dry season: 7 months or more in the warm season, can be severe

Temperature

Mean maximum of hottest month: 25°C
Mean minimum of coldest month: 5°C
Frosts: 30

Characteristics

Tree height in Australia: mallee or tree up to 12 m; widely spreading branches
Bark type: smooth and light grey; youngest branchlets are quadrangular and may be red
Juvenile leaves: opposite, elliptical or almost orbicular, sessile with leaf edges continued on stem as noticeable wings
Adult leaves: alternate, lanceolate, stalked
Wood: pale pink, fairly dense, has been used in local building and in mines; the bark has been used for tannin
Buds and fruits: Figure a7-35 (584)
Viable seeds per gram: 135

Uses. Mainly as an ornamental

Prospects for planting. As an ornamental in suitable localities

Success outside Australia. As an ornamental in California, Cyprus and North Africa

E. forrestiana Diels subsp. forrestiana

Refs. Blakely No. 596 Code SLOBEA Chipp. p. 177

Common name in Australia. Fuchsia gum

Regions of natural occurrence. Southern Western Australia between Salmon Gums and Scaddan and 80 km east and west

Latitudinal range. 33°-34°S

Altitudinal range. Up to 100 m

Rainfall

Type: winter rainfall
Total: 330-400 mm
Dry season: 7 months or more in the warm season, severe

Temperature

Mean maximum of hottest month: 25°C
Mean minimum of coldest month: 5-8°C
Frosts: 25-30

Characteristics

Tree height in Australia: up to 4-5 m (mallee form)
Bark type: smooth grey
Juvenile leaves: alternate, ovate and stalked
Adult leaves: alternate, lanceolate to lanceolate-oblong, abruptly pointed
Wood: not commonly available
Buds and fruits: Figure a7-36 (596). Fruits shown are of *E. forrestiana* Diels subsp. *dolichorhyncha* Brooker.
Viable seeds per gram (France): 12

Uses. Ornamental; usually with one flower; buds and fruits red, four-sided and four-winged

Prospects for planting: as an ornamental

Success outside Australia: it is being used as an ornamental

E. fraxinoides Deane & Maid.

Refs. Blakely No. 381 Code MAKIB FTA p. 190

Common name in Australia. White ash

Regions of natural occurrence. Tablelands of southeast New South Wales, growing to a large tree on brown podsolic or alpine humus soils; sometimes on rocky outcrops or near the tops of mountains.

Latitudinal range. 34°-36°S

Altitudinal range. 500-900 m

Rainfall

Type: uniform to winter rainfall
Total: 1 100-1 500 mm
Dry season: up to 4 months, not severe

Temperature

Mean maximum of hottest month: 21°C
Mean minimum of coldest month: 0°C
Frosts: 50-100; frequent snow

Characteristics

Tree height in Australia: 20-40 m; in its best form a straight tree with a heavy crown
Bark type: lower stocking of fibrous bark; smooth above
Juvenile leaves: opposite first then alternate, stalked, broadly lanceolate
Adult leaves: alternate, stalked, lanceolate-falcate
Wood: pale coloured, open textured, straight-grained and fissile; light for a eucalypt; not durable
Buds and fruits: Figure a7-37 (381)
Viable seeds per gram: 96

Uses. A very good wood but not much of it in Australia

Prospects for planting. Probably limited because of more vigorous alternatives

Success outside Australia. The species has done well in New Zealand and South Africa where the largest are probably larger than the best Australian examples

E. glaucescens Maid. & Blakeley

Refs. Blakely No. 237 Code SPINH FTS No. 8

Common name in Australia. Tingiringi gum

Regions of natural occurrence. The southern tablelands of New South Wales where it is usually a mallee or small tree on difficult high mountain sites. Also as a large tree on good soils on the southern mountains of the Victorian Alps, occupying a narrow belt between *E. regnans* below and *E. delegatensis* above.

Latitudinal range. 35.5°-37°S

Altitudinal range. 1 000-1 800 m

Rainfall

Type: winter rainfall
Total: 500-1 500 mm or more
Dry season: up to 3 months, not severe

Temperature

Mean maximum of hottest month: 18-20°C
Mean minimum of coldest month: 0°C or less
Frosts: many; considerable snow

Characteristics

Tree height in Australia: sometimes as a mallee 5 m high; occasionally as a good tree 30-40 m high

Bark type: on large trees persistent at base, smooth above
Juvenile leaves: opposite, sessile, orbicular, glaucous
Adult leaves: alternate, stalked, lanceolate
Wood: darker than associated *E. regnans* and *E. delegatentis*; tends to be woolly off the saw
Buds and fruits: Figure a7-38 (237)
Viable seed per gram: 92-418

Uses. One of the most cold-resistant eucalypts

Prospects for planting. Should be tried out where cold resistance is required and if seed of the better tree forms can be obtained

Success outside Australia. Limited experiments only, confirming the resistance to cold

E. globulus Labill. subsp. bicostata (Maid. et al.) Kirkp. (previously planted under the names E. bicostata, E. stjohnii)

Refs. Blakely No. 250 Code SPIFK FTA p. 130

Common name in Australia. Southern blue gum

Regions of natural occurrence. Several scattered occurrences in mountainous areas of Victoria and New South Wales.

Latitudinal range. 31°-40.5°S

Altitudinal range. Near sea-level to more than 1 000 m

Rainfall

Type: winter to uniform rainfall
Total: 750-1 250 mm
Dry season: 3 months, not severe

Temperature

Mean maximum of hottest month: 21-27°C
Mean minimum of coldest month: 2-7°C
Frosts: up to 25-40; occasional snow

Characteristics

Tree height in Australia: up to 40 m; with a good trunk and a heavv crown (Kirkpatrick, 1975)
Bark type: lower bark rough, grey-brown and persistent; upper smooth, shedding in strips
Juvenile leaves: square stemmed, glaucous, sessile or stem-clasping, ovate to broadly lanceolate
Adult leaves: alternate, stalked, lanceolate, usually curved and tapering to a long point
Wood: light yellow-brown, open textured, grain commonlv interlocked; density 770-1 000 kg/m^3, strong and moderately durable

Buds and fruits: Figure a7-39 (250); somewhat like subsp. *globulus* but usually two or three in the leaf axil against the normal single fruit of subsp. *globulus*.
Viable seeds per gram: 106

Uses. A useful hardwood in Victoria and southern New South Wales. Frequently used as a roadside or ornamental tree in the tableland areas of southern New South Wales. Extensively used in the Australian Capital Territory (Canberra) for block ornamental plantings. As individual ornamental trees in private gardens, they are very attractive for a few years, but soon become too big, casting excessive shade, shedding large branches in storms and being expensive to remove.

Prospects for planting. Good, very similar to subsp. *globulus* but tolerates much colder and drier conditions. Probably underestimated as a potential exotic. It will be attacked by the same pests that attack subsp. *globulus*, but it may succeed at altitudes at which the pests are less active.

Success outside Australia. Not many reports have been received but there are good trees in the cooler parts of Latin America

E. globulus Labill. subsp. globulus (previously known as E. globulus Labill.)

Refs. Blakely No. 248 Code SPIFL FTA p. 128

Common name in Australia. Tasmanian blue gum

Regions of natural occurrence. Tasmania and Wilson's Promontory and the adjacent coast of Victoria; the islands in Bass Strait between Tasmania and the mainland.

Latitudinal range. 38.5°-43.5°S

Altitudinal range. 0-330 m

Rainfall

Type: winter to uniform rainfall
Total: 500-1 500 mm
Dry season: up to 3 months, not severe

Temperature

Mean maximum of hottest month: 18-23°C
Mean minimum of coldest month: 4°C
Frosts: 0-5

Characteristics

Tree height in Australia: 45-55 m; with a straight massive trunk and a heavy spreading crown
Bark type: rough, grey and persistent at base: smooth above
Juvenile leaves: opposite, sessile, stem-clasping, glaucous
Adult leaves: alternate, stalked, lanceolate, often curved

Wood: light yellow-brown, open texture, commonly interlocked grain, fairly distinct growth rings, strong and moderately durable
Buds and fruits: Figure a7-40 (248)
Viable seeds per gram: 70

Uses. Was highly regarded for light and heavy construction, poles, piles and even railway sleepers. One of the better eucalypts for paper-making. A good fuel.

Prospects for planting. This was the first eucalypt to be extensively planted outside Australia, probably because cattle and sheep do not eat the juvenile leaves and it could be planted without fencing. There was disenchantment in several countries when efforts were made to saw it because of growth stress problems, but it is widely used for pulp.

Success outside Australia. E. globulus subsp. *globulus* was the first of the eucalypts to become widely known outside Australia, and at one time its common name blue gum was synonymous with eucalypt for the general public. Early successes led to its becoming the most extensively planted eucalypt species in the world. By the end of 1973, there were over 800 000 hectares of subsp. *globulus* plantations. The region of greatest concentration is the Iberian Peninsula where Portugal, with 238 000 hectares, and Spain, with 205 000 hectares, together account for more than half the total. Portugal may have introduced subsp. *globulus* as early as 1829, but reliable records are not available until 1852. Some of the trees planted in 1875 at Choupal and Vale near Coimbra and at Ponte Nova in Marinha Grande are now among the tallest in Europe — 60 to 70 m high. Other early introductions were to Chile, perhaps as early as 1823; South Africa, 1828; India, 1843; United States, 1853; Uruguay, mid-1850s; and Peru, 1860. In the Nilgiri mountains in Southern India, the oldest surviving stand was planted in 1863; at 90 years the tallest tree was 76 m high, the largest diameter tree was 1.8 m in diameter, and the current annual increment of the stand was 26 m^3/ha. About 9 000 ha of plantations had been planted in India to 1972 and on suitable sites the species is considered the fastest growing in the country.

According to Jacobs (1970), one reason for the great and widespread early popularity of subsp. *globulus* may have been the unpalatability of its juvenile leaves. In its juvenile form, subsp. *globulus* is seldom browsed by cattle, sheep or goats, which gives it an advantage over most other species where fencing is not practicable. The species is also easy to establish, is generally of good stem form, grows fast, closes canopy rapidly, coppices vigorously and is wind-firm. It seeds readily in plantations, sometimes as early as age 5, and yields seed of high germination percent. Important for erosion control is its widespreading and dense root system. It is also an attractive ornamental with large, dark green, glossy adult leaves; glaucous and bluish juvenile leaves and stems; and showy flowers and fruits.

Subsp. *globulus* has been planted on a wide range of soil types. Best development is on deep, sandy clay soils, but good growth is also attained on clay-loams and clay soils, providing they are well drained. The principal limiting soil factors are insufficient depth, poor drainage, salinity and the

Table 14.5 *E. globulus* subsp. *globulus* climatic stations

LOCATION AND TEMPERATURE

Station	Latitude	Longitude	Altitude (m)	No. of frost days	Temperature (°C)					
					Hottest			Coldest		
					Month	Mean temp.	Mean max.	Month	Mean temp.	Mean min.
Temperate climates										
Hythe, Tasmania (Australia)	43°24′S	147°00′E	5	10	February	14.8	20	July	7.5	3
Concepción (Chile)	36°50′S	73°03′W	15		January	17.8	24	July	9.1	3
Rotorua (New Zealand)	38°10′S	176°16′E	306	81	January	18.0	24	July	7.7	3
Oporto (Portugal)	41°08′N	8°36′W	95		August	19.8	25	January	9.0	5
Huelva (Spain)	37°11′N	6°57′W	18	1-10	July	25.0	33	January	11.0	3
Santander (Spain)	43°24′N	3°49′W	65	4	August	19.0	23	February	9.0	6
Montevideo (Uruguay)	34°52′S	56°12′W	22		January	22.5	28	July	10.5	6
San Francisco, Calif. (USA)	37°47′N	122°25′W	16		September	16.7	21	January	10.4	7
Montane climates in tropical latitudes										
Bogotá (Colombia)	4°38′N	74°06′W	2 560		February	14.9	19	July	13.5	9
Quito (Ecuador)	0°12′S	78°29′W	2 819		September	13.2	23	November	12.8	7
Addis Ababa (Ethiopia)	9°02′N	38°45′E	2 450		May	16.0	25	November	13.0	4
Ootacamund (India)	11°24′N	76°44′E	2 250		May	16.5		January	12.5	
Cuzco (Peru)	13°31′S	71°58′W	3 366		November	12.9	23	July	8.8	—1
Nuwara Eliya (Sri Lanka)	6°58′N	80°46′E	1 900		April	16.7	22	February	14.3	8

Table 14.5 *E. globulus* subsp. *globulus* climatic stations *(concluded)*

RAINFALL (mm)

Station	J	F	M	A	M	Jn	Jl	A	S	O	N	D	Total
Temperate climates													
Hythe, Tasmania (Australia)	68	56	73	91	84	105	97	89	88	95	78	74	998
Concepción (Chile)	21	22	38	79	245	252	242	198	96	66	45	27	1 331
Rotorua (New Zealand)	112	104	89	117	140	135	124	127	122	124	109	94	1 397
Oporto (Portugal)	159	112	147	86	87	41	20	26	51	105	148	168	1 150
Huelva (Spain)	67	47	73	40	26	7	2	1	19	52	64	67	465
Santander (Spain)	113	91	78	89	87	66	55	81	112	131	146	154	1 202
Montevideo (Uruguay)	77	73	99	103	95	95	67	85	89	70	78	80	1 011
San Francisco, California (USA)	116	93	74	37	16	4	—	1	6	23	51	108	529
Montane climates in tropical latitudes													
Bogotá (Colombia)	38	48	66	96	103	60	48	37	53	157	140	93	939
Quito (Ecuador)	125	135	158	180	129	50	19	22	81	131	112	106	1 248
Addis Ababa (Ethiopia)	16	44	70	86	95	136	282	294	192	21	15	6	1 256
Ootacamund (India)	35	13	33	86	159	156	201	147	139	202	158	49	1 378
Cuzco (Peru)	158	128	126	38	9	5	1	8	24	43	81	128	749
Nuwara Eliya (Sri Lanka)	145	76	97	154	237	266	223	180	165	222	209	190	2 164

presence of a high content of assimilable carbonates. However, where climatic conditions are favourable, suitable performance is reported on shallow and sometimes stony soils, particularly if subsoiling is practised. Soil factors are generally less important than climate in limiting its development.

Although sometimes considered to be a species of great plasticity with regard to climate, the major successes of subsp. *globulus* have been attained largely in mild, temperate climates and at high elevations in cool tropical climates; success in other climates is rare, except where moderating conditions occur. Table 14.5 gives representative temperature and rainfall data from temperate regions in Australia, Chile, Portugal, Spain, Uruguay and the United States, and from high elevation tropical areas in Colombia, Ecuador, Ethiopia, India and Peru, where subsp. *globulus* has been successful. Also included are data from New Zealand and Sri Lanka where the species has failed.

As an exotic plantation tree, climatic conditions are said to be ideal for subsp. *globulus* along the northwestern coasts of Spain and Portugal where mean annual precipitation is above 900 mm, there is no severe dry season, and minimum temperatures do not drop below −7°C. Most countries report a rainfall requirement of 900-1 400 mm, but drier climatic conditions can be tolerated, provided a sufficient level of soil moisture can be maintained. In southwestern Spain, for example, the effects of a 465-mm rainfall and up to a four-month dry season are mitigated by a deep alluvial soil, available groundwater and annual mechanical weedings; whereas on drier and shallower soils *E. camaldulensis* is preferred. In California, United States, fall and winter fogs, averaging 21 per year, and the siting of plantations on deep residual soils and alluvial flood plains compensate in part for the low annual rainfall of 529 mm and long dry season. Similarly, subsp. *globulus* performs well in a coastal strip north of Concepción, Chile, where rainfall is less than 500 mm, but where soils are deep and fertile and there are frequent fogs, low clouds and relatively low night temperatures (Pryor, 1965).

Where compensating factors do not occur, drought is a serious limitation. For example, after four consecutive years of low rainfall (1928-31), subsp. *globulus* failed in Nairobi Arboretum, Kenya (mean annual precipitation 838 mm), after growing satisfactorily for 20 years (Streets, 1962). Similarly, in Ethiopia it is rarely successful in regions of less than 800 mm rainfall, and even with a rainfall of up to 1 200 mm is liable to be killed by drought in unusually dry years, particularly on shallow soils.

Failure is also reported in excessively humid areas. In the montane zone of Sri Lanka at elevations of 610-2 460 m and with annual rainfall above 2 000 mm, subsp. *globulus* has been dropped from cultivation because of poor form, spiral grain and unthrifty growth.

Planting subsp. *globulus* at latitudes above 44° and above 2 800 m elevation at the equator is severely limited by frost and low temperatures. Frosts is particularly damaging to seedlings and sprouts of 1-2 years, but larger plants are moderately resistant to light frosts. Temperatures of −6 and −7°C have been reported as the limit of its cold resistance; Lacaze (1963) gives −8°C.

Although there are indeed inferior forms of subsp. *globulus* (Pryor, 1965), provenances have not been thoroughly tested because most countries were fortunate in having propagated a good form initially. Good-quality seed can be obtained from almost any of the well-established larger plantations in many parts of the world. There is, however, a strong case for more trials to compare seed sources within the whole *E. globulus* complex, including subsp. *maidenii*, subsp. *bicostata* and subsp. *pseudoglobulus*, and seed collections for this purpose have been made (Orme, 1977).

Subsp. *globulus* hybridizes with a number of other related eucalypt species. Few of its hybrids have had any economic importance, but Portugal has reported marked hybrid vigour from a cross with *E. robusta*. Two cultivar varieties are recognized: *E. globulus* var. *compacta* and *E. globulus* var. *coronifera*.

A wide range of growth and yield figures have been reported for subsp. *globulus*, but most give no indication whether inside or outside bark diameters were used, what minimum diameter or merchantable tops were, or the age of the stand. In La Coruña in northwestern Spain, one fertilized plot is reported to produce 70 m³/ha/yr, whereas increments of 30 m³/ha/yr are frequent and 20 m³/ha/yr are average. In Portugal growth varies from 4 to 40 m³/ha/yr, and in favourable, but not exceptional, conditions in Uruguay 25 m³/ha/yr are attained. With scientific management on favourable sites in Ethiopia, 35 m³/ha/yr at age 10 are expected, but under present management the best growth is 20 m³/ha/yr and the average is 10 m³/ha/yr. The Peruvian average is also 10 m³/ha/yr. In Huelva in southwestern Spain, production varies from 4 to 20 m³/ha/yr, depending on the site and management regime; on non-terraced, non-subsoiled sites growth does not surpass 5-6 m³/ha/yr. The most reliable yield tables available are from Santander, northern Spain, and from north of the Tagus river in Portugal. These are reproduced in Appendix 3. At age 10 on site quality I, the mean annual increment of merchantable wood (under bark) is 23 m³/ha/yr in Santander and 20 m³/ha/yr in Portugal. On site quality II it drops to 19 m³/ha/yr and 12 m³/ha/yr respectively.

In India the following MAIS are reported for three site quality classes at age 10 for total stacked volume overbark. The equivalent solid volumes, with an assumed conversion factor of 0.625, are shown in parentheses.

SQ 1	52.6 m³/ha stacked	(32.9 m³/ha solid)
SQ 2	38.3 m³/ha stacked	(23.9 m³/ha solid)
SQ 3	24.1 m³/ha stacked	(15.1 m³/ha solid)

The rotations used depend principally on the site and the desired end product. Most subsp. *globulus*, including the large stands in Portugal and Spain, is grown on rather short rotations of 8-12 or 10-15 years to produce a product of pulpwood, fuelwood, post or pitprop size. In California rotations of 7-10 years are used for chips. Ethiopia uses fuelwood rotations of generally 5-7 years. An 8-year rotation is preferred in Peru for pitprops and fuelwood. Coppicing is vigorous, and usually at least three, and occasionally more, coppice harvests are obtained. The first and second coppice stands are more productive than the seedling stand but growth falls off rapidly beginning with the third coppice.

Undesirable shoots are cut back during the first two years after sprouting. In India four rotations of 15 years each are used before replacing the stools. A fall in yield of about 9 percent has been recorded in the third rotation (i.e., second coppice rotation) and of about 20 percent in the fourth rotation (third coppice rotation). Thinning is rarely practised anywhere, although for larger products, Uruguay recommends removal of 70 percent of the stems in two cuts at ages 5-7 and 10-11, leaving 500 trees/ha for the final harvest at age 16. In Portugal, after the second or third harvest 100-150 of the straightest and best developed trees per hectare are left to produce sawtimber. Sawtimber rotations in Chile are 30 years and more.

Subsp. *globulus* is attacked by a number of diseases and insect pests. In Spain, *Penicillium* sp. and *Fusarium* sp. are important seed diseases, with the latter highly destructive to stored seed. Damping-off, seedling blights (e.g., *Botrytis cinerea*) and other nursery diseases have been problematic in many countries, but fortunately these can largely be controlled by proper phytosanitary techniques. Although most plantations have been remarkably free of serious disease, in Pontevedra (northwestern Spain) an unknown fungus thought to be of the genus *Stereum* is present on 20-year-old stock and causes severe damage to coppice regeneration. *Alternaria* attacks are also frequent in Pontevedra, but the damage done is very slight. Other diseases including *Diplodia* cankers and *Armillariella* root disease have been detected in plantations in various countries, but they are generally of lesser importance. In India subsp. *globulus* is susceptible to the "pink disease" fungus *Corticium salmonicolor*.

A number of insect pests are known to damage subsp. *globulus* plantations. In Africa the most serious is a defoliator, the *Eucalyptus* snout beetle, *Gonipterus scutellatus*, which was imported from Australia and has been found damaging in Kenya, Zimbabwe, South Africa and Uganda. Biological control through a Mymarid egg parasite has often been highly successful. The beetle has not been reported in Ethiopia. A relative from Queensland, however, *G. gibberus*, is found on subsp. *globulus* in Uruguay.

In Spain and Portugal, the principal pest is *Ctenarytaina eucalypti* (syn. *Rhinocola eucalypti*) which was introduced from Tasmania. The nymphs feed on the sap of leaves in both plantations and nurseries. Severe damage occurred in Portugal in 1971. The larvae of *Melolontha* sp. also attack the roots in Portugal, especially on previously vegetated sandy soils.

Subsp. *globulus* is also subject to infestation from the *Eucalyptus* longhorn beetle, *Phoracantha semipunctata*. It is reported in *E. globulus* plantations in Chile, coastal Peru, Uruguay and South Africa.

Insect attacks have been extraordinarily fierce on subsp. *globulus* in New Zealand. Although once a major component of woodlots and shelterbelts, serious attacks by *Eriococcus coriaceus* in the early 1900s killed mature trees over a wide area.

Later attacks by *Paropsis obsoleta, Gonipterus scutellatus, Ctenarytaina eucalypti* and *Rhicnopeltella eucalypti* led to its abandonment for planting. Most trees are now stag-headed and unsightly and the area occupied by subsp. *globulus* has greatly diminished through mortality and felling without replacement.

Die-back of an unknown cause occurs in some Colombian plantations after six years, particularly in humid conditions where mean annual precipitation is 2 000 mm and mean annual temperature is 15°C. In Peru there have been isolated occurrences of gummosis in plantations, probably the result of physiological stresses due to drought, fire, frost or insect attack (Bazán de Segura, 1967).

Subsp. *globulus* has a number of uses. The tree is valuable for erosion control, amenity and roadside plantings, windbreaks and shelterbelts and other watershed and environmental purposes. The principal uses of the wood are for fuelwood, pulpwood, mine-timbers, posts, poles and piling. It is a good firewood with an oven-dry calorific value of about 19 900 kilojoules/kg, burns freely and leaves little ash, and carbonizes easily for good charcoal (FAO, 1959). It is still used for charcoal in many countries. In Spain and Portugal a good-quality pulp, mostly bleached, is made from either the sulphite, sulphate or bisulphite processes. Other important wood products are fibreboard, particle board, parquet flooring, cooperage, low-grade veneer, furniture and various types of sawntimber. The timber is hard and strong but requires special care in sawing and drying because of growth stresses and a high incidence of spiral grain. The wood is difficult to nail. The leaves are also valuable for the extraction of essential oils, and in Portugal honey farms thrive near many plantations. In the Nilgiris in India a cottage industry has been based on the distillation of essential oils for the pharmaceutical trade. A yield of 2 750 kg of leaves per ha is expected; the oil content is 1 percent of the air-dry weight of the leaves and the oil normally contains 62 percent cineole.

E. globulus Labill. subsp. maidenii (F. Muell.) Kirkp. (previously planted as E. maidenii)

Refs. Blakely No. 261 Code SPIFI FTA p. 132

Common name in Australia. Maiden's gum

Regions of natural occurrence. Seaward slopes of Great Dividing Range in southern New South Wales and northeastern Victoria, occurring in high-quality closed forests on sheltered slopes and gullies on good soils.

Latitudinal range. 34°-39°S

Altitudinal range. 230-915 m

Rainfall

Type: winter to uniform rainfall
Total: 750-1 500 mm
Dry season: 3 months, not severe

Temperature

Mean maximum of hottest month: 21-25°C
Mean minimum of coldest month: 5°C
Frosts: 20-120

Characteristics

Tree height in Australia: 60-70 m; a very good bole and a fairly heavy crown
Bark type: smooth, decorticating in strips, sometimes a short stocking of old bark at the base
Juvenile leaves: opposite, sessile, sometimes amplexicaul, oblong-ovate, glaucous, stem markedly square
Adult leaves: alternate, stalked, lanceolate
Wood: hard, interlocked grain, moderately strong and durable
Buds and fruits: Figure a7-41 (261)
Viable seeds per gram: 110

Uses. A useful wood for light and heavy construction; similar to subsp. *globulus*

Prospects for planting. A good planting species of the group containing subsp. *globulus,* subsp. *bicostata* and *E. nitens.* There is not much left in Australia. Pure seed supplies might be obtained from the Mt Meru district in Tanzania, where there are very fine stands.

Success outside Australia. Classed with the best eucalypts in Italy and the Iberian peninsula. In Africa it is successful in Burundi, Tanzania, Kenya and South Africa. Fair in Brazil. Excellent in Hawaii in 2 500-mm rainfall and at 700-m elevation. Probably better than Subsp. *globulus* in regions tending to uniform and summer rainfalls, and in colder and drier climates.

E. gomphocephala DC.

Refs. Blakely No. 98 Code SICAA FTA p. 76

Common name in Australia. Tuart

Regions of natural occurrence. Sand plains near the coast in far southwest Western Australia

Latitudinal range. 31.5°-34°S

Altitudinal range. 0-30 m

Rainfall

Type: winter rainfall
Total: 750-1 000 mm
Dry season: 4-5 months, not severe

Temperature

Mean maximum of hottest month: 25-29°C
Mean minimum of coldest month: 4-7°C
Frosts: 1-15

Characteristics

Tree height in Australia: 25-35 m, with a shortish trunk and a heavy crown
Bark type: persistent throughout, light grey, subfibrous and lightly fissured
Juvenile leaves: alternate, at first narrowly lanceolate, later broadly lanceolate to ovate-deltoid, on long stalks
Adult leaves: alternate, stalked, narrow-lanceolate, frequently curved
Wood: yellowish, close-textured with interlocked grain; very hard, tough and durable
Buds and fruits: Figure a7-42 (98)
Viable seeds per gram: 66

Uses. Because of short supply, use in Australia is mainly restricted to railway carriage constuction; a feature is lack of corrosive effect on metal objects such as bolts or spikes; wood not liable to collapse. Wood is rich in tannin (7 percent).

Prospects for planting. A popular introduction in many countries on sands or sandy loams with a high percentage of lime or with a limestone parent material

Success outside Australia. Introduced into a number of countries at the end of the nineteenth or early in the twentieth century, e.g., South Africa 1898, Morocco 1920, Israel 1910, Malta 1925. The largest plantation areas are in North Africa. Morocco had 65 789 ha by the end of 1974 and there are large areas in Libya and Tunisia. Other Mediterranean countries have smaller areas, e.g., Israel 1 500 ha, Cyprus nearly 1 000 ha. Promising results have been obtained in trials or pilot plantations in Ethiopia, Greece, Italy, Turkey and Uruguay.

The species has proved outstanding for planting in winter-rainfall conditions on calcareous soils on which some other species such as *E. camaldulensis* become chlorotic. It has shown considerable plasticity in acclimatization to drier conditions than occur within its natural range, but should not be planted in situations which are too cold (absolute minimum less than −4°C) or which suffer from extreme aridity (rainfall less than 300 mm). Its tolerance of dry soils is due to its rooting system which combines a deep taproot (to depth of 3 m if the water table is that deep) and extensive surface rooting up to a radius of 8-12 m. The taproot absorbs moisture from the deeper soil layers during the dry season, while the surface roots make possible an immediate use of the first rains in winter. The species is wind-firm and hence suitable for planting as a windbreak. It is easy to raise in the nursery and regenerates readily from coppice, but it is frequently crooked or forked, especially during the first (seedling) rotation. Careful selection of seed stands of better than average form could do much to improve subsequent generations (Pryor, 1964).

In North Africa it has given good results in the semi-arid (350-600 mm) and subhumid (600-900 mm) zones, at altitudes between 0 and 350 m. It has also shown promise in Turkey in a rainfall of 1 035 mm and at higher elevation in Ethiopia (rainfall 855 mm, altitude 2 070 m). An average figure for mean maximum temperature of the hottest month is around 33°C and for mean minimum of the coldest month around 6°C. It will not tolerate temperatures lower than −4°C.

It will grow well on deep, free-draining sands, both calcareous and non-calcareous, as well as on more fertile loams. It will tolerate up to 25 percent of active calcium. However, there are limits to its tolerance of calcium. In Israel severe chlorosis was recorded on rendzina soils derived from Lower Eocene containing more than 70 percent calcium carbonate, with a pH of 7.7-7.8. It also tolerates slightly saline soils, but not waterlogging. Even on non-calcareous soils it will tolerate lower fertility than *E. camaldulensis.* It has been used successfully for the stabilization of sand dunes in a number of countries; in Libya it performs better on the inland dunes than on the most exposed coastal dunes, where *Tamarix* and *Acacia* spp. are more hardy to salt spray.

No differences in performance between different seed origins in Australia have been reported, a fact which may be accounted for by its restricted area of occurrence in Western Australia. Most Mediterranean countries now collect their own seed locally. Promising results have been obtained in Morocco from hybrids of *E. gomphocephala* with *E. cornuta* and *E. occidentalis.*

Initial spacing varies greatly from 2 × 2 m to 4 × 5 m. Where mechanical operations are to be done, 2 × 6 m is sometimes used. For sawlog production, rotations vary from 10 to 15 years; thinnings are carried out at 6, 9 and 11 years in Morocco. For unthinned coppice crops, for production of smallwood, rotations of 7-10 years are used. Yield varies greatly according to climate and soil. In Morocco yields between 21 and 44 m^3/ha/yr have been recorded on very fertile soils with irrigation for the first five years, but on more typical sites in the semi-arid zone yield is less than 7 m^3/ha/yr. In Israel a yield of 10.6 m^3/ha/yr at 15 years has been obtained on rendzina soils, while on sandy soils the yield at 12 years is less than 6 m^3/ha/yr.

The principal pest of *E. gomphocephala* is the borer *Phoracantha semipunctata* which does severe damage, especially where the trees are suffering from drought stress. In Cyprus moderate damage has resulted from gummosis. Young plantations are susceptible to fire.

Sawnwood is used for flooring blocks (Cyprus) and for boxwood, framing timber, etc. (Israel, Morocco). Smaller material is used for particle and fibreboard and for agricultural use as fenceposts and stakes. The species is also planted widely for environmental purposes, e.g., for stabilization of sand dunes, for windbreaks, for soil protection and as avenue and shade trees.

E. grandis Hill ex Maid.

Refs. Blakely No. 58 Code SECAB FTA p. 54

Common name in Australia. Flooded gum

Regions of natural occurrence. Northern New South Wales and southern Queensland coastal areas with two outlier occurrences in central and northern Queensland.

55. 15-year-old plantation of *E. grandis* in Pine Creek forest, New South Wales
Forestry Commission of New South Wales

Latitudinal range. Main occurrence: 26°-32°S
Central Queensland: 22°S
Northern Queensland: 17°S

Altitudinal range. Main occurrence: 0-300 m
Central Queensland: <300 m
Northern Queensland: 900 m

Rainfall

Type: summer rainfall
Total: 1 000-1 750 mm
Dry season: 3 months, rarely severe

Temperature

Mean maximum of hottest month: 29-32°C
Mean minimum of coldest month: 5-6°C
Frosts: several away from the coast

Characteristics

Tree height in Australia: 45-55 m; usually with an excellent trunk and a widespreading rather thin crown
Bark type: a light grey fibrous stocking for several metres; smooth above
Juvenile leaves: alternate, shortly stalked, oblong-lanceolate, slightly wavy
Adult leaves: alternate, stalked, lanceolate, slightly wavy with a long point
Wood: pink to light reddish brown
Buds and fruits: Figure a7-43 (58)
Viable seeds per gram: 632

Uses. The timber of flooded gum is lighter, softer and more fissile than that of most eucalypts. It is used extensively in Australia for house construction when the wood is cut from mature trees. Immature trees are sawn for fruitcases. The wood is likely to warp in seasoning, especially when sawn from fast-grown trees, but has a potential for peeler logs.

Prospects for planting. Already widely planted and plantations are being rapidly extended

• Relationship to *E. saligna.* There has always been some confusion between *E. grandis* and *E. saligna.* The reasons for the confusion are discussed here under *E. grandis* and a South African table showing the difference is also given (p. 425).

The name *E. saligna* was given to the type specimens of that tree in 1797. Trees that looked like *E. saligna* occurring up the New South Wales and Queensland coasts were known by that name until 1918, when Maiden revived the name *E. grandis* proposed by Walter Hill in *The catalogue of the timbers of Queensland* in 1862. There was thus a long period of 121 years when seed from trees looking like either of these species would have been sent out from Australia as *E. saligna.* It is understandable that confusion arose, as many introductions of this group of two closely related species were made into several countries in the 121 years between 1797 and 1918. It is now recognized that the two species are close but distinct. For example *E. saligna* has lignotubers, whereas *E. grandis* does not develop them. These organs were not understood or named for several years after 1918 when *E. grandis* was named. The organs were observed on seedlings of the complex in South Africa, and on the suspicion that they might be pathogenic cankers the seedlings were destroyed.

Both *E. grandis* and *E. saligna* are excellent and important species. *E. grandis* is more a species of the lower latitudes of Australia and *E. saligna* a species of higher latitudes. *E. grandis* is more a species of rich valleys and lowlands where its great early vigour permits it to overtop the undergrowth after a catastrophic fire. *E. saligna* does very well in valleys also but it may be found mixed with a wide range of good eucalypts up the coastal side of the Great Dividing Range, even to the altitude where it receives occasional falls of snow.

Both *E. saligna* and *E. grandis* are likely to hybridize with close relatives in the subgenus *Symphyomyrtus* which occur over the same latitudes and are in adjacent localities. *E. saligna* may cross with *E. botryoides* and *E. grandis* with *E. robusta* and *E. resinifera.* Both *E. grandis* and *E. saligna* have been grown in very successful industrial plantations in Brazil, South Africa and India. Pure old plantations of both species are lovely forests but quite distinct. It is of interest to list the differences and for this purpose the table in the "Handbook on eucalypt growing" published by the Wattle Research Institute in Pietermaritzburg, South Africa, is reproduced thanks to the courtesy of the Director of the Institute.

- Differences between *E. grandis* and *E. saligna*

The so-called "Saligna gum" complex which forms the largest proportion of eucalypt plantations in the wattle-growing areas of the republic is predominantly composed of *E. grandis*, and the main differences between this species and *E. saligna* are as follows:

	E. grandis	*E. saligna*
Bark:	Smooth, white/silvery, sometimes greenish. Rough on lower stem, often extending higher than in *E. saligna.* Debarks more easily.	Smooth, bluish, sometimes greenish. Rough on lower stem.
Buds:	Larger than *E. saligna* with a bluish bloom.	Smaller than *E. grandis* with less bloom.
Main flowering season:	July to December (in South Africa)	January to April.
Fruits:	Usually with bluish bloom. Valves 4-6, predominantly 5, pale, with blunt tips turned inward like clutching fin-	No bloom. Valves predominantly 3-4, colour the same as fruit, tips straight or spreading and sharp-pointed,

	gers. Fruits clearly pear-shaped with very gradual taper to ill-defined stalk. Usually longer and coarser than *E. saligna.*	often broken off. Fruits egg-cupped to pear-shaped tapering suddenly to stalk. Usually smaller and more delicate than *E. grandis.*
Roots:	Without swellings (lignotubers) just below the soil surface.	Lignotuberous.
Branches:	Die off quickly under shade.	More persistent and live longer under shade.
Suitable sites:	Moist, warm, subtropical.	Moist, cool mountainous.

Timber qualities. *E. saligna* is denser than *E. grandis.* Radial density gradient occurs in both species from the core outward, but is more pronounced in *E. saligna.* Radial density gradient increases with age in both species and produces wild grain. *E. saligna* tends to develop wider splits per unit of log circumference in a given time than does *E. grandis.* Radial shrinkage is greater in *E. saligna* than in *E. grandis.* Mechanical properties of *E. saligna* have higher values than *E. grandis*, but corrugation in *E. saligna* during seasoning, together with higher density and higher shrinkage, makes *E. saligna* less suitable than *E. grandis* as a furniture timber.

An additional difference is that, whereas the sapwood of *E. saligna* is usually susceptible to attack by larvae of the powder post beetle (*Lyctus* spp.), that of *E. grandis* is not often attacked and then only lightly [Queensland Forest Service quoted in Marsh and Haigh (1963)].

Success outside Australia. Both for the extent to which it has been planted and for its excellent performance *E. grandis* is one of the most important exotic eucalypts. Well over half a million hectares have been planted. The biggest area in one country is in South Africa, where it was introduced before 1885 and where by 1973 there were 275 000 hectares of plantation, 79 percent of all the eucalypts in the country. The species was introduced into a number of other countries during the last decade of the nineteenth and the first two decades of the twentieth centuries. There are substantial areas in Angola, Zimbabwe, East Africa, India (mainly in Kerala), Brazil, Argentina and Uruguay. If account is taken of the 0.6 million ha of *E. saligna* reported in Brazil, the *E. grandis/saligna* complex is unquestionably the most widely planted eucalypt in the world. A number of countries report a tendency to change from planting *E. saligna* to *E. grandis* (*sensu stricto*).

When it is planted on suitable sites, there is probably no other eucalypt to compare with *E. grandis.* It combines very rapid height growth (2-3 m a year over the first 10 years) with a tall, columnar, naturally self-pruning stem. It forms a dense crown which will shade out weed competition at an early age. It flowers and seeds early, normally after 4 or 5 years. It coppices freely when young, although Zambia has reported that coppicing becomes more difficult at ages over 10 or 12 years. Its wood is acceptable for a wide range of purposes.

For best performance, *E. grandis* must be planted on suitable sites. It does best in a humid subtropical or warm temperate climate, with the greater part of the rain falling in the summer, but has been planted successfully in areas showing a considerable range in the severity of the dry season. Although the minimum rainfall is affected by other factors, such as evapotranspiration and soil type, most countries specify a minimum of 800 mm, and for best growth over 1 000 mm are preferable. In tropical climates with a high rainfall and uniformly high temperatures throughout the year it tends to get diseased as in Suriname (Boerboom and Maas, 1970), and in Kerala at low elevations (Sujan Singh and Pratap Singh, 1975). In Kerala it remains healthy and grows excellently at altitudes between 800 and 2 000 m; rainfall is over 2 500 mm but mean monthly temperatures drop from 29°C in the summer to 13°C in the winter (Pillai, 1966).

E. grandis will not withstand severe frost and the altitude at which it may safely be planted depends largely on this factor. In Kenya on the equator it does best in the highlands above 1 800 m. At higher latitudes it needs to be planted at a correspondingly lower altitude.

The tables which follow give data for rainfall and temperature at a number of representative stations. Numbers 1-3 are within the natural range in Australia; 4-12 are from stations in the vicinity of plantation areas in Africa; 13-16 are in South America and 17 is in India.

A few stations have been included which are *not* suitable for good growth of *E. grandis*. Thus, number 6 — Ermolo — is too cold, as well as marginally too dry. Mortality or die-back from frost is liable to occur. Number 8 — Choma — is too dry. There are seven successive months with less than 30 mm rainfall. Numbers 16 and 17 — Nieuw Nickerie and Alleppey — may give excellent initial growth, but there is a severe risk of epidemic fungal pathogens. Temperatures are high throughout the year (mean temperature of coolest month 26°C), combined with a high rainfall.

The remaining stations are representative of conditions where *E. grandis* grows well. It may be noted that some stations have rainfall well distributed throughout the year (Nos. 12-14), but mean temperatures of the coldest month are considerably lower than at Nos. 16 and 17, i.e., 20°C at Entebbe, 12°C at Paysandú and 16°C at Posadas. Other stations have a more or less pronounced dry season which coincides with the cool season or "winter" (June-August in the southern hemisphere). The most northern Australian provenance at Atherton has a much more pronounced dry season than those further south and for this reason may be worth further trial in areas with 3-6 successive months of less than 30 mm rainfall (e.g., Nairobi, Nova Lisboa, Ndola).

E. grandis needs a deep free-draining soil, and does best on fertile loam or clay-loam soils, but will also perform well on the lighter sandy soils, provided these are of adequate depth. On fertile soils a depth of 1 m may be sufficient but on the less fertile sandy soils in Zambia a depth of 2 m is considered desirable. In Uruguay excellent growth has been obtained on deep sandy soils near the River Uruguay where soil/moisture relations are excellent.

Provenance trials have been carried out in a number of countries. In Australia it was found that local provenances grew better in the Coff's Harbour area than provenances from either Atherton, the most northern occurrence, or from Minmi, the extreme southern point in the range. They were also better than land races from Uganda and Zululand. In Zambia there was little difference between the various provenances tried. In Zimbabwe it was found that provenances within the range 28°-32°S and below an elevation of 183 m were the most successful. In Brazil the Atherton provenance appears to be more resistant to attacks by the fungus *Diaporthe* in hot wet climates than other provenances. Other provenance trials are in progress in Argentina and Uruguay, and in the latter country genotypes selected in South Africa for frost resistance have also proved most frost resistant in Uruguay.

Clonal seed orchards of *E. grandis* have been established in South Africa and Zambia and a seedling seed orchard at Coff's Harbour in Australia (Eldridge, 1975a). In South Africa the main selection criteria are bole straightness, freedom from splitting, fast growth and acceptable crown features (van Wyk, 1978). Initially the number of clones in clonal orchards was small, but was subsequently increased to enlarge the gene pool. In South Africa recently planted progeny tests will be converted later to seedling seed orchards. Seed yields as high as 1 kg per ramet at 10 years have been obtained, but germination percentage is lower than that of commercial plantations. This may be due to an increased degree of selfing. In one test selfing varied from 10 percent to 33 percent under seed orchard conditions during the main flowering season; selfing results in decreased seed yield (20 percent of outcrossing) and a reduction of 8-49 percent in growth rate of surviving seedlings, as well as an increase in the number of abnormal seedlings (Hodgson, 1976b; Eldridge, 1977; van Wyk, 1977). Several different methods for increasing the yield and ease of collection in *E. grandis* seed orchards have been described (Hodgson, 1977).

Graft incompatibility problems in *E. grandis* have been experienced in several countries. The use of cuttings is one method of overcoming these. Selections can be made from trees already of substantial stature at 4 or 5 years of age, by felling outer lines in plantations and selecting the best trees in these lines. Coppice shoots from the stumps will strike quite readily under standard mist spray from most trees, giving at least 50 percent success in Australia if taken during spring or early summer (Pryor, 1977). Good results have been obtained by this method in Brazil (Campinhos and Ikemori, 1978).

As mentioned above, some hybridization between *E. grandis* and *E. saligna* probably takes place from time to time. Another hybrid which has occurred both naturally and artificially in countries such as Zambia, Uganda and Zimbabwe is that between *E. grandis* and *E. tereticornis*. In Zambia it has been found that the growth of the hybrid is better than that of either parent and the form is as good as *E. grandis*. Drought resistance is better than that of *E. grandis*, but not so good as that of *E. tereticornis*. Wood properties are intermediate between the two parents.

Like all eucalypts, young trees of *E. grandis* in the first year or two after planting are extremely susceptible to attack by termites, where these occur. Effective protection can be ensured by the use of insecticide. In Zambia older trees have been attacked by the borers *Phoracantha semipunctata* and

P. recurva, but attacks by these insects seem to follow after severe drought stress during the dry season. They do not occur if *E. grandis* is planted where the dry season is not too severe. Another condition which appears to be related to drought stress is that of gummosis. In Angola the lepidopterous defoliator *Buzura abruptaria* has caused some damage, while in Australia the beetle *Anoplagnathus* has also caused defoliation.

In Suriname a serious disease, the fungus *Diaporthe cubensis*, has caused stem cankers and deaths in plantings of *E. grandis* and *E. saligna*. The fungus was identified as *Endothia havanensis* (Boerboom and Maas, 1970). In Brazil in the wetter areas *E. grandis* is classed as moderately susceptible to the fungus *Diaporthe cubensis*, which causes a canker disease. It is less susceptible than *E. saligna*, but more so than *E. urophylla*. In Kerala the fungus *Corticium salmonicolor* has caused severe losses in low altitude plantations with uniformly high temperatures and high rainfall, but plantations at high elevations on grassland sites are free from disease (Sujan Singh and Pratap Singh, 1975). In South Africa some heart rot is to be expected in trees grown on a sawlog rotation, while investigations in Zambia showed butt decay affected 0.2 percent of volume and stem decay 0.1 percent of volume in trees 6½ years old (Ivory, 1975). Several different fungi were associated with the decay. *E. cloeziana* at the same age was less susceptible than *E. grandis*.

In early years *E. grandis* is susceptible to the effect of strong winds and may develop basal lean in such conditions. In some countries it is also susceptible to boron die-back, but this can be readily corrected by the application of boron at planting.

One pest to which *E. grandis* is more resistant than many eucalypts is the snout beetle *Gonipterus scutellatus*. This is one strong reason for preferring *E. grandis* to, for example, *E. globulus* or *E. maidenii*, where the site conditions are otherwise suitable for all three species.

E. grandis has been used for a large number of purposes. It has been used for the manufacture of sulphate pulp, for example in Brazil, where 5 million steres were used for pulp in 1974, Uruguay, South Africa, Angola, etc. In Brazil large quantities are also used for charcoal for iron smelting. It has been much used for fuelwood, both for domestic purposes and for the curing of tobacco. In addition, it has been used for fenceposts, building, transmission and telephone poles, mining timber, box shooks, panel boards, etc. It can also be used for sawtimber, but it has a strong tendency to split, so that conversion losses are high. These can be reduced by suitable techniques, such as the use of frame-saws. In addition to its useful wood, it also makes a good honey and is being used in a number of countries, e.g., Uruguay, for shelterbelts, windbreaks and amenity planting.

The specific gravity of plantation-grown *E. grandis* wood varies generally between 0.40 and 0.55, with a tendency for both specific gravity and fibre length to increase with distance from the pith. In Zambia it has been found that preservation by means of creosote has not been entirely effective, since penetration does not occur to any extent in the heartwood, which is susceptible to termite attack.

Table 14.6 *E. grandis* climatic stations: location and temperature

Station	Lat.	Long.	Alt. (m)	Frost days	Temperature (°C)					
					Hottest			Coolest		
					Month	Mean temp.	Mean max.	Month	Mean temp.	Mean min.
1. Taree (Australia)	31°55′S	152°27′E	9		Jan.	23		July	12	
2. Grafton (Australia)	29°43′S	152°56′E	6		Jan.	26		July	14	
3. Atherton (Australia)	17°17′S	145°27′E	752		Dec.	24		July	16	
4. Empangeni (S. Africa)	28°46′S	31°55′E	64		Feb.	25	30	July	17	10
5. Piet Retief (S. Africa)	27°00′S	30°38′E	1 260		Jan.	19	27	July	12	4
6. Ermelo (S. Africa)	26°31′S	29°59′E	1 698		Jan.	19	26	July	8	—1
7. Chipinga (Zimbabwe)	20°12′S	32°38′E	1 126		Jan.	21		July	15	
8. Choma (Zambia)	16°51′S	27°04′E	1 267		Oct.	22	31	July	12	3
9. Ndola (Zambia)	13°00′S	28°39′E	1 270		Oct.	22	34	July	16	6
10. Nova Lisboa (Angola)	12°48′S	15°45′E	1 700		Sept.	21	29	Jn/Jul	15	8
11. Nairobi (Kenya)	1°18′S	36°45′E	1 798		Feb.	19	26	July	15	9
12. Entebbe (Uganda)	0°03′N	32°27′E	1 146		Feb.	22	27	Aug.	20	16
13. Paysandú (Uruguay)	32°20′S	58°05′W	52	27	Jan.	26	32	July	12	6
14. Posadas (Argentina)	27°23′S	55°54′W	111	1.3	Jan.	26	34	July	16	11
15. Piracicaba (Brazil)	22°43′S	47°38′W	556		Jan.	23		July	17	
16. Nieuw Nickerie (Suriname)	5°57′N	56°57′W	2		Sept.	28		Jan.	26	
17. Alleppey (Kerala, India)	9°33′N	76°25′E	4		April	29		July	26	

Table 14.6 *E. grandis* climatic stations: rainfall *(concluded)*

Station	J	F	M	A	M	Jn	Jl	A	S	O	N	D	Total
	millimetres												
1. Taree (Australia)	128	119	124	152	109	89	99	51	85	71	77	101	1 205
2. Grafton (Australia)	116	106	94	80	70	62	52	24	46	57	84	89	880
3. Atherton (Australia)	284	305	241	109	60	42	30	20	20	24	70	167	1 372
4. Empangeni (S. Africa)	113	124	159	74	68	59	46	42	60	74	117	120	1 056
5. Piet Retief (S. Africa)	153	122	107	50	22	11	13	15	43	95	131	157	919
6. Ermelo (S. Africa)	127	94	89	33	15	5	8	10	28	89	130	122	750
7. Chipinga (Zimbabwe)	216	211	152	54	20	25	23	21	19	37	129	171	1 078
8. Choma (Zambia)	200	185	86	23	6	6	0	0	1	22	93	209	831
9. Ndola (Zambia)	307	245	183	39	3	1	0	1	2	20	131	280	1 212
10. Nova Lisboa (Angola)	209	179	231	144	16	0	0	1	19	124	231	233	1 386
11. Nairobi (Kenya)	88	70	96	155	189	29	17	20	34	64	189	115	1 066
12. Entebbe (Uganda)	100	86	141	280	257	98	65	91	87	108	146	126	1 585
13. Paysandú (Uruguay)	127	111	146	116	78	87	54	77	94	112	92	93	1 587
14. Posadas (Argentina)	142	176	177	176	206	143	93	69	126	147	124	138	1 717
15. Piracicaba (Brazil)	226	298	103	48	60	40	22	22	75	67	157	248	1 366
16. Nieuw Nickerie (Suriname)	190	114	111	191	247	316	266	168	61	62	79	176	1 981
17. Alleppey (Kerala, India)	42	52	66	139	314	686	513	381	268	309	265	63	3.098

For pulpwood, fuelwood and wood for mining a 6- to 10-year rotation is common. In most countries no thinning is done on these short rotations. In Zambia, for industrial plantations, an 8-year rotation is used and thinning is done at age 2 and age 5. On the other hand, in the same country a 4-year rotation without thinning is used for production of small wood for domestic purposes. In Uganda, with initial spacings of 2.4 × 2.4 to 3.0 × 3.0 m a 7- to 8-year rotation is sufficient to produce trees of 15- to 20-cm breast height diameter, the preferred size for fuelwood for tobacco curing. In India a 9-year rotation is used with initial spacing of 3 × 3 or 3.5 × 3.5 m.

For most types of produce one seedling rotation, followed by at least two coppice rotations, is common practice.

In Brazil it is expected that, after the use of improved seed becomes common, the present 1 plus 2 rotations will be extended to 1 plus 4 rotations.

In South Africa a rotation of 30 years is recommended when the purpose is production of sawlogs. Thinnings at ages 7, 11 and 15 are recommended, leaving a final stocking of 250 stems per hectare.

In a number of cases a significant increase in growth rate has been obtained by the use of fertilizers. In Zambia the use of boron is essential in order to reduce die-back and improve growth rate. Addition of NPK has had no direct effect on growth rate in that country, but may have an indirect effect through its influence on the uptake of boron. In Australia in the Coff's Harbour area it was found that addition of N and P together more than doubled height growth at the age of 1 year. Either alone had much less effect. In South Africa it was found that N was not required on land which had been previously used to grow *Acacia mearnsii* (a nitrogen-fixing species), but the addition of P on these sites had a significant effect. On other sites, where *Acacia* had not been grown before, N and P in combination had a significant effect on growth and it was shown that the effect was economically profitable on an 8-year rotation (Schönau and Pennefather, 1975; Schönau, 1977). In Brazil increasing use is being made of fertilizers, especially on the poorer Cerrados sites. P is the most important element in these conditions. In Zambia an experiment showed that the use of fertilizers did not make any significant difference to the wood quality of the crops grown at age 5.

E. grandis has been shown to respond well to irrigation. In Zimbabwe irrigated crops produced a mean annual increment of 40 m^3 per hectare per annum when irrigated in a dry area receiving only 600 mm of rainfall. Volume tables have been constructed for *E. grandis* in South Africa, India and Uganda. Although the formulae used differ, the figures in the tables are comparable for most size classes.

The yield of *E. grandis* varies considerably according to climate and soil. Yields quoted are not always given in identical terms, nor is it always clear whether volumes quoted are overbark or underbark, up to what top diameter they refer and whether they refer to true volume or stacked volume. Bark percent varies according to the size of the tree. For a tree of 40 cm DBHOB and 35 m height, both the Indian and Ugandan volume tables indicate that bark accounts for about 13 percent of overbark volume. On small trees the percentage may be as much as 17-20 percent.

Yield has been studied over several rotations at Muguga in Kenya. The results confirm that coppice rotations normally yield appreciably more than the first seedling rotation. At Muguga the mean annual increment was 30 m^3 (stacked) and 46 m^3 (stacked) respectively for the seedling and coppice rotation. Assuming a conversion factor of 0.7, this would correspond to a solid volume MAI of 21 m^3/ha/yr for seedling and 32 m^3/ha/yr for coppice to produce the preferred mid-diameter of 10 cm. *E. grandis* from Queensland gave a higher yield than *E. saligna* from New South Wales, while Kenya "*saligna*" was intermediate. In Uganda a MAI of 14-25 m^3 is quoted for good savanna sites, and 17-45 m^3 for high forest sites (Kriek, 1970). In South Africa a figure of 25-35 m^3 is quoted and in Zimbabwe a range from 7 to 30 m^3 on rainfed sites. In Angola 28 steres (20 m^3 true volume) are quoted for good sites (Petroff, 1968). In Zambia a MAI of 28 m^3 is expected on Copperbelt sites. In Argentina on the red soils in Misiones province a yield of 50 m^3 per hectare per year has been obtained at 14 years. In New South Wales a yield of 22 m^3 is expected.

Yield tables are available for South Africa, Zambia and Uganda. Monographs which deal predominantly or exclusively with *E. grandis* are Barrett, Carter and Seward, 1975; Wattle Research Institute, 1972; and Pillai, 1976.

E. gummifera (Sol. ex Gaertn.) Hochr. (syn. E. corymbosa Sm.)

Refs. Blakely No. 45 Code CAFUF FTA p. 36

Common name in Australia. Bloodwood

Regions of natural occurrence. Queensland coast south of Fraser Island, all along the New South Wales coast with a slight extension into the northeast Victorian coast, growing on a wide variety of sites near the sea

Latitudinal range. 26°-37.5°S

Altitudinal range. Up to 300 metres in the south and 500 metres in the north

Rainfall

Type: uniform to summer rainfall
Total: 750-2 000 mm
Dry season: 3 months, rarely severe

Temperature

Mean maximum of hottest month: 29-30°C
Mean minimum of coldest month: 5°C
Frosts: 0-15

Characteristics

Tree height in Australia: 30-35 m; usually with a fairly good trunk and a heavy crown
Bark type: bloodwood type
Juvenile leaves: opposite then alternate, stalked, peltate, surface bristly
Adult leaves: alternate, stalked, lanceolate, venation at a high angle to the midrib and veins close together
Wood: pink to deep red, heavy, strong and durable; frequent gum pockets and rings are a defect
Buds and fruits: Figure a7-44 (45)
Viable seeds per gram (France): 84

Uses. Useful shade tree; used in the round or hewn; gum veins have prevented extensive use

Prospects for planting. Limited because of gum veins

Success outside Australia. Grows well in South Africa and Brazil but the defects prevent it being planted extensively

E. gunnii Hook. f.

Refs. Blakely No. 239 Code SPINI FTA p. 124

Common name in Australia. Cider gum

Regions of natural occurrence. Central Tasmania, growing on the plateaus and upper slopes of the central massif on the better-drained sites of alpine humus soils or on rocky soils

Latitudinal range. 41°-43.75°S

Altitudinal range. 600-1 200 m

Rainfall

Type: winter rainfall
Total: 750-1 500 mm
Dry season: 3 months, not severe

Temperature

Mean maximum of hottest month: 15-18°C
Mean minimum of coldest month: 0°C or less
Frosts: 100-150, with frequent snow

Characteristics

Tree height in Australia: 20-25 m; with a short trunk and heavy crown
Bark type: persistent at base of old trees, smooth greenish to whitish above
Juvenile leaves: opposite for several pairs, sessile or shortly stalked, cordate to orbicular; glaucous
Adult leaves: alternate, stalked, ovate to broadly lanceolate
Wood: little known
Buds and fruits: Figure a7-45 (239)
Viable seeds per gram: 212

Uses. An attractive ornamental, very frost resistant

Prospects for planting. Limited as an ornamental

Success outside Australia. Very good in the South Island of New Zealand, also in Sheffield Park, Sussex, and other places in England; poor in Brazil. The trees growing as windbreaks north of Invercargill (latitude 46.5°S) in the South Island of New Zealand are more than 30 m high and much bigger than any trees of the species in Australia.

E. intertexta R.T. Bak.

Refs. Blakely No. 291 Code SUH:A FTS No. 37

Common name in Australia. Gum-barked coolibah

Regions of natural occurrence. Widespread in inland Australia in the arid zones of New South Wales, Queensland, South Australia, Western Australia and the Northern Territory, growing on plains and small rises in association with other dry-country trees in a very open woodland

Latitudinal range. 22°-32°S

Altitudinal range. 60-760 m

Rainfall

Type: rainfall of the arid-zone type
Total: 150-400 mm
Dry season: 8 months, severe

Temperature

Mean maximum of hottest month: 32-38°C — parts of its zone of natural occurrence have an evaporation rate from a free water surface of more than 3 800 mm annually
Mean minimum of coldest month: 8-12°C
Frosts: 10-15

Characteristics

Tree height in Australia: up to 25 m as a fair tree; there is also a mallee form
Bark type: lower trunk has a rough box bark; upper part smooth
Juvenile leaves: sub-opposite, becoming alternate, stalked, very broadly ovate
Adult leaves: varies from oblong-lanceolate to ovate over the wide range
Wood: red, hard, heavy, interlocked
Buds and fruits: Figure a7-46 (291)
Viable seeds per gram: 143

Uses. A good tree in a very difficult climate

Prospects for planting. The very widespread occurrence and great variability would make careful provenance testing necessary before any recommendations could be made but it is one of the better trees in one of the most difficult parts of Australia

Success outside Australia. Failed in Brazil

Refs. Blakely No. 56 Code MAF:A FTA p. 48

E. jacksonii Maid.

Common name in Australia. Red tingle

Regions of natural occurrence. Far southwest Western Australia along the lower reaches of the Deep, Frankland and Bow rivers, on good soils

Latitudinal range. 34.5°-35°S

Altitudinal range. Up to 100 m

Rainfall

Type: winter rainfall
Total: 1 250-1 500 mm
Dry season: 3 months, not severe

Temperature

Mean maximum of hottest month: 21-24°C
Mean minimum of coldest month: 7-10°C
Frosts: absent to few very light frosts

Characteristics

Tree height in Australia: up to 70 m in height and 20 m girth over buttresses; a magnificent tree
Bark type: stringy-bark type
Juvenile leaves: opposite then alternate, ovoid or broadly elliptical with wavy margins
Adult leaves: alternate, shortly stalked, lanceolate, tapering to a point and slightly oblique
Wood: deep pink to reddish brown, strong, tough, durable, straight grain, density 720 kg/m^3
Buds and fruits: Figure a7-47 (56)
Viable seeds per gram (France): 164

Uses. One of the best woods in Western Australia but not used much because of location. A very good forest species to handle.

Prospects for planting. Very limited because there are few places in the world as mild and yet moist and without frosts as the *E. jacksonii* country

Success outside Australia. Grows well on Matakana Island off the north coast of New Zealand. Failed in Brazil. It grew fairly well in trials in South Africa.

E. laevopinea R.T. Bak.

Refs. Blakely No. 327 Code MAHAB FTA p. 166

Common name in Australia. Silvertop stringybark

Regions of natural occurrence. New England tableland, New South Wales, showing best growth on basaltic soils and good growth on well-drained soils derived from granites

Latitudinal range. 29°-33°S

Altitudinal range. 800-1 300 m

Rainfall

Type: summer rainfall
Total: 750-1 250 mm
Dry season: up to 4 months, not severe

Temperature

Mean maximum of hottest month: 24-29°C
Mean minimum of coldest month: 0°C
Frosts: 40-70; moderately heavy snowfalls on the higher occurrences

Characteristics

Tree height in Australia: up to 40 m; a good straight bole and a good crown
Bark type: stringybark to branches about 8-cm diameter
Juvenile leaves: opposite then sub-opposite to alternate, stalked, broadly lanceolate, crenulate and sometimes subdenticulate margins
Adult leaves: alternate, stalked, lanceolate tending to be falcate with a slightly oblique base
Wood: moderate weight and strength, light colour
Buds and fruits: Figure a7-48 (327)
Viable seeds per gram (France): 24

Uses. A useful construction timber

Prospects for planting. The New England tableland eucalypts are well worth further provenance trial evaluations

Success outside Australia. Did not do well in Brazil. South African trials were very promising.

E. largiflorens F. Muell. (syn. E. bicolor A. Cumm. ex Hook.)

Refs. Blakely No. 472 Code SUDEC FTA p. 228

Common name in Australia. Black box

Regions of natural occurrence. Most of western inland New South Wales, with extensions into Queensland, South Australia and Victoria

Latitudinal range. 28°-35°S

Altitudinal range. 30-300 m

Rainfall

Type: winter to uniform rainfall of the arid-zone type
Total: 250-400 mm
Dry season: 7 months, can be severe

Temperature

Mean maximum of hottest month: 38°C
Mean minimum of coldest month: 5°C
Frosts: 5

Characteristics

Tree height in Australia: 10-20 m; a short trunk with an open crown
Bark type: typical box, dark grey

Juvenile leaves: first opposite, then alternate, shortly stalked, lanceolate
Adult leaves: alternate, stalked, lanceolate
Wood: pink or reddish brown, heavy, hard and durable; density 1 000 kg/m^3
Buds and fruits: Figure a7-49 (472)
Viable seeds per gram: 722

Uses. Useful as fuel, house-blocks, farm purposes and amenity purposes in difficult, frequently inundated areas of the inland River Murray region

Prospects for planting. It is a hardy species with a wide range. Provenance testing could be interesting if trees are wanted in difficult regions of its type.

Success outside Australia. None known

E. lehmannii (Schau.) Benth.

Refs. Blakely No. 97 Code SICBE Chipp. p. 46

Common name in Australia. Bushy yate

Regions of natural occurrence. On rocky hills from near Albany, Western Australia, eastward to Cape Arid and also near Eucla.

Latitudinal range. 32°-36°S

Altitudinal range. 10-30 m

Rainfall

Type: winter rainfall
Total: 380-940 mm
Dry season: up to 8 months, can be severe

Temperature

Mean maximum of hottest month: 38°C
Mean minimum of coldest month: 4°C
Frosts: few to 11

Characteristics

Tree height in Australia: mallee or small tree up to 8 m
Bark type: smooth bark
Juvenile leaves: seedling leaves have sparse, star-shaped clusters of hairs on the surface and small teeth on the margin, later alternate, ovate or orbicular
Adult leaves: slightly flattened stalk, elliptical to lanceolate
Wood: yellow-brown, very hard
Buds and fruits: Figure a7-50 (97)
Viable seeds per gram (France): 88

Uses. Environmental and ornamental

Prospects for planting. As an ornamental because of the curious fruits and red flowers. It is tolerant of salt-affected soils and suitable for seaside planting.

Success outside Australia. Successfully grown as an ornamental in California. Tried in South Africa but the form was reported as poor.

E. leucoxylon F. Muell. var. leucoxylon

Refs. Blakely No. 542 Code SUX:CA FTA p. 260

Common name in Australia. Yellow gum

Regions of natural occurrence. South Australia, Victoria; there is a tree form and a mallee form

Latitudinal range. 32.5°-38.25°S

Altitudinal range. 160-600 m

Rainfall

Type: winter rainfall
Total: 400-900 mm
Dry season: up to 5 months

Temperature

Mean maximum of hottest month: 27-32°C
Mean minimum of coldest month: 3°C
Frosts: 5-15

Characteristics

Tree height in Australia: 20-30 m; the tree form has a good trunk half the height of the tree and a fairly good crown
Bark type: smooth, shedding in irregular oval sheets
Juvenile leaves: opposite for many pairs, shortly stalked or stalkless, broadly lanceolate to circular, subglaucous
Adult leaves: alternate, stalked, lanceolate
Wood: hard, pale brown, interlocked grain, density 770-1 200 kg/m³, durable
Buds and fruits: Figure a7-51 (542)
Viable seeds per gram: 239

Uses. Useful for poles, sleepers and hewn products

Prospects for planting. Limited; it is a good species but there are more vigorous species to recommend.

Success outside Australia. Fair in Argentina and Brazil, poor in South Africa

E. longifolia Link & Otto

Refs. Blakely No. 81 Code SECGA FTA p. 72

Common name in Australia. Woollybutt

Regions of natural occurrence. Southeast coast of New South Wales; scattered trees in good closed forest with such species as *E. elata*

Latitudinal range. 33°-37.5°S

Altitudinal range. Sea-level to 300 m

Rainfall

Type: winter to uniform rainfall
Total: 625-1 000 mm
Dry season: 3 months, not severe

Temperature

Mean maximum of hottest month: 22-28°C
Mean minimum of coldest month: 2-9°C
Frosts: nil to 20

Characteristics

Tree height in Australia: 30-35 m; commonly of good form with a heavily branched crown
Bark type: persistent to the large branches; subfibrous, ridged and cracked; smooth on small branches
Juvenile leaves: first opposite, then alternate, stalked, ovate, oblong or lanceolate
Adult leaves: alternate, stalked, narrow-lanceolate, usually curved
Wood: red-brown, moderately hard, strong and durable; density 1 010 kg/m^3
Buds and fruits: Figure a7-52 (81)
Viable seeds per gram (France): 129

Uses. An excellent general-purpose hardwood in Australia. Unfortunately there is not much of it.

Prospects for planting. Limited

Success outside Australia. Frequently reported as "moderate success". In Hawaii it grows well in mixture with *E. robusta* on a similar range of sites.

E. macarthurii Deane & Maid.

Refs. Blakely No. 273 Code SPIKC FTA p. 138

Common name in Australia. Camden woollybutt

Regions of natural occurrence. Restricted occurrence on tablelands near Sydney, New South Wales, including parts of the Blue Mountains. It is usually found as scattered individuals on flats and near streams in country of moderate relief. The better trees grow on fertile soils.

Latitudinal range. 33°-34.5°S

Altitudinal range. 300-900 m

Rainfall

Type: uniform rainfall
Total: 750-1 150 mm
Dry season: 4 months, rarely severe

Temperature

Mean maximum of hottest month: 26°C
Mean minimum of coldest month: 2-3°C
Frosts: 30-40

Characteristics

Tree height in Australia: 30-40 m; the bole is usually straight but heavily branched
Bark type: rough, somewhat box-like, persistent to smaller branches, deeply fissured at base of large trees; difficult to debark
Juvenile leaves: opposite, sessile, amplexicaul
Adult leaves: alternate, stalked, lanceolate
Wood: medium weight and strength, not durable, used on farms
Buds and fruits: Figure a7-53 (273)
Viable seeds per gram: 366

Uses. Excellent for shelterbelts and shade when "on site". Leaves have a high percentage of geranyl acetate and free geraniol (used in perfumery).

Prospects for planting. Good shelterbelt tree; vigorous; possible essential oil industry from leaves; coppices well but difficult to debark the wood

Success outside Australia. Moderate to good as shelterbelt tree in South Africa and Brazil; essential oil prospects good if skilled selection made for the best oil trees; not popular as a pulpwood coppice crop because of debarking problems

E. macrorhyncha F. Muell. ex Benth. subsp. macrorhyncha (previously spelt macrorrhyncha)

Refs. Blakely No. 331 Code MAHACA FTA p. 168

Common name in Australia. Red stringybark

Regions of natural occurrence. New South Wales and Victoria on the slopes on the inland side of the Great Dividing Range. Small occurrence in South Australia. The species does not usually form dense pure stands but may be the dominant species in an open dry sclerophyll woodland of mixed species. The strange isolated occurrence in South Australia is hundreds of kilometres from the main belt in the eastern States and is practically pure *E. macrorhyncha.*

Latitudinal range. 32°-38°S

Altitudinal range. 150-1 000 m

Rainfall

Type: winter to uniform rainfall
Total: 600-800 mm
Dry season: fairly long droughts occur periodically

Temperature

Mean maximum of hottest month: 26-32°C
Mean minimum of coldest month: 3-4°C
Frosts: 10-40

Characteristics

Tree height in Australia: 15-30 m; the shortish bole is usually straight and the large crown spreading
Bark type: stringybark
Juvenile leaves: opposite first then alternate, shortly stalked, broadly ovate
Adult leaves: alternate, stalked, lanceolate, bases slightly oblique
Wood: light pinkish brown; moderate strength and durability; easily split: density 830 kg/m^3
Buds and fruits: Figure a7-54 (331)
Viable seeds per gram: 100

Uses. A good tree for local use on farming and grazing land in Australia

Prospects for planting. Limited; there are better trees for plantations aimed at wood production; the leaves contain up to 11 percent rutin

Success outside Australia. Unenthusiastic reports because of slow growth. The South African trials showed fair growth and good stem form.

E. maculata Hook. f.

Refs. Blakely No. 54 Code CCC:B FTA p. 46

Common name in Australia. Spotted gum

Regions of natural occurrence. It occurs over a large area on the coast in Queensland, extending inland up to 380 km near its northernmost limit at 25°S; it occurs along most of the coast of New South Wales with occasional gaps in the southern third of the State; there is a small outlier occurrence in the Mottled Ranges of eastern Victoria

The northernmost occurrence in Queensland occasionally overlaps the most southeasterly occurrence of *E. citriodora.* The two species hybridize, both in Australia and in overseas plantings, but they are regarded as separate species, although with similar wood characteristics. Each has a wide latitudinal range, making the latitudinal range covered by the two species 17°-37°S. They were regarded as distinct species by the botanist Hooker, who named both of them; their rather different behaviour — and acceptance — outside Australia confirms that they should be treated as distinct species.

Over most of its range, *E. maculata* occurs on hilly country, in almost pure stands on the lower slopes of valleys and on ridges where the soil is fairly fertile and not too dry. It will grow on a wide range of moderately heavy soils but not poor sandy soils. The parent rocks of the soils are usually slates, shales and granites.

Latitudinal range. 25°-37°S

Altitudinal range. Up to 800 m

Table 14.7 Climatic data for *E. maculata*

	J	F	M	A	M	Jn	Jl	A	S	O	N	D	Total	Recorded extremes Highest	Lowest
Dalby, Queensland (Lat. 27.5°)	85	77	69	35	33	42	41	29	40	55	71	89	666	1 270	267
Grafton, New South Wales (Lat. 29.7°)	131	126	117	85	68	67	56	40	46	62	77	99	964	1 847	414
Batemans Bay, New South Wales (Lat. 35.7°)	98	93	100	98	106	103	75	60	62	70	70	86	1 021	2 082	517

Rainfall

Type: uniform to summer rainfall. The New South Wales occurrences south of Coff's Harbour and the Victorian outlier are in the zone of uniform rainfall >800 mm as shown in Figure IV. North of Coff's Harbour it lies in the zone of summer rainfall.

Total: 625-1 250 mm; in most occurrences over 800 mm

Dry season: varies from south to north from 3-6 months. The southern half rarely has a long dry season, but inland from Bundaberg in Queensland a long dry season of six months can occur.

Temperature

Mean maximum of hottest month: 22-35°C; in most of the New South Wales forest it is under 30°C
Mean minimum of coldest month: 2-5°C
Frosts: few and not severe; it is not a frost-hardy species

Characteristics

An attractive tree; when it is the dominating species over the ancient cycad *Macrozamia* as an understorey, it forms one of the most beautiful forests in Australia.

Tree height in Australia: 35-45 m; with a straight bole and a large crown

Bark type: smooth throughout, pink or blue-grey, thick unless thinned by severe fires; shed in patches which are usually elliptical, leaving slight depressions on the surface; in Australia there are frequently small deeper depressions caused by insects living in the bark, the resulting small damaged patches being shed; it is a most efficient species in forming a new phellogen around and below an injury.

Juvenile leaves: vary over the wide latitudinal range; first opposite, then alternate on long stalks, ovate or orbicular, with glandular hairs on the surface; sometimes peltate

Adult leaves: alternate, stalked, lanceolate or narrowly lanceolate; a feature common to most of the bloodwoods is that, if new developing leaves are pinched, but not cut, the cuticle may be partly separated from the rest of the leaf and stretched 5-10 mm, making a transparent tube

Wood: light brown to grey; hard, strong and tough; moderately durable; readily worked.

Buds and fruits: Figure a7-55 (54)

Viable seeds per gram: 111

Uses. Widely used for structural purposes and tool handles. The starch in the sapwood attracts the powder post beetle *Lyctus brunneus*, which oviposits in the end grain. The larval stage eats the starchy sapwood and then pupates, the mature insects emerging from the sides of boards or tools. The attacks of *Lyctus brunneus* can be prevented by a borax bath.

Prospects for planting. This should be a good plantation species. It has been tried out in many countries and some encouraging results have been reported from subtropical and some tropical countries, but it has not become a major plantation species. It covers a range of 12° latitude and better series of provenance trials should be arranged.

Success outside Australia. The largest successful plantings are in South Africa where several thousand hectares have been planted and managed since 1905. The species has been found a good coppicing species, reasonably resistant to fire and easy to debark. There are 150 hectares in Zone B of Colombia. In Brazil it is successfully planted on a small scale in the cool humid subtropical region. Provenance trials are in progress at Mogi Guacu in São Paulo State but few differences are yet significant (Pasztor and Coelho, 1978). Promising small plantings are reported from the Comoros, Cuba, Ghana, Israel, Madagascar, Sierra Leone, Turkey and Zambia. Failures have been reported from Zones C and D of Colombia, Indonesia, the Ivory Coast and Swaziland. Métro (1955) reported that there did not appear to have been many acclimatization trials bordering the Mediterranean, but the few specimens in arboreta showed that it could be acclimatized. On the whole, fewer countries have made use of *E. maculata* than of its close relative, *E. citriodora*. This may be because, on sites suitable for *E. maculata*, faster-growing species such as *E. grandis* and *E. saligna* will also thrive, whereas *E. citriodora* will tolerate somewhat hotter and drier conditions than any of these.

E. mannifera Mudie subsp. mannifera (previously known as E. maculosa) R.T. Bak.

Refs. Blakely No. 220 Code SPECHA FTA p. 110

Common name in Australia. Brittle gum

Regions of natural occurrence. Tablelands of southern New South Wales and Victoria; frequent trees in mixed species dry sclerophyll

Latitudinal range. 33°-37.5°S

Altitudinal range. 500-1 000 m

Rainfall

Type: winter to summer rainfall
Total: 500-1 000 mm
Dry season: fairly long droughts occur occasionally

Temperature

Mean maximum of hottest month: 26-32°C
Mean minimum of coldest month: 2-3°C
Frosts: 10-40

Characteristics

Tree height in Australia: 25 m; rather short trunk and open crown
Bark type: smooth, white
Juvenile leaves: stalked, linear, elliptical to oblong, subglaucous
Adult leaves: alternate, petiolate, narrow-lanceolate
Wood: weak, not useful
Buds and fruits: Figure a7-56 (220)
Viable seeds per gram: 402

Uses. Environmental and ornamental; useful street tree

Prospects for planting. Limited to ornamental use

Success outside Australia. An ornamental in California

E. marginata Donn. ex Sm.

Refs. Blakely No. 304 MADCA FTA p. 150

Common name in Australia. Jarrah

Regions of natural occurrence. Southwest Western Australia; along the Darling Range plateau and western slopes to the sea and the eastern slopes to the 650-mm isohyet. It grows on laterite cappings, gravels and sands.

Latitudinal range. 31.5°-35°S

Altitudinal range. Up to 33 m

Rainfall

Type: winter rainfall
Total: 625-1 250 mm
Dry season: 4 months

Temperature

Mean maximum of hottest month: 24-26°C
Mean minimum of coldest month: 5°C
Frosts: few and light

Characteristics

Tree height in Australia: 30-40 m; a good trunk but a thin crown
Bark type: stringybark type
Juvenile leaves: opposite for several pairs, shortly stalked, oblong to ovate
Adult leaves: alternate, stalked, lanceolate, not symmetrical
Wood: dark red to reddish brown, hard, coarse textured, strong and durable
Buds and fruits: Figure a7-57 (304)
Viable seeds per gram: 14

Uses. Probably still the most important sawtimber in Australia. It has provided a good forest on a difficult laterite capping. Unfortunately it is threatened by the insidious root pathogen *Phytophthora cinnamomi* and its future is unsure.

Prospects for planting. Nil or limited. There are so many promising species to try.

Success outside Australia. It has usually failed. There is a 40-year-old plot in the Knysna forest in Cape Province (South Africa) where the species is finally making trees that look like jarrah in Western Australia.

E. melanophloia F. Muell.

Refs. Blakely No. 526 Code SUP:V FTA p. 252

Common name in Australia. Silver-leafed ironbark

Regions of natural occurrence. Covers a very large area in Queensland and northern New South Wales; a species of savanna woodlands and a wide variety of soils on gentle slopes, tablelands and plains

Latitudinal range. 17°-33°S

Altitudinal range. 60-650 m

Rainfall

Type: summer rainfall
Total: 400-750 mm
Dry season: 6 months

Temperature

Mean maximum of hottest month: 32-38°C
Mean minimum of coldest month: 2-7°C
Frosts: 10-20

Characteristics

Tree height in Australia: 10-30 m; frequently of poor form
Bark type: ironbark type, dark and deeply furrowed
Juvenile leaves: opposite to sub-opposite, shortly stalked or sessile and amplexicaul, cordate to broadly ovate, glaucous
Adult leaves: sub-opposite, very shortly stalked, broadly lanceolate, glaucous
Wood: heavy, hard, durable
Buds and fruits: Figure a7-58 (526)
Viable seeds per gram: 143

Uses. Of value as a farm tree, for shelter and ornament. It is very hardy in a hot, dry climate. The glaucous nature of the foliage makes it ornamental.

Prospects for planting. Limited. If desired for commercial planting, the large area of natural occurrence makes provenance testing desirable.

Success outside Australia. Reports generally unenthusiastic. One South Africa test in Zone M produced straight trees but in others the trees were crooked.

E. melliodora A. Cunn. ex Schau.

Refs. Blakely No. 550 Code SUX:A FTA p. 240

Common name in Australia. Yellow box

Regions of natural occurrence. A very wide latitudinal range on the inland side of the Great Dividing Range in Victoria, New South Wales and extending to the Carnarvon Range in central southern Queensland. The best development is on good agricultural soils in the southern part of the range. In the drier parts it occurs on flats near watercourses. It is a species of the savanna woodland or the open dry sclerophyll forest.

Latitudinal range. 23°-38°S

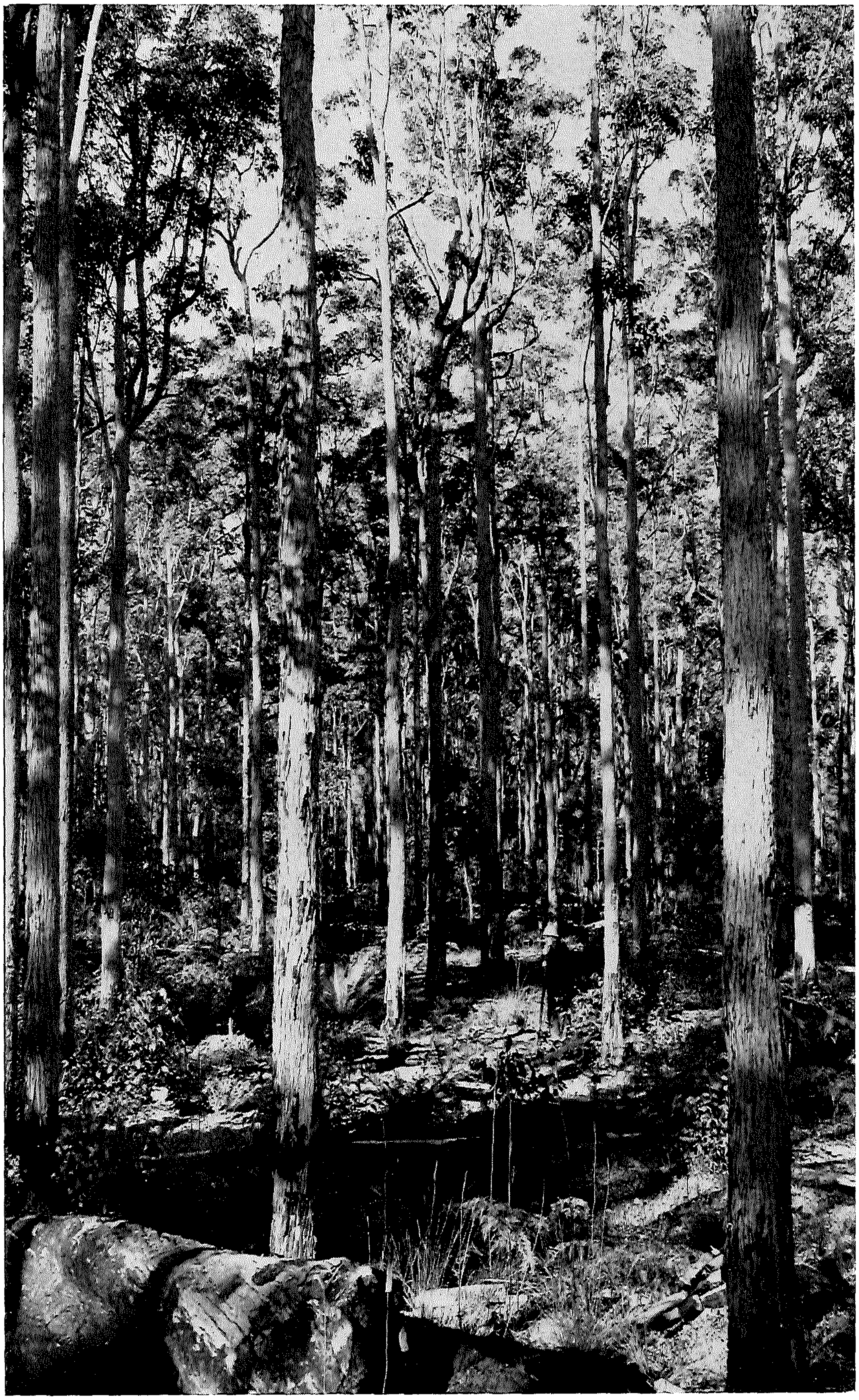
Altitudinal range. 150-1 250 m

Rainfall

Type: winter to summer rainfall
Total: 400-900 mm or more
Dry season: 3-7 months

Temperature

Mean maximum of hottest month: 22-38°C
Mean minimum of coldest month: 0-7°C
Frosts: 5-30



56. 53-year-old *E. marginata*, natural regeneration from a regeneration burn
Forests Department of Western Australia

57. E. *microtheca,* about 9 years old, being felled for fuelwood and poles in an irrigated plantation in Gezira, the Sudan
L.D. Pryor

Characteristics

Tree height in Australia: 20-30 m; usually with a good but rather short trunk and an attractive round crown
Bark type: typical box until high on trunk; inner bark yellow, hence the name "yellow box"
Juvenile leaves: first opposite then alternate, stalked, oblong or elliptical
Adult leaves: alternate, stalked, lanceolate to narrowly lanceolate
Wood: pale yellow-brown, heavy, strong, hard and durable, coarse texture and interlocked grain
Buds and fruits: Figure a7-59 (550)
Viable seeds per gram: 366

Uses. A very useful farm tree in Australia. One of the best honey eucalypts. An excellent fuelwood.

Prospects for planting. Limited because this type of wood will not be required in large quantities. If required, the huge range should be explored for the best provenances.

Success outside Australia. Limited. Poor in Brazil and North Africa. Some South African trials showed fair growth.

E. microcorys F. Muell.

Refs. Blakely No. 314 Code SWA:A FTA p. 158

Common name in Australia. Tallowwood

Regions of natural occurrence. The Pacific Ocean side of the Great Dividing Range in northern New South Wales and southern Queensland, growing in the better mixed wet sclerophyll forests.

Latitudinal range. 25°-32.5°S

Altitudinal range. 0-800 m

Rainfall

Type: summer rainfall
Total: 900-1 500 mm
Dry season: 3 months, not usually severe

Temperature

Mean maximum of hottest month: 32°C
Mean minimum of coldest month: 5°C
Frosts: 10-30

Characteristics

Tree height in Australia: 30-55 m; usually with a good trunk and crown
Bark type: persistent to smaller branches, flaky, soft, the thumb may be

pushed well into the bark
Juvenile leaves: shortly stalked, ovate to elliptical
Adult leaves: alternate, stalked, lanceolate, sharply pointed
Wood: yellowish brown, shiny and rather greasy to the feel, hard, strong and durable; density 910-1 070 kg/m^3
Buds and fruits: Figure a7-60 (314)
Viable seeds per gram: 232

Uses. One of the best Australian hardwoods, highly valued for dance floors. One of the best eucalypt shade trees.

Prospects for planting. When grown in plantations it grows slowly at first but later makes a very dense dark forest. The wood is not liked by paper-makers. Not a popular planting species.

Success outside Australia. Very fine stands in Sri Lanka, South Africa and Brazil. Excellent growth in Hawaii at elevations of 300-800 m and a rainfall of 1 500-2 500 mm.

E. microtheca F. Muell.

Refs. Blakely No. 507 Code SUADFA FTA p. 220

Common name in Australia. Coolabah

Regions of natural occurrence. Covers a huge area of inland mid-northern and northern Australia

Latitudinal range. 14°-33°S

Altitudinal range. Up to 700 m

Rainfall

Type: summer or storm rainfall
Total: 200-1 000 mm
Dry season: up to 7 months

Temperature

Mean maximum of hottest month: 35-38°C
Mean minimum of coldest month: 5°C
Frosts: up to 12

Characteristics

Tree height in Australia: 15-20 m; with a short trunk and thin crown
Bark type: grey box bark on trunk with smooth white branches, or completely smooth white bark all over
Juvenile leaves: sub-opposite, stalked, lanceolate to linear-lanceolate
Adult leaves: alternate, stalked, markedly variable in form, from linear-lanceolate to broadly lanceolate
Wood: dark brown to black, with numerous vessels with white contents, interlocked grain

Buds and fruits: Figure a7-61 (507)
Viable seeds per gram: 419

Uses. Valuable for conservation purposes. The wood is a good fuel.

Prospects for planting. It can tolerate flooding and irrigation and could be useful for irrigated plantations in desert areas. The species can tolerate calcareous soils.

Success outside Australia. Successful in the Sudan, Iran, Iraq, Pakistan. Not good in Brazil. In the Sudan it has been the most successful species in irrigated plantations on cracking clays with low rainfall, e.g., in the Gezira. It has proved more drought- and heat-resistant than either *E. camaldulensis* or *E. tereticornis*. Its form is poor but this could be improved either by testing new provenances from within the natural range or by individual selection. Yields were estimated to be directly related to the amount of irrigation water used; according to Foggie (1967) a MAI of about 10 m^3/ha could be expected with an annual irrigation rate equivalent to about 1 700 mm of rainfall. With an irrigation rate reduced by one third (to about 1 100 mm) a reduction in MAI to about 7 m^3/ha could be expected. A good average yield would be about 6 m^3/ha/yr for first rotation trees, with about 25 percent more from subsequent coppice rotations (Jackson, 1977). Irrigation water is normally available for forest plantations only in the period August to March. *E. microtheca* has the merit of being able to withstand the long, hot period between March and August when no irrigation water is available and there is very little rainfall. In Nigeria *E. microtheca* is promising in the Sudan Zone.

E. miniata A. Cunn. ex Schau.

Refs. Blakely No. 14 Code EFC:A FTA p. 18

Common name in Australia. Darwin woollybutt

Regions of natural occurrence. Far northern Australia in fairly close savanna woodland and on lateritic or sandy soils

Latitudinal range. 11°-17°S

Altitudinal range. Up to 300 m

Rainfall

Type: summer rainfall
Total: 750-1 500 mm
Dry season: 7 months

Temperature

Mean maximum of hottest month: 35°C
Mean minimum of coldest month: 5°C
Frosts: nil or rare

Characteristics

Tree height in Australia: up to 30 m; a well-formed trunk and crown
Bark type: stringybark type at base and up to half tree height; smooth above
Juvenile leaves: opposite to alternate, shortly stalked, elliptical, with tufts of hair
Adult leaves: alternate, stalked, lanceolate or oblong-lanceolate
Wood: red to red-brown, hard, not very durable, the insides of trees eaten by termites
Buds and fruits: Figure a7-62 (14); it has attractive orange-coloured flowers
Viable seeds per gram: 17

Uses. Wood used locally. Trees give a forest cover in a rather difficult tropical climate. Rather ornamental.

Prospects for planting. Very limited. Nevertheless it is a stable species and if required in a treeless low-latitude area provenance testing could be useful; also as an ornamental tree.

Success outside Australia. Not encouraging as yet in Brazil

Refs. Blakely No. 484 Code SUL:B FTA p. 234

E. moluccana Roxb. (syn. E. hemiphloia F. Muell. ex Benth.)

Common name in Australia. Grey box

Regions of natural occurrence. Coastal and some inland areas of southern Queensland and New South Wales, growing in open woodland, usually on heavy soils

Latitudinal range. 15°-36°S

Altitudinal range. Up to 500 m

Rainfall

Type: summer to uniform rainfall
Total: 500-1 000 mm
Dry season: up to 4 months

Temperature

Mean maximum of hottest month: 35°C
Mean minimum of coldest month: 5°C
Frosts: up to 15

Characteristics

Tree height in Australia: up to 30 m; usually a good trunk and crown
Bark type: typical box
Juvenile leaves: alternate, stalked, oblong to circular
Adult leaves: alternate, stalked, lanceolate

Wood: light brown, hard and strong, durable, density 960-1 200 kg/m^3
Buds and fruits: Figure a7-63 (484)
Viable seeds per gram: 331

Uses. Widely used for poles and piles and structural purposes, a very good fuel, a good honey tree

Prospects for planting. A valuable tree for planting if a box-type wood is required. The latitudinal range of occurrence of more than 20° would make provenance testing desirable.

Success outside Australia. The species did not do well in Brazil and was not commented on very favourably in other reports

E. muellerana Howitt

Refs. Blakely No. 308 Code MAHAA FTA p. 162

Common name in Australia. Yellow stringybark

Regions of natural occurrence. Coastal southeastern New South Wales and eastern Victoria, growing on a wide range of soils on sheltered slopes and valleys

Latitudinal range. 34°-39°S

Altitudinal range. Up to 600 m

Rainfall

Type: uniform rainfall
Total: 750-1 200 mm
Dry season: 3 months and mild

Temperature

Mean maximum of hottest month: 25-27°C
Mean minimum of coldest month: 5°C
Frosts: up to 20

Characteristics

Tree height in Australia: 30-40 m; with a good trunk and well-developed crown

Bark type: finely fibrous stringybark type; inner bark yellow
Juvenile leaves: alternate, stalked, lanceolate
Adult leaves: opposite first then alternate, stalked, lanceolate with oblique base
Wood: heavy, hard, strong and durable
Buds and fruits: Figure a7-64 (308)
Viable seeds per gram: 55

Uses. General construction purposes; a good pole timber

Prospects for planting. It could be tried more frequently as it is a good planting species which handles well as a forest. It has done very well when planted in Western Australia in the karri country.

Success outside Australia. Liked by private growers in New Zealand; it did not do well in central Brazil; the form in South African trials is reported as good

E. nesophila Blakely

Refs. Blakely No. 46a Code CAFUL FTA p. 38

Common name in Australia. Melville Island bloodwood

Regions of natural occurrence. Northern Territory, Kimberley region of Western Australia and north Queensland. The range is now known to be much wider than that shown in *Forest trees of Australia.*

Latitudinal range. 11°-12°S

Altitudinal range. Up to 300 m

Rainfall

Type: summer rainfall
Total: 1 250-1 500 mm
Dry season: 4-6 months

Temperature

Mean maximum of hottest month: 32°C
Mean minimum of coldest month: 5°C
Frosts: nil

Characteristics

Tree height in Australia: up to 25-30 m; a good trunk and a fair crown
Bark type: persistent up to small branches, flaky, subtessellated
Juvenile leaves: alternate, stalked, oblong to broadly ovate, hairy
Adult leaves: alternate, stalked, lanceolate to narrow-lanceolate, tending to be falcate
Wood: dark reddish brown, moderately hard, durable
Buds and fruits: Figure a7-65 (46a)
Viable seeds per gram: 101

Uses. One of the best timbers in the Northern Territory

Prospects for planting. Probably the best available bloodwood if this type of wood should be required in latitude 11°-12°

Success outside Australia. A good stand reported in Maceió, northeast Brazil

E. nitens (Deane & Maid.) Maid.

Refs. Blakely No. 263 Code SPIFG FTA p. 136

Common name in Australia. Shining gum

Regions of natural occurrence. In southern Victoria it tends to be found above the main stands of *E. regnans* and below the main *E. delegatensis* forest; it is found almost to the western edge of the main *E. regnans* belt in the Great Dividing Range northeast of Melbourne. In the regeneration that followed the holocaust of 1939, *E. nitens* has sometimes outgrown *E. regnans* and can be recognized among the tall trees by its shining leaves. In eastern Victoria and adjacent parts of New South Wales, the best remaining forest of *E. nitens* occurs around the town of Bendoc. It may be mixed with either *E. fastigata* or *E. regnans*, and occasionally both. Further north along the Great Dividing Range, *E. nitens* is found on a number of high niches of better wet sclerophyll forest often associated with and standing above *Nothofagus* and other rain-forest species. It can tolerate the incursion of rain-forest species for a longer period than either *E. delegatensis* or *E. regnans.*

The parent material of the soils over the range of *E. nitens* varies with the rocks that make up the Great Dividing Range, but all the soils have a great deal of organic matter in their upper layers and are reasonably well drained. All the occurrences have humid climates.

Covering a latitudinal range of 8°, the species is one where provenance trials must be tried, but there is one difficulty. *E. nitens* is a notoriously shy seeder, and seed collection tends to be concentrated on the occasional trees which carry seed. A high degree of selfing is suspected.

Latitudinal range. 30°-38°S

Altitudinal range. 1 000-1 300 m

Rainfall

Type: winter to uniform rainfall
Total: 750-1 250 mm or more
Dry season: up to 3 months, not severe

Temperature

Mean maximum of hottest month: 21-24°C
Mean minimum of coldest month: −2-+2°C
Frosts: 50-150; occasional snow

Characteristics

Tree height in Australia: up to 60 m with a splendid trunk and a crown usually about one third the tree height
Bark type: basically smooth, decorticating in ribbons
Juvenile leaves: opposite, sessile, amplexicaul, ovate to broadly lanceolate, glaucous. When crushed the juvenile leaves exude an odour somewhat like varnish.

Adult leaves: alternate, stalked, lanceolate to falcate
Wood: pale pinkish colour, light for a eucalypt; density 670 kg/m^3
Buds and fruits: Figure a7-66 (263)
Viable seeds per gram: 261

Uses. Wood used in general building construction; not a favoured wood in Australia but used for general sawnwood purposes

Prospects for planting. Very good for vigour and volume growth. One of the more frost-resistant eucalypts. It handles well in nurseries; it tolerates root-pruning and can be prepared for bare-root planting in a suitable climate. The lower branches of young plantation trees tend to stand out at right angles to the trunk and do not shed as well as those of most eucalypts. In the same way that the bluish juvenile leaves of *E. globulus* are not willingly eaten by cattle, sheep or goats, the juvenile leaves of *E. nitens* are unpalatable to many pests, in some cases even to the leaf-cutting *Atta* ants of Brazil, and the Australian possums which attack eucalypt foliage in New Zealand. The pests soon attack the adult leaves.

Success outside Australia. One of the more promising eucalypts under trial. It has proved very vigorous in Argentina, Brazil, New Zealand, Zimbabwe, South Africa and the United States (California, Hawaii). There appear to be differences in behaviour, including incidence of defects, between provenances of *E. nitens.* Poles in Natal, South Africa, show severe spiral grain, which has not been commented upon in native forests in Australia. The Wattle Research Institute of South Africa has recently established a provenance trial of 27 Australian and one South African seed lots (PWRI Annual Report 1975-76). The Australian seed lots covered a wide range of the species. Interesting variations in the size and shape of juvenile leaves and early height growth were noted. The more westerly Victorian provenances were proving superior in height growth at the time of the report.

E. obliqua L'Herit.

Refs. Blakely No. 362 Code MAKAA FTA p. 178

Common name in Australia. Messmate stringybark

Regions of natural occurrence. The principal occurrence is in Victoria where it extends from the east coast at latitude 37°S right through the State along this latitudinal line, continuing into the Mt Gambier region of South Australia. It is also an important species in Tasmania. There are occurrences in the Mt Lofty Range and on Kangaroo Island in South Australia, and interrupted occurrences along the Great Dividing Range through New South Wales and into southern Queensland.

In most of its occurrences, *E. obliqua* grows on a wide range of soils in hilly or mountainous country. It is usually found in closed forest or wet sclerophyll forests associated with the better eucalypts of southeastern Australia. In western Victoria and the Mt Gambier region of southern South Australia, it may grow on sandy soils.

Latitudinal range. 29°-43.5°S

Altitudinal range. 0-1 300 m

Rainfall

Type: winter rainfall in South Australia; mainly uniform rainfall in eastern Victoria and New South Wales
Total: 700-1 250 mm
Dry season: up to 4 months, not usually severe

Temperature

Mean maximum of hottest month: 27-32°C
Mean minimum of coldest month: 2-5°C
Frosts: 10-100

Characteristics

Tree height in Australia: up to 70 or 80 m; a long straight trunk and a good crown
Bark type: stringybark
Juvenile leaves: opposite at first then alternate, stalked, broadly lanceolate, faintly toothed
Adult leaves: alternate, stalked, obliquely lanceolate
Wood: pale brown to brown, open textured, usually straight-grained; well-defined annual rings; moderate strength and durability; splits readily; density 640-900 kg/m^3
Buds and fruits: Figure a7-67 (362)
Viable seeds per gram: 86

Uses. Used as a sawnwood for general building and construction purposes and for paper manufacture in Australia. Together these uses make the species the most used native timber in Australia.

Prospects for planting. E. obliqua is a stable species, but with its wide range of occurrence provenance trials would be worth while should it be considered by a planting country for extensive industrial plantation. It does not seem likely at present that *E. obliqua* will be planted extensively unless some pathogen attacks the more popular planting species.

Because of its importance, the Division of Forest Research, CSIRO, Canberra, initiated a study of the genetic variation of the species in a series of field trials started in 1966 (Brown *et al.*, 1972, 1976). Twenty-six provenances covering the full range of natural occurrence of the species were collected and planted in three suitable districts in Tasmania and Victoria.

Periodic measurements of growth in height, diameter and volume, and of survival were made and are reported in the paper. The analysis shows a marked and significant variation in performance between the 26 provenances on the three sites of the field tests and indicates promise of substantial improvement in the species, not only by selection of the most suitable provenances but also by selection of superior individual trees within a provenance. The results suggest that the Otway region of southern Victoria and the southeastern corner of Tasmania would be favourable seed sources for the site conditions tested.

Success outside Australia. *E. obliqua* has been successfully established in many countries with similar conditions to those of its natural occurrence. The plantings have been "satisfactory" but they have not given such good yields as the popular planting species such as *E. globulus, E. regnans* and *E. grandis.*

E. occidentalis Endl.

Refs. Blakely No. 110 Code SIDAA Chipp. p. 47

Common name in Australia. Flat-topped yate

Regions of natural occurrence. Southern wheatbelt of Western Australia, on clay flats sometimes adjacent to salt lakes

Latitudinal range. 30°-33°S

Altitudinal range. Up to 100 m

Rainfall

Type: winter rainfall
Total: 380-760 mm
Dry season: 7 months

Temperature

Mean maximum of hottest month: 36-38°C
Mean minimum of coldest month: 0-2°C
Frosts: 2-20

Characteristics

Tree height in Australia: up to 21 m; a fair trunk and wide-spreading crown
Bark type: fibrous on main trunk and lower branches
Juvenile leaves: first opposite then alternate, elliptical, ovate with a slightly undulate margin
Adult leaves: alternate, stalked, lanceolate, sometimes falcate
Wood: pale, hard, durable
Buds and fruits: Figure a7-68 (110)
Viable seeds per gram: 229

Uses. Used for local purposes, fuel, etc. There is a high tannin content in the bark.

Prospects for planting. A valuable eucalypt for planting because of its potential to provide a crop on dry, marginal lands in Mediterranean-type regions

Success outside Australia. In Israel it prefers clay soils and has proved to be resistant to heat, prolonged drought, high salinity and calcium carbonate content of the soil. It also stands prolonged flooding, even with saline water. In its region of natural occurrence, it withstands up to 20 frosts a year and it is proving moderately frost-tolerant in Israel. 500 ha had been planted to the end of 1973.

In Italy, on the other hand, it has proved to be highly susceptible to frost damage. It is of rather poor form but has shown high survival and good adaptation to difficult, compacted clay soils in dry areas of Calabria (winter rainfall 600-700 mm). It coppices well. Yield tables have been compiled (Ciancio and Hermanin, 1976) and are reproduced in Appendix 3. Although the yields in the first rotation are low (MAI 1.5 to 6.0 m^3/ha/yr at age 12 according to site quality), the plantations also fulfil an important protective function on difficult sites on slopes subject to flooding. Over 5 000 ha had been planted by 1975.

In Morocco over 2 700 ha had been planted by 1974. It tolerates similar heavy clay and marl soils as *E. astringens* in the semi-arid zone, but coppices much better than that species. In Tunisia it is planted mainly in the more arid southern part of the country. It has been a comparative failure in Chad.

E. oleosa F. Muell. ex Miq.

Refs. Blakely No. 578 Code SIT:C Chipp. p. 100

Common name in Australia. Giant mallee

Regions of natural occurrence. Wide longitudinal range from Western Australia through South Australia, Victoria and New South Wales

Latitudinal range. 29°-37°S

Altitudinal range. Up to 300 m

Rainfall

Type: winter rainfall
Total: 200-450 mm
Dry season: up to 8 months

Temperature

Mean maximum of hottest month: 36-38°C
Mean minimum of coldest month: 4°C
Frosts: up to 8

Characteristics

Tree height in Australia: up to 12 m; usually a mallee form
Bark type: lower stem has a rough, fibrous or flaky bark, the upper being smooth
Juvenile leaves: linear, apparently in threes or spirally arranged, stalkless, but with the two edges of the leaf continued on to the stem
Adult leaves: narrowly lanceolate or lanceolate, stalked, with many oil glands
Wood: brown or red-brown, hard, durable
Buds and fruits: Figure a7-69 (578)
Viable seeds per gram (France): 183

Uses. Firewood and posts; environmental values; also for oil distillation

Prospects for planting. Limited, but useful as a shelterbelt in difficult terrain

Success outside Australia. Successfully planted in Morocco and Cyprus

Refs. Blakely No. 380 Code MAKDA FTS No. 16

E. oreades R.T. Bak.

Common name in Australia. Blue mountain ash

Regions of natural occurrence. Central and northern tablelands of New South Wales to the Macpherson Ranges in southeastern Queensland. The main occurrence is on the Hawkesbury sandstones, but the better trees are found only where the soil is moderately deep and well drained. It may occur in small pure stands or in association with other tableland species.

Latitudinal range. 28°-34°S

Altitudinal range. 800-1 300 m

Rainfall

Type: summer rainfall
Total: 800-1 500 mm
Dry season: 4 months, not severe

Temperature

Mean maximum of hottest month: 21-27°C
Mean minimum of coldest month: 0°C
Frosts: 30-60

Characteristics

Tree height in Australia: up to 40 m; usually a good trunk and a substantial crown
Bark type: a basal stocking of bark remnants up to 2-4 m, then smooth
Juvenile leaves: first opposite then alternate, stalked, ovate to broadly lanceolate with an oblique base
Adult leaves: lanceolate with an oblique base, stalked, more or less falcate
Wood: pale to light brown, moderately strong but not durable; density 610 kg/m^3
Buds and fruits: Figure a7-70 (380)
Viable seeds per gram: 74

Uses. Wood used for general industrial purposes. The trees have valuable environmental features, the white bark contrasting well with the other associated species.

Prospects for planting. Probably limited. The plantations at Knysna, South Africa, are excellent, but the coppicing ability of the species is poor, limiting its use for industrial plantations.

Success outside Australia. Very good in New Zealand and South Africa. Poorer in Brazil.

E. ovata Labill.

Refs. Blakely No. 210 Code SPEAB FTA p. 106

Common name in Australia. Swamp gum

Regions of natural occurrence. Southeastern New South Wales, southern Victoria, Tasmania; Mt Lofty Range, Kangaroo Island and Mt Gambier districts of South Australia. The species grows on a wide variety of sites; it can tolerate sites which are inundated for appreciable periods and yet grow on dry, well-drained slopes. In the regions of its natural occurrence it is a good frost hollow species. Its associated species are usually those which tolerate cold, wet sites.

Latitudinal range. 32°-43.5°S

Altitudinal range. From sea-level to 760 m

Rainfall

Type: winter rainfall
Total: 500-1 000 mm
Dry season: up to 3 months, not severe

Temperature

Mean maximum of hottest month: 18-24°C
Mean minimum of coldest month: 0-7°C
Frosts: 5 to 90

Characteristics

Tree height in Australia: usually up to 25 m; there is a larger form in north-west Tasmania; usually with a good trunk and spreading crown
Bark type: a rough stocking at the base, then a smooth clean upper surface
Juvenile leaves: opposite for several pairs, then alternate, ovate or circular, shortly stalked
Adult leaves: alternate, stalked, ovate to lanceolate
Wood: pale, not durable
Buds and fruits: Figure a7-71 (210)
Viable seeds per gram: 593

Uses. Not used extensively in Australia but useful for farm purposes; some is sawn; valuable for shade and shelter on cool, wet sites

Prospects for planting. Success as an industrial coppice crop still to be proved, and the best provenances chosen. The species has the desirable character that logs can be barked easily in the forest during droughty periods which make the bark of other species very tight.

Success outside Australia. Seedling crops in New Zealand are excellent and vigorous but are attacked by an Australian beetle, *Paropsis charybdis.*

E. paniculata Sm.

Refs. Blakely No. 537 Code SUV:D FTA p. 256

Common name in Australia. Grey ironbark

Regions of natural occurrence. There has been some confusion about the identity of members of the ironbark group in eastern Australia. As the situation stands in 1977, *E. paniculata* occurs in the forests of the central coast of New South Wales. When the first edition of this book (Métro, 1955) was prepared, the good ironbark species of southern Queensland was also called *E. paniculata*, but the Queensland species is now identified as *E. drepanophylla.* Métro (1955) correctly reported that the anthers of *E. drepanophylla* are porantheroid and not terminal, as is the case with *E. paniculata. E. paniculata* grows on a wide range of soils, but the better trees are on good soils.

Latitudinal range. 30°-36.5°S

Altitudinal range. Sea-level to 500 m

Rainfall

Type: uniform rainfall over most of the range; summer rainfall in the northernmost part
Total: 820-1 250 mm
Dry season: not usually severe

Temperature

Mean maximum of hottest month: 24-29°C
Mean minimum of coldest month: 2-5°C
Frosts: rare

Table 14.8 Distribution of rainfall (mm)

Locality	Lat. (S)	Alt (m)	Rainfall J	F	M	A	M	Jn	Jl	A	S	O	N	D	Total	Frosts per year
Coffs Harbour	30.3°	18	164	211	242	191	144	124	96	77	70	95	104	140	1 658	rare
Newcastle	32.9°	28	88	103	118	121	117	108	107	82	78	72	64	84	1 142	rare
Wollongong	34.4°	8	108	109	118	131	116	109	90	61	67	68	72	86	1 135	rare
Bateman's Bay	35.7°	3	98	93	100	98	106	103	75	60	62	70	70	86	1 021	rare

Characteristics

Tree height in Australia: 30-35 m; typically it has a good strong trunk and a good form
Bark type: ironbark type
Juvenile leaves: first opposite, then alternate, shortly stalked, broadly lanceolate
Adult leaves: alternate, stalked, lanceolate
Wood: brown, dark brown or red-brown with fine uniform texture and interlocked grain; density 1 070-1 200 kg/m³
Buds and fruits: Figure a7-72 (537)
Viable seeds per gram (France): 112-336

Uses. Largely used hewn for sleepers, bridge and wharf timbers. When sawn, valuable for ship construction and building; a good pole species; excellent fuelwood and charcoal timber.

Prospects for planting. Promising if this type of wood is required. It is a good to very good plantation species.

Success outside Australia. There are excellent plantations of *E. paniculata* in Brazil, Argentina and several countries of Africa. It is an important species in Mozambique and South Africa where it is listed as a good coppice species but hard to debark. It is promising in Kenya, Madagascar, Sierra Leone, California and Hawaii. It failed in Ethiopia, Italy, the Ivory Coast Zone A, Nigeria, Sri Lanka and Zambia. There is frequently some doubt about the identity of some of the ironbarks, but plantations labelled as *E. paniculata* are usually good.

E. patens Benth.

Refs. Blakely No. 299 Code MABBA FTA p. 148

Common name in Australia. Western Australian blackbutt

Regions of natural occurrence. Throughout the jarrah forest region in southwest Western Australia.

Latitudinal range. 31.5°-35°S

Altitudinal range. Up to 330 m

Rainfall

Type: winter rainfall
Total: 625-1 250 mm
Dry season: 4 months

Temperature

Mean maximum of hottest month: 24-26°C
Mean minimum of coldest month: 5°C
Frosts: few and light

Characteristics

Tree height in Australia: up to 40 m; trunk of good form with a dense crown
Bark type: persistent to small branches, grey or grey-brown, deeply furrowed
Juvenile leaves: opposite for many pairs, stalkless, ovate and heart-shaped at the base
Adult leaves: alternate, stalked, narrowly lanceolate or lanceolate, usually curved
Wood: pale yellow, hard, tough and moderately durable, interlocked grain; density 860 kg/m^3
Buds and fruits: Figure a7-73 (299)
Viable seeds per gram (France): 8

Uses. A first-class general-purpose timber for construction work; a good flooring and panelling timber

Prospects for planting. Probably limited

Success outside Australia. The reports on experimental trials outside Australia have not been enthusiastic

E. pauciflora Sieb. ex Spreng. subsp. pauciflora (syn. E. coriacea A. Cunn.)

Refs. Blakely No. 394 Code MAKHAA FTA p. 194

Common name in Australia. Snow gum

Regions of natural occurrence. Tasmania, mountainous parts of Victoria and New South Wales, with a small extension into Queensland. There is a small occurrence in the southeast of South Australia, growing on the upper parts of small sandy hills.

In eastern Australia, the species occurs on upper mountain slopes and ridges which are covered with snow annually, but also in broad valleys and tablelands. In the broad, more or less treeless, valleys of the Great Dividing Range at an altitude of 600 m or higher, *E. pauciflora* is frequently the first tree found at the edge of the treeless frost hollows. Above this narrow band of *E. pauciflora* is found a mixture of eucalypts in savanna woodland formation, such as *E. macrorhyncha*, *E. melliodora*, *E. dives* and others. At the top of higher mountains, regularly snowcovered in winter, above shelf species such as *E. delegatensis*, *E. pauciflora* occurs almost as a pure stand, but mixed with occasional *E. dalrympleana*.

Latitudinal range. 29.5°-43°S

Altitudinal range. Up to 1 800 m

Rainfall

Type: winter to summer rainfall
Total: 625-1 250 mm
Dry season: up to 4 months, not usually severe

Temperature

Mean maximum of hottest month: 28°C
Mean minimum of coldest month: -2-$+2$°C

Frosts: 50 to over 100; frequent snow except in the South Australian occurrence

Characteristics

Tree height in Australia: up to 20 m; a short trunk and an open crown
Bark type: shed in irregular patches over whole trunk, leaving a smooth surface
Juvenile leaves: first opposite, then alternate, shortly stalked, ovate
Adult leaves: alternate, stalked, lanceolate, often curved
Wood: pinkish brown, light, comparatively soft, moderately strong but with many gum veins
Buds and fruits: Figure a7-74 (394)
Viable seeds per gram: 59

Uses. The main value of the forest is as a protection forest, but the wood is a useful fuel

Prospects for planting. Very limited. If protection forests must be planted in snow country, there are probably better species; it is a reasonable ornamental tree.

Success outside Australia. There is a good plantation in southern Brazil; successful in places in Europe

E. pellita F. Muell.

Refs. Blakely No. 73 Code SECCA FTS No. 146

Common name in Australia. Large-fruited red mahogany

Regions of natural occurrence. This species has two widely separated areas of occurrence: Cape York Peninsula, Queensland; and from near Fraser Island, Queensland, to south of Bateman's Bay, New South Wales

Latitudinal range. 12°-18°S (the first area); and 27°-36°S (the second area)

Altitudinal range. Up to 800 m

Rainfall

Type: uniform to summer rainfall
Total: 900-2 400 mm
Dry season: rarely significant

Temperature

Mean maximum of hottest month: 24-33°C
Mean minimum of coldest month: 12-16°C
Frosts: rare in south, absent in north

Characteristics

Tree height in Australia: up to 47 m; a good trunk and a heavily branched crown

Bark type: shortly fibrous, rough to small branches
Juvenile leaves: opposite then sub-opposite, stalked, lanceolate
Adult leaves: alternate but sometimes reverting to sub-opposite, stalked, sometimes slightly falcate
Wood: red to dark red, moderately heavy, strong and durable; density 990 km/m³
Buds and fruits: Figure a7-75 (73)
Viable seeds per gram: 69

Uses. A wide range of building and heavy construction uses

Prospects for planting. This species could be important to planting countries. The southern form is a scattered insignificant tree which probably provided the seed used in planting outside Australia. The northern form is a useful low-latitude eucalypt (12°-18°S). Good provenances of the northern form could provide the basis for important new eucalypt trials in tropical countries in future years.

Success outside Australia. The tree known under this name in Brazil has done quite well, but the crop is irregular. It is very promising in coastal northeast Brazil.

E. pilularis Sm.

Refs. Blakely No. 306 Code MAIAA FTA p. 154

Common name in Australia. Blackbutt

Regions of natural occurrence. Along the coast and coastal ranges of New South Wales and southern Queensland, with a very small extension to eastern Victoria. It is typically a tree of the slopes, growing on sandy loams or loams but able to adapt to clays and volcanic soils.

Latitudinal range. 25°-37.5°S

Altitudinal range. Sea-level to 700 m

Rainfall

Type: uniform to summer rainfall
Total: 1 000-1 500 mm
Dry season: 3-4 months, not usually severe

Temperature

Mean maximum of hottest month: 29-32°C
Mean minimum of coldest month: 5-6°C
Frosts: 5-15

Characteristics

Tree height in Australia: up to 60 or 70 m; usually a very good trunk and crown
Bark type: rough, grey-brown, fibrous over most of trunk, smooth above
Juvenile leaves: opposite then alternate, stalkless or very shortly stalked;

green on upper surface but a characteristic purplish bloom on the under surface. This is a marked character of the species.
Adult leaves: alternate, stalked, lanceolate, occasionally asymmetric
Wood: light yellowish brown, hard, strong, moderately durable; density 720-1 000 kg/m^3
Buds and fruits: Figure a7-76 (306)
Viable seeds per gram: 55

Uses. One of the three most important hardwoods in Australia. An excellent forest tree to manage in Australia, with few problems in enrichment planting or plantations.

Prospects for planting. Some of the best individual eucalypts outside Australia are of this species, but it is not as easy to handle in the nursery as *E. grandis/saligna* and is not classed as a reliable coppicing species in South Africa. Its de-barking qualities are good.

Success outside Australia. Success as individuals in several countries but not popular as an industrial coppice crop. It is successful in Hawaii on sites with a rainfall of 1 500-2 000 mm but fails on wetter sites. It makes an excellent sawtimber in Hawaii. In Nigeria it shows promise in the northern Guinea zone. In Brazil it is successfully planted on a small scale in parts of the humid, cool subtropical zone and is under trial in some other zones. In provenance trials at Mogi Guaçu, a typical savanna area, Australian provenances were consistently superior to Brazilian seed sources from Rio Claro, but there were no significant differences between the Australian provenances (Pasztor, 1978a). In trials carried out in Australia, on the other hand, there were marked differences between provenances (Burgess, 1973b).

E. polyanthemos Schau.

Refs. Blakely No. 558 Code SUT:D FTA p. 244

Common name in Australia Red box

Regions of natural occurrence. Southern New South Wales and Victoria on the inland slopes of the Great Dividing Range, usually growing on the harder sites and soils

Latitudinal range. 33°-38.5°S

Altitudinal range. 150-700 m

Rainfall

Type: winter or uniform rainfall
Total: 500-750 mm
Dry season: up to 6 months, can be severe

Temperature

Mean maximum of hottest month: 27-32°C
Mean minimum of coldest month: 3-4°C
Frosts: 10-50

Characteristics

Tree height in Australia: up to 25 m; a shortish trunk and a good crown
Bark type: shed from trunk and branches in irregular flakes and short strips, leaving a mottled grey, cream and pinkish surface
Juvenile leaves: firstly opposite, then stalked and orbicular
Adult leaves: alternate, stalked, ovate or lanceolate, grey-green on both surfaces
Wood: red, fine-textured, interlocked grain, tough; density 850-1 200 kg/m^3; dries slowly and difficult to season, good fuelwood
Buds and fruits: Figure a7-77 (558)
Viable seeds per gram: 383

Uses. Useful farm timber; frequently an attractive grey-green tree. A good honey tree.

Prospects for planting. Limited; there are better species for most purposes

Success outside Australia. Rather poor results outside Australia

Refs. Blakely No. 464 Code SUNED FTS No. 5

E. polybractea R.T. Bak. (includes part of E. fruticetorum F. Muell. ex Miq.)

Common name in Australia. Blue-leafed mallee

Regions of natural occurrence. Central west New South Wales, central Victoria

Latitudinal range. 34°-36.5°S

Altitudinal range. 150-300 m

Rainfall

Type: winter to uniform rainfall
Total: 400-500 mm
Dry season: 8 months, can be severe

Temperature

Mean maximum of hottest month: 30°C
Mean minimum of coldest month: 3°C
Frosts: up to 10

Characteristics

Tree height in Australia: up to 10 m; it has a mallee form
Bark type: slightly rough, subfibrous
Juvenile leaves: shortly stalked, alternate after few early pairs, linear
Adult leaves: alternate, stalked, linear-lanceolate
Wood: hard and strong; was used for spear shafts
Buds and fruits: Figure a7-78 (464)
Viable seeds per gram: 766

Uses. Used for distillation of essential oils; high cineole content

Prospects for planting. Limited unless for essential oils. There are several requests for seed for this purpose.

Success outside Australia. Not fully known, but being grown in some countries for its oils

E. populnea F. Muell. (syn. E. populifolia Hook.)

Refs. Blakely No. 501 Code SUDEAA FTA p. 238

Common name in Australia. Bimble box

Regions of natural occurrence. Inland Queensland and New South Wales; a wide occurrence. Grows on flats likely to be flooded in the wet season and to dry out and crack in the dry season.

Latitudinal range. 23°-26°S

Altitudinal range. 150-500 m

Rainfall

Type: uniform to summer rainfall
Total: 350-500 mm
Dry season: up to 8 months, can be severe

Temperature

Mean maximum of hottest month: 33°C
Mean minimum of coldest month: 5°C
Frosts: 15

Characteristics

Tree height in Australia: up to 25 m; a reasonably good short trunk and a compact crown
Bark type: box bark, subfibrous; persistent on trunk and larger branches
Juvenile leaves: opposite first, then alternate, shortly stalked, ovate to orbicular
Adult leaves: alternate, stalked, diamond shaped, ovate or sub-orbicular, shining
Wood: pale brown, hard, strong and durable
Buds and fruits: Figure a7-79 (501)
Viable seeds per gram: 1 790

Uses. Useful for shade and ornament. Useful for pastoral purposes.

Prospects for planting. A useful tree for black cracking soils in hot areas

Success outside Australia. Not reported

E. propinqua Deane & Maid. var. propinqua

Refs. Blakely No. 75 Code SECEA FTA p. 68

Common name in Australia. Grey gum

Regions of natural occurrence. Northern New South Wales and southern Queensland, such as the Blackdown tableland, growing on lower slopes

Latitudinal range. 24°-33°S

Altitudinal range. Near sea-level to 350 m

Rainfall

Type: summer rainfall
Total: 875-1 400 mm
Dry season: 4 months, not usually severe

Temperature

Mean maximum of hottest month: 27-33°C
Mean minimum of coldest month: 4-10°C
Frosts: 1-10

Characteristics

Tree height in Australia: up to 35 or 40 m; a good trunk and crown
Bark type: shed from trunk in large irregular scales; smooth; grey-gum type
Juvenile leaves: first opposite, then alternate, stalked, ovate to lanceolate
Adult leaves: alternate, stalked, lanceolate
Wood: red to red-brown, uniform texture, very hard and strong, durable; density 1 060 kg/m^3
Buds and fruits: Figure a7-80 (75)
Viable seeds per gram: 425

Uses. One of the prime structural timbers of Australia

Prospects for planting. A good planting prospect, particularly for poles and sawtimber

Success outside Australia. Plantations of *E. propinqua* in Brazil are good and very even, which is an asset at harvesting and in successive coppice rotations. The species does not appear to present any hybridization problem. The species gave fair results in South Africa but is not a preferred species there.

E. pulchella Desf. (syn. E. linearis Dehnh.)

Refs. Blakely No. 405 Code MATEG FTS No. 55

Common name in Australia. White peppermint

Regions of natural occurrence. Southern Tasmania, mainly on lowlands

Latitudinal range. 42°-43.5°S

Altitudinal range. 150-500 m

Rainfall

Type: winter rainfall
Total: 600-700 mm
Dry season: not severe

Temperature

Mean maximum of hottest month: 21°C
Mean minimum of coldest month: 1-4°C
Frosts: up to 50

Characteristics

Tree height in Australia: up to 25 m; fine drooping branches
Bark type: gum type, decorticating in short or elongated strips
Juvenile leaves: opposite to sub-opposite, becoming alternate, sessile, connate to shortly stalked, more or less glaucous, later linear
Adult leaves: alternate, shortly stalked, linear to rarely linear-lanceolate
Wood: light brown, fairly heavy, used for pulpwood and fuelwood
Buds and fruits: Figure a7-81 (405)
Viable seeds per gram: 88

Uses. Excellent for ornamental planting; used as pulpwood and fuelwood

Prospects for planting. Good as an ornamental tree that does not grow to too large a size

Success outside Australia. Succeeding as an ornamental in several countries

E. pulverulenta Sims

Refs. Blakely No. 245 Code SPINQ FTS No. 28

Common name in Australia. Silver-leafed mountain gum

Regions of natural occurrence. Several mountain regions in New South Wales

Latitudinal range. 33.5°-36°S

Altitudinal range. 900-1 000 m

Rainfall

Type: uniform rainfall
Total: 760-900 mm
Dry season: not severe

Temperature

Mean maximum of hottest month: 26°C
Mean minimum of coldest month: 0°C
Frosts: 50

Characteristics

Tree height in Australia: up to 10 m; a small tree
Bark type: gum type, smooth, light coloured
Juvenile leaves: opposite and decussate; sessile and adhering to stem, glaucous
Adult leaves: on larger trees becoming alternate, broadly lanceolate, glaucous
Wood: properties not known
Buds and fruits: Figure a7-82 (245)
Viable seeds per gram: 318

Uses. A popular ornamental

Prospects for planting. Good as an ornamental

Success outside Australia. Successful as an ornamental in England, southern Brazil and California

E. punctata DC. var. punctata

Refs. Blakely No. 78 Code SECEDA FTA p. 70

Common name in Australia. Grey gum

Regions of natural occurrence. Central New South Wales coast and coastal ranges, extending to the Carnarvon Ranges in central southern Queensland. Grows on low hills and ridges, not exacting with regard to soils.

Latitudinal range. 32°-35°S

Altitudinal range. Near sea-level to 1 000 m

Rainfall

Type: uniform to summer rainfall
Total: 625-1 250 mm
Dry season: 4 months, not usually severe

Temperature

Mean maximum of hottest month: 27-32°C
Mean minimum of coldest month: 4-5°C
Frosts: few, not severe

Characteristics

Tree height in Australia: up to 35 m; a short or moderate trunk and fair crown
Bark type: shed from trunk in large irregular scales; smooth; grey-gum type
Juvenile leaves: opposite, then alternate, stalked, variable shape and size — linear to broadly lanceolate
Adult leaves: alternate, stalked, lanceolate
Wood: heavy, hard and durable

Buds and fruits: Figure a7-83 (78)
Viable seeds per gram: 81

Uses. A good construction timber, not quite as good as *E. propinqua*

Prospects for planting. Limited. *E. propinqua* would be recommended rather than *E. punctata.*

Success outside Australia. Fairly good in Brazil

E. pyriformis Turcz.

Refs. Blakely No. 600 Code SIVEM Chipp. p. 128

Common name in Australia. Pear-fruited mallee

Regions of natural occurrence. Western Australia to the northeast of Perth, growing on sandy soil in flat or gently undulating heathland

Latitudinal range. 30°-32°S

Altitudinal range. Up to 150 m

Rainfall

Type: winter rainfall
Total: 280-400 mm
Dry season: 7 months, severe

Temperature

Mean maximum of hottest month: 38°C
Mean minimum of coldest month: 2-4°C
Frosts: 2-7

Characteristics

Tree height in Australia: up to 4-6 m; mallee form
Bark type: smooth, decorticating in strips
Juvenile leaves: alternate, stalked, ovate-lanceolate
Adult leaves: opposite first then alternate, lanceolate to ovate-lanceolate
Wood: hard, heavy, durable
Buds and fruits: Figure a7-84 (600) (bud only)
Viable seeds per gram: 36

Uses. Valuable in its natural occurrence for environmental purposes; very ornamental

Prospects for planting. Good as an ornamental

Success outside Australia. Grown as an ornamental in New Zealand; California

E. radiata Sieb. ex DC. subsp. radiata (syn. E. australiana R.T. Bak. & H.G. Sm.)

Refs. Blakely No. 411 Code MATELA FTS No. 3

Common name in Australia. Narrow-leafed peppermint

Regions of natural occurrence. Uplands and tablelands of Victoria and New South Wales in mixed forest on a variety of soils. One of the few eucalypts that make an attractive understorey in the better mountain forests of eastern Australia.

Latitudinal range. 30°-38.5°S

Altitudinal range. 150-1 000 m

Rainfall

Type: winter to uniform rainfall
Total: 625-1 250 mm
Dry season: 4 months, not severe

Temperature

Mean maximum of hottest month: 23°C
Mean minimum of coldest month: 0-5°C
Frosts: 15-80

Characteristics

Tree height in Australia: up to 25 m; a short trunk and a spreading and drooping crown
Bark type: typical peppermint; fibrous on trunk and larger branches
Juvenile leaves: opposite, sessile
Adult leaves: alternate or sub-opposite, stalked, lanceolate
Wood: pale pink or light brown; open texture, straight-grained but with many gum veins
Buds and fruits: Figure a7-85 (411)
Viable seeds per gram: 106

Uses. Valuable for shelter and ornament; wood used for light construction and joinery. Eucalypts now considered to be provenances of *E. radiata*, such as *"E. phellandra"* which yields 3-4.5 percent of a pale-coloured oil, and *E. radiata* var. *australiana* which yields 2.5-5 percent of an oil containing 70 percent or more of cineole, are valuable provenances. The provenances must be expertly selected.

Prospects for planting. Limited except for essential oil production from provenances selected by experts

Success outside Australia. E. radiata subsp. *radiata* has been grown successfully in several countries. It is a good coppicing species, so a useful provenance for essential oils could be reproduced by annual coppice cuts.

E. radiata Sieb. ex DC. subsp. robertsonii (Blakely) L. Johnson & D. Blaxell (previously E. robertsonii Blakely)

Refs. Blakely No. 407 Code MATELC FTA p. 204

Common name in Australia. Narrow-leafed peppermint

Regions of natural occurrence. On the inland slopes of the Great Dividing Range in southern New South Wales and northern Victoria; also on northern coast of Tasmania. It grows on slopes and in sheltered valleys on good soils. It is frequently an attractive understorey to more vigorous species.

Latitudinal range. Mainland 33°-37°S; Tasmania 41°S

Altitudinal range. 150-1 000 m

Rainfall

Type: winter or uniform rainfall
Total 625-1 250 mm
Dry season: up to 4 months, not severe

Temperature

Mean maximum of hottest month: 23°C
Mean minimum of coldest month: 0-5°C
Frosts: 15-80

Characteristics

Tree height in Australia: up to 25 m; a rather short straight trunk with an attractive weeping crown
Bark type: peppermint
Juvenile leaves: opposite, sessile
Adult leaves: alternate or sub-opposite, stalked, lanceolate
Wood: pale pink, open textured, with many gum veins
Buds and fruits: Figure a7-86 (407)
Viable seeds per gram: 75

Uses. As for *E. radiata* subsp. *radiata*

Prospects for planting. As for subsp. *radiata*; requires expert selection of provenances if wanted for essential oils

Success outside Australia. Is used for essential oils

E. raveretiana F. Muell.

Refs. Blakely No. 438 Code SBA:C FTA p. 218

Common name in Australia. Black ironbox

Regions of natural occurrence. Coast and inland ranges of central Queensland, growing on fertile soils on stream banks or on the edge of rain forests

Latitudinal range. 19.5°-24.5°S

Altitudinal range. Near sea-level to 300 m

Rainfall

Type: summer rainfall
Total: 750-1 500 mm
Dry season: 6-7 months, can be severe

Temperature

Mean maximum of hottest month: 30-35°C
Mean minimum of coldest month: 10°C
Frosts: nil

Characteristics

Tree height in Australia: 15-25 m; a short bole and a spreading open crown
Bark type: box-like bark on trunk and larger branches; on smaller branches there is a smooth bark of a dirty bluish colour
Juvenile leaves: opposite first, then alternate, stalked, broadly ovate to sub-orbicular
Adult leaves: alternate, stalked, lanceolate
Wood: dull, brownish black, very heavy, very hard and durable but somewhat brittle
Buds and fruits: Figure a7-87 (438)
Viable seeds per gram: N.A.

Uses. It has been used for railway sleepers, light and heavy construction and fencing

Prospects for planting. As a companion with *E. microtheca* in irrigated plantations in very dry climates.

Success outside Australia. Not reported. It is surprising that this species has not been tried more.

Refs. Blakely No. 369 Code MAKCA FTA p. 182

E. regnans F. Muell.

Common name in Australia. Mountain ash (swamp gum in Tasmania)

Regions of natural occurrence. Tasmania and Victoria; growing on good soils in sheltered valleys or on slopes. Frequently the only tree species over tree ferns and other species which take part in the succession following catastrophic fires (for natural variation, see Eldridge, 1972).

Latitudinal range. 37°-43.5°S

Altitudinal range. Near sea-level in Tasmania to 900 m in Victoria

Rainfall

Type: winter rainfall
Total: 750-1 650 mm
Dry season: not severe

Temperature

Mean maximum of hottest month: 23°C
Mean minimum of coldest month: 0-2°C
Frosts: few to 80

Characteristics

Tree height in Australia: up to 90 m or more; a magnificent trunk and a crown which seems to be small but is substantial when measured
Bark type: rough and fibrous at base, deciduous on upper trunk, decorticating in long strips
Juvenile leaves: first opposite, then alternate, shortly stalked, broadly lanceolate
Adult leaves: alternate, stalked, narrow-lanceolate, curved, slightly oblique at base
Wood: pale brown, open texture, straight, prominent growth rings, moderately strong but not durable; density 580-800 kg/m^3
Buds and fruits: Figure a7-88 (369)
Viable seeds per gram: 181

Uses. One of the most important hardwoods in Australia as sawnwood for construction and joinery purposes, and for groundwood and other pulping purposes. The *E. regnans* forest is a magnificent forest and the tallest hardwood forest in the world.

Prospects for planting. Good in suitable winter-rainfall climates. The species can be planted bare-rooted but requires careful handling. See notes on nursery handling.

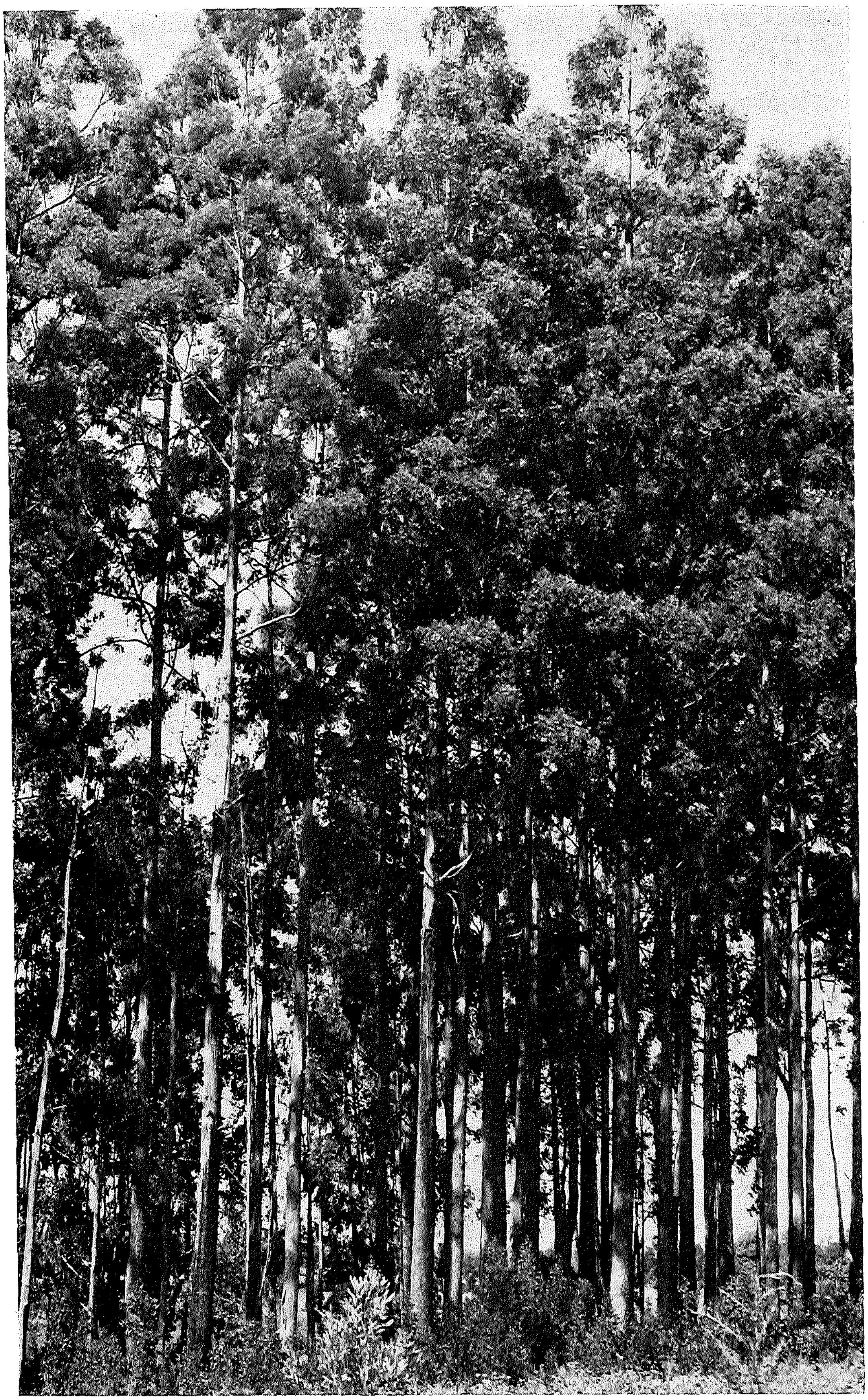
Success outside Australia. *E. regnans* is an important production forest species in New Zealand where it has been grown for several decades. Plantations have been successfully grown, utilized and re-established in the South Island. On pumice soils in high rainfall areas in the North Island, *E. regnans* must be carefully sited to avoid frost hollows, and preferably fertilized; if this is done it grows faster than *Pinus radiata* of high quality and produces at least 25 m^3/ha per year. In South Africa, *E. regnans* has been grown successfully on the southern coastline close to very good plantations of *E. diversicolor*, but there is not enough land to make significant industrial plantations of sawtimber and it is not a coppicing species. In Kenya, on the equator, but at about 3 000 m altitude, a small plantation of *E. regnans* had a top height of 80 m in 30 years.

E. resinifera Sm.

Refs. Blakely No. 69 Code SECCC FTA p. 64

Common name in Australia. Red mahogany

Regions of natural occurrence. The principal occurrence is on coastal areas and ranges in northern New South Wales and southern Queensland; occasionally as far north as the Atherton tableland in Queensland. It grows



58. 42-year-old plot of *E. regnans* at south Kinangop, Kenya. This species does not coppice, but note profuse regeneration from seed
W.G. Dyson

in the better sclerophyll forests in association with such species as *E. pilularis* and *E. microcorys.*

Latitudinal range. 17°-34°S

Altitudinal range. Sea-level to 600 m

Rainfall

Type: summer rainfall in north to uniform rainfall in the south
Total: 1 350-1 500 mm
Dry season: 4 months, not severe

Temperature

Mean maximum of hottest month: 27-32°C
Mean minimum of coldest month: 4-5°C
Frosts: 5-10

Characteristics

Tree height in Australia: up to 45 m; a good bole and a compact crown
Bark type: persistent to small branches, fibrous, stringy, red-brown
Juvenile leaves: opposite, then alternate, shortly stalked, narrow-lanceolate
Adult leaves: alternate, stalked, lanceolate
Wood: dark red, moderately open textured; interlocked grain; hard, strong and tough, moderately durable; density 960 kg/m^3
Buds and fruits: Figure a7-89 (69)
Viable seeds per gram: 163

Uses. Widely in demand for house construction, ship-building and railway sleepers. One of the best Australian hardwoods.

Prospects for planting. Very good; easy to handle in establishment, vigorous growth; classified as a good coppicing species in South Africa but difficult to debark in the winter. A problem is that it hybridizes readily with other species of the subgenus *Symphyomyrtus.*

Success outside Australia. Very successful in Argentina, Brazil, Hawaii, Kenya, South Africa and Sri Lanka. Seed collected from plantations of *E. resinifera, E. grandis, E. urophylla, E. robusta* and some other members of the subgenus *Symphyomyrtus* which have been planted close to each other are likely to have a proportion of hybrid seed. Plantations based on this seed may be good but the trees tend to be irregular in size, large trees being mixed with small ones. The total volume production of the plantation may be satisfactory but the irregularity in size may introduce a harvesting problem which can be accentuated in successive coppice crops. The influence of *E. resinifera* in hybrid crops introduces a red tendency in the wood; it may also add some increased durability if that quality is desired by the grower, but in general the hybrid plantations are not as good as pure plantations.

E. robusta Sm. (syn. E. multiflora Poir)

Refs. Blakely No. 67 Code SECAP FTA 62

Common name in Australia. Swamp mahogany

Regions of natural occurrence. Coastal regions of New South Wales and southern Queensland. In the narrow zone of its natural occurrence, down the southern Queensland and New South Wales coasts, *E. robusta* can only maintain itself in the valley bottoms and swamps which give it the name "swamp mahogany." The tree does not *prefer* these conditions and, if artificially assisted in the better soils of the lower slopes outside the swamps, it grows much faster than when in the swamps, but it cannot maintain itself against the vigorous eucalypts of the mixed forest such as *E. pilularis, E. saligna* and *E. grandis.* This is not a matter of relative resistance to fire, because *E. robusta* recovers from the worst Australian holocausts, shooting from relatively small branches a few centimetres in diameter.

Latitudinal range. 23°-36°S

Altitudinal range. The natural occurrence is close to sea-level, mainly on wet valley soils and freshwater swamps

Rainfall

Type: uniform rainfall from the southernmost occurrence up to Taree in New South Wales, then summer rainfall north of Taree
Total: 1 000-1 500 mm
Dry season: up to 4 months, not usually severe

Temperature

Mean maximum of hottest month: 30-32°C
Mean minimum of coldest month: 3-5°C
Frosts: up to 5 or 10, not severe

Table 14.9 Distribution of rainfall (mm) for *E. robusta*

	Alt. (m)	J	F	M	A	M	Jn	Jl	A	S	O	N	D	Total
Gympie, Qnsld. (Lat. 26.2°S)	78	163	171	161	86	71	62	52	40	50	71	86	135	1 148
Taree, N.S.W. (Lat. 31.9°S)	8	123	144	144	123	92	98	84	68	65	69	77	105	1 192
Bateman's Bay (Lat. 35°S)	13	98	93	100	98	106	103	75	60	62	70	70	86	1 021

Characteristics

Tree height in Australia: up to 30 m; a rather short trunk and a heavy crown
Bark type: rough, flaky, persistent to smaller branches
Juvenile leaves: opposite first then alternate, stalked, lanceolate or ovate-lanceolate
Adult leaves: alternate, stalked, broadly lanceolate
Wood: light red to reddish brown, coarse textured, moderately hard, strong and durable; density 770 kg/m^3
Buds and fruits: Figure a7-90 (67)
Viable seeds per gram: 415

Uses. The wood is used for general construction but is in limited supply in Australia; it is difficult to season

Prospects for planting. E robusta does not have a very wide range in its natural occurrence, but it is a remarkably plastic species which adapts to varied conditions from equatorial regions to about latitude 35°, provided frosts are not severe. A difficulty is that it hybridizes readily with many other species of the subgenus *Symphyomyrtus*, and the hybrids may not be an improvement on either parent. *E. robusta* has a dense crown and makes a good roadside shade tree. The large leaves are oriented much more in a horizontal plane than most eucalypts and this improves overhead shade.

E. robusta and *E. camaldulensis* have a common characteristic in Australia. Each regenerates in freshwater flooded areas and their roots appear to be able to penetrate the heavy gley clays found in these conditions and reach aerated soils below. This growth habit also appears to help them establish themselves on difficult but not necessarily flooded soils in localities widely different from their normal habitat. Each can throw aerial roots from the trunk. *E. robusta* does it frequently in Hawaii, Uganda and Brazil, sometimes from many metres up the trunk, like a jungle fig. This phenomenon has also been reported in the case of *E. camaldulensis* (Jacobs, 1955) and *E. deglupta* (Davidson, 1974).

Success outside Australia. E. robusta is one of the most widely planted eucalypts. In low-latitude countries it grows vigorously in Hawaii, Sri Lanka, Brazil, Fiji, Madagascar, Malaysia and the Congo. In middle latitudes it thrives in the Mediterranean and South Africa. Extensive plantations were reported by Madagascar (150 000 ha), Mozambique, Papua New Guinea (483 ha), Sri Lanka (800 ha) and Hawaii. Promising trials were reported by Argentina, the Comoros, Ethiopia, Malaysia, the Philippines and Tanzania (along the coast). Failures with *E. robusta* were reported by Colombia Zone E, Cyprus, Ghana, Greece, Israel Zone B, and the Ivory Coast Zone A. *E. robusta* planted at Zaria, northern Nigeria (1 113 mm rainfall, 5- to 6-month dry season) grew well for 3-4 years and then, as the canopy closed, began to die off. This appeared to be due to dry season water availability being insufficient to maintain the transpiration of a dense canopy.

In Hawaii, *E. robusta* does well on a wide variety of sites. There are extensive plantations in areas with both evenly and seasonally distributed rainfall varying from 750 mm to 7 500 mm, and at elevations varying from 100 m to 1 200 m, in swamps, deep well-drained soils, shallow histosols and eroded hillsides. The tree does well everywhere except where rainfall is below 900 mm, on impoverished former agricultural land, or where exposed to strong trade winds. It coppices well up to age 25, poorly thereafter. It is used for both sawnwood (preferred over *E. saligna* because it has less growth stress problems) and as a pulpwood. It is not as good pulpwood as *E. globulus* or *E. saligna.*

In the well-known Muguga research plots in Kenya, *E. robusta* has not been happy, mainly due to wind, all trees being wind-bent and with other signs of wind damage. Early vigour was quite good but deteriorated with age. At age 18 the dominant height is 17.0 m and the mean diameter 16.7 cm. Flowering and fruiting started at age 2 and have continued profusely. Natural regeneration is dense. The crop was heavily attacked by *Gonipterus scutellatus* at ages 7 and 8 years.

E. robusta was planted in southern Florida, United States, before 1900 by homesteaders wanting to establish early protection around homesites. Many eucalypts were experimented with but only a few showed promise for timber production. Of these, *E. robusta* displayed wide site adaptability, relatively fast growth and good form. In 1966 it was chosen for an accelerated programme of genetic improvement for pulpwood production. This programme has been interesting and successful, in spite of a severe frost which killed the growing tips of smaller trees. It is of interest that taller trees, whose crowns were above the inversion layer that trapped cold air near the ground at the time of the frost, were not damaged. There was significant variation between the families of *E. robusta* being investigated and the test programme shows considerable promise. Of interest also was the preference of experimenters for summer planting. The chance of a killing frost in winter is greater than the chance of a killing drought in summer. If *E. robusta* seedlings die back because of summer drought, they are likely to sprout again and recover.

E. rudis Endl.

Refs. Blakely No. 204 Code SNEER FTA p. 102

Common name in Australia. Western Australian flooded gum

Regions of natural occurrence. Southwest Western Australia from north of Geraldton to the far south. Associated with moist flats and banks of streams.

Latitudinal range. 27.5°-34.5°S

Altitudinal range. Sea-level to 220 m

Rainfall

Type: winter rainfall
Total: 450-900 mm
Dry season: up to 5 months, not usually severe

Temperature

Mean maximum of hottest month: 28-35°C
Mean minimum of coldest month: 4-11°C
Frosts: 5 or more

Characteristics

Tree height in Australia: up to 20 m; usually with a short trunk and wide-spreading crown
Bark type: flaky, rough, persistent on the trunk and larger branches, grey in colour
Juvenile leaves: opposite first then alternate, stalked, broadly ovate to sub-orbicular
Adult leaves: alternate, stalked, lanceolate
Wood: pale brown to reddish, heavy, hard, cross-grained, low durability
Buds and fruits: Figure a7-91 (204)
Viable seeds per gram: 604

Uses. The species occurs mainly in farming country and has been used for farming purposes. It is not a commercial timber in Australia.

Prospects for planting. *E. rudis* has been planted in several countries and has done reasonably well. There are probably other relatives, or provenances of *E. camaldulensis* and *E. tereticornis*, which would be better prospects.

Success outside Australia. Reasonable success in several countries

E. saligna Sm. *Refs.* Blakely No. 60 Code SECAC FTA p. 56

Common name in Australia. Sydney blue gum

Regions of natural occurrence. Catchments of coastal and tableland rivers flowing into the Pacific Ocean in south Queensland and most of New South Wales

Latitudinal range. 28°-35°S

Altitudinal range. In the south of its range the species occurs from sea-level to about 300 m, being mainly a tree of fertile valleys. In the northern part of its range in New South Wales and southern Queensland it extends to the higher slopes and ridges to an altitude of up to 1 000 m. In mid-northern New South Wales it may have occasional falls of snow in the higher occurrences.

Rainfall

Type: uniform rainfall in the south to summer rainfall north of Taree in New South Wales
Total: 800-1 200 mm or more in the summer-rainfall region, up to 800 or more in the uniform rainfall region
Dry season: not severe, up to 4 months

Temperature

Mean maximum of hottest month: 28-30°C
Mean minimum of coldest month: 3-4°C
Frosts: 5-15

Characteristics

Tree height in Australia: up to 55 m; with straight bole half to two thirds of total height
Bark type: upper bark mainly smooth but with a stocking of persistent rough bark extending up to a few metres up the trunk
Juvenile leaves: opposite first, then alternate, shortly stalked, lanceolate
Adult leaves: alternate, stalked, lanceolate
Wood: red or pink, hard, stiff, coarse textured, moderately durable; easy to work and takes a good polish
Buds and fruits: Figure a7-92 (60)
Viable seeds per gram: 560

Uses. An important general-purpose hardwood in Australia

Prospects for planting. Excellent at latitudes between 25° and 35° or at higher altitudes in lower latitudes; a first-class species for short coppice rotations

Success outside Australia. Successfully used in many countries. The term "saligna gum" frequently covers either *E. saligna* or *E. grandis.* As explained under *E. grandis, E. saligna* was named in 1797 and *E. grandis* in 1918. For 121 years seeds sent out from Australia as "*E. saligna*" could have been either species. Methods of deciding which species any individual tree may happen to be are discussed under *E. grandis.* There would appear to be at least half a million hectares of successful *E. saligna* plantations outside Australia. There are many very good plantations between latitudes 25° and 35°S that are undoubtedly true *E. saligna.* It is classed as an important plantation species in Angola (50 000 ha planted), Argentina (20 000 ha planted of which some is *E. grandis*), Brazil (500 000 ha planted), Morocco (2 600 ha planted, including *E. grandis*), Mozambique, Tanzania (more than 1 000 ha planted) and Uruguay (10 000 ha planted).

Interest is shown and promising small trial plantations have been established in China, Cuba, Ethiopia, Greece, Indonesia, Kenya, Malaysia, New Zealand, Panama, the Philippines, Sierra Leone, Turkey and the United States.

In Hawaii it is the fastest growing eucalypt in spite of the rather low latitude; the best volume growth in unfertilized plots is 50 m^3/ha/yr, and 42 m^3/ha/yr are commonly obtained. The tallest tree is 71 m in height. Growth stress problems limit its use for sawtimber in Hawaii.

South Africa has very good plantations of true *E. saligna*, quite apart from their very large plantations of "saligna gum" which are mainly *E. grandis.*

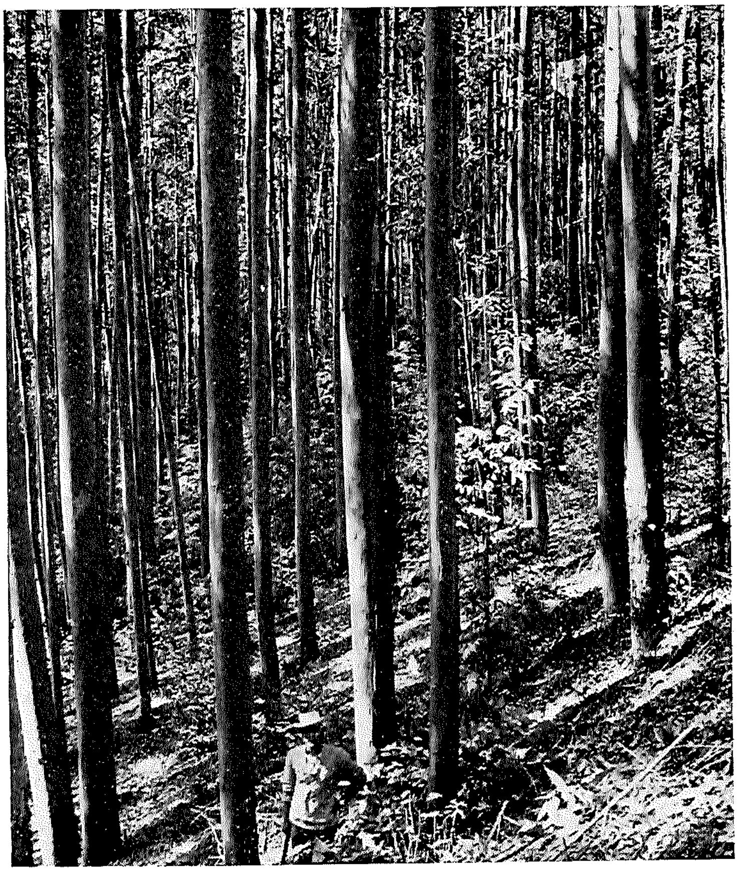
E. saligna is reported to have failed in the Central African Republic, Chad, Zones E & D of Colombia, the Congo, Italy, the Ivory Coast and Zambia.

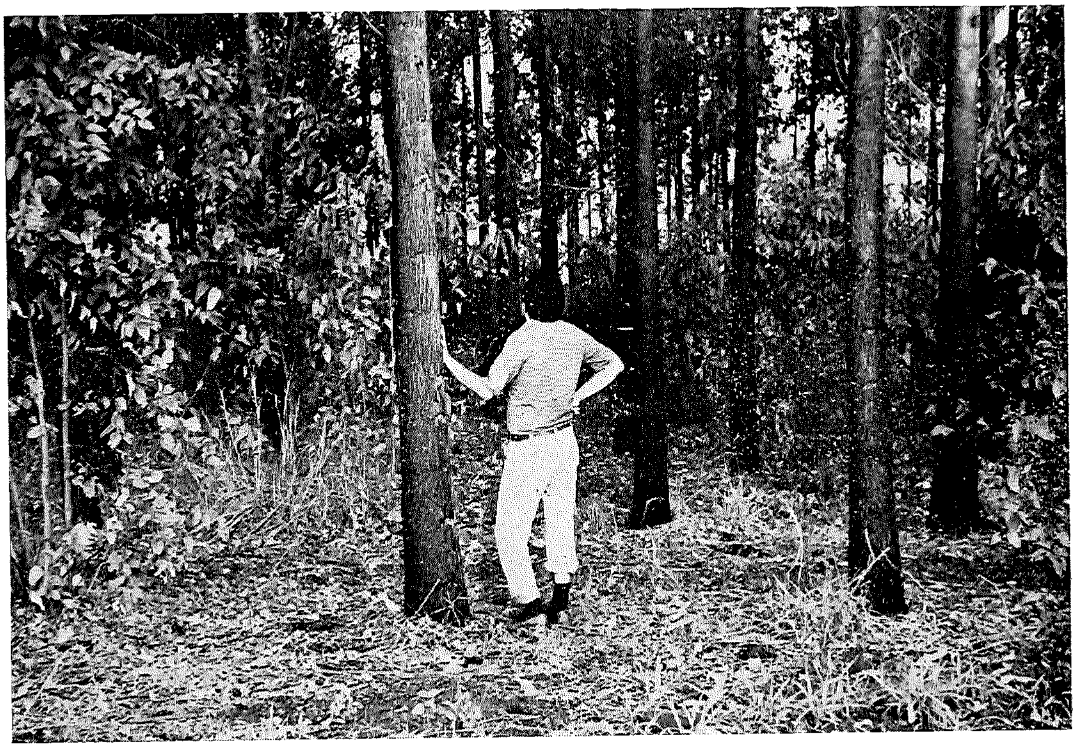
E. salmonophloia F. Muell.

Refs. Blakely No. 593 Code SIU:A FTA p. 266

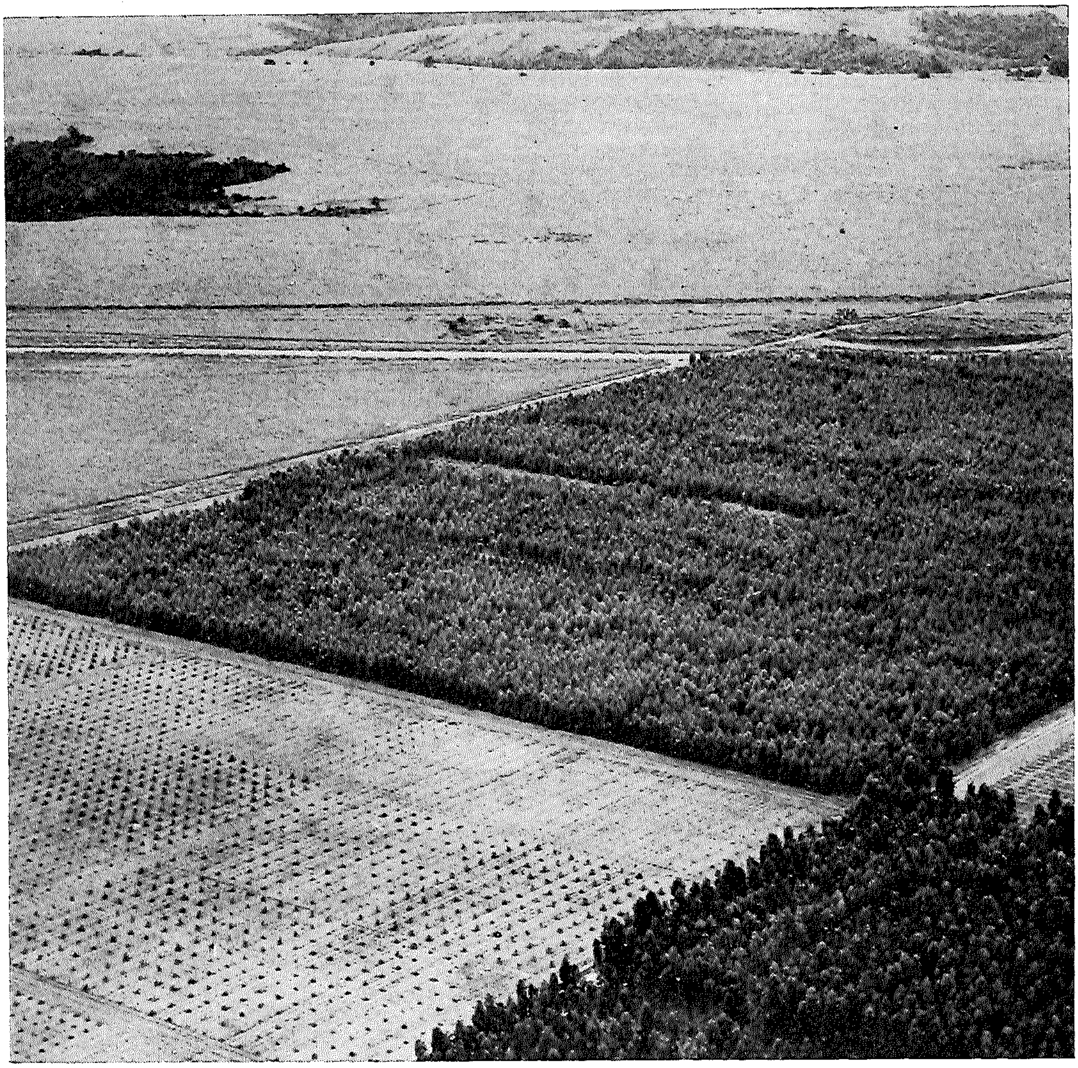
Common name in Australia. Salmon gum

59. 22-year-old plantation of *E. saligna* at Nova Friburgo, Brazil; well adapted and of good stem form
L. Golfari





60. 5-year-old seed stand of *E. urophylla* at Piracicaba, Brazil. Seed origin, Dilli, Timor
M. Ferreira



61. Aerial view of provenance trials of *E. urophylla,* aged 1 year, at Pointe-Noire, the Congo, with current year's trials in foreground
Centre technique forestier tropical, Nogent-sur-Marne

Regions of natural occurrence. Around the goldfields and inland wheat country of Western Australia

Latitudinal range. 29.5°-33.5°S

Altitudinal range. 300-400 m

Rainfall

Type: irregular storm rains
Total: 200-500 mm
Dry season: irregular dry periods of several months, can be severe

Temperature

Mean maximum of hottest month: 32-35°C
Mean minimum of coldest month: 4°C
Frosts: up to 10

Characteristics

Tree height in Australia: 25 or even 30 m; remarkably good trunk for the climate; crown rather thin
Bark type: smooth, salmon pink with light grey patches
Juvenile leaves: opposite, then alternate, stalked, narrowly lanceolate
Adult leaves: alternate, stalked, narrowly lanceolate
Wood: red to red-brown, straight grained, very strong, durable; density 1 070 kg/m^3
Buds and fruits: Figure a7-93 (593)
Viable seeds per gram: 590

Uses. This remarkable species was milled for local construction on the goldfields but is now used mainly in the round for mining timbers, light railway sleepers and fuel. A valuable shelter tree in dry areas.

Prospects for planting. It makes a very good woodland for such a low rainfall. The best growth is on fertile red clay loams but it is satisfactory over a range from sandy loams to rather heavy clays. Useful for shelter-belt or avenue planting in rainfalls as low as 200 mm.

Success outside Australia. Moderately successful in Mediterranean countries, but sensitive to frost. It failed in Brazil, but did better in South Africa. The species has not been widely tried.

E. salubris F. Muell.

Refs. Blakely No. 594 Code SIK:A Chipp. p. 79

Common name in Australia. Gimlet. The name alludes to the twisted, fluted nature of the trunk.

Regions of natural occurrence. Widely spread over inland southwest Western Australia

Latitudinal range. 32°-34°S

Altitudinal range. 300-400 m

Rainfall

Type: winter rainfall or storm rains
Total: 250-400 mm
Dry season: irregular dry periods of several months, can be severe

Temperature

Mean maximum of hottest month: 32-35°C
Mean minimum of coldest month: 4°C
Frosts: up to 10

Characteristics

Tree height in Australia: up to 20 m; a shortish trunk and a spreading crown
Bark type: shining copper-coloured bark on spirally fluted trunk
Juvenile leaves: alternate, stalked, narrowly lanceolate
Adult leaves: alternate, narrowly lanceolate, shortly stalked
Wood: pale brown, hard, dense, strong; used for posts and firewood
Buds and fruits: Figure a7-94 (594)
Viable seeds per gram: 288

Uses. Useful small tree and attractive ornamental

Prospects for planting. It grows naturally on sandy loam to clayey soil; easy to propagate, should be useful in dry winter-rainfall areas

Success outside Australia. Trials have been made in Cyprus, Ghana, India, Kenya, South Africa, Zimbabwe and Tanzania

Refs. Blakely No. 113 Code SIDAE Chipp. p. 51

E. sargentii Maid.

Common name in Australia. Salt river gum

Regions of natural occurrence. *E. sargentii* occurs in a small area from Lake Mears to Cumerdin, Wyola Siding and Hines Hill in south-central Western Australia. It grows on grey or brown sandy loams, frequently in areas where salt is evident on the surface of the soil. It is one of the last species to die in areas of increasing salinity.

Latitudinal range. 30°-32°S

Altitudinal range. 300 m

Rainfall

Type: winter rainfall or storm rains
Total: 300-380 mm
Dry season: irregular periods of several months, severe

Temperature

Mean maximum of hottest month: 34-36°C. An average of more than 20 days over 37.8°C.
Mean minimum of coldest month: 4°C
Frosts: 25

Characteristics

Tree height in Australia: 8-11 m; a short trunk and a wide-spreading crown
Bark type: rough on lower trunk, smooth on upper branches
Juvenile leaves: opposite, stalked, elliptical
Adult leaves: alternate, stalked, narrowly lanceolate or linear-lanceolate
Wood: pale brown, tough, dense, straight-grained; not common enough to be used
Buds and fruits: somewhat like *E. astringens*, Figure a7-95 (113)
Viable seeds per gram: 237

Uses. Successfully established on salty areas and mine dumps at Broken Hill, New South Wales; grown as a street tree in Perth and Adelaide

Prospects for planting. It is one of the most salt-tolerant eucalypts and is resistant to drought and moderate frost.

Success outside Australia. It has demonstrated its tolerance of drought and saline conditions in Mediterranean conditions

E. sideroxylon A. Cunn. ex Woolls subsp. sideroxylon

Refs. Blakely No. 541 Code SUX:IA FTA p. 258

Common name in Australia. Red ironbark

Regions of natural occurrence. A good ironbark from mainly inland Victoria, New South Wales and Queensland, with some coastal occurrences in Victoria and New South Wales. Usually found on poor shallow soils, including sands, gravels, ironstones and clays; frequent in gold-bearing country.

Latitudinal range. 25°-39°S

Altitudinal range. Sea-level to 600 m

Rainfall

Type: winter to summer rainfall
Total: 375-625 mm
Dry season: 6-8 months, can be severe

Temperature

Mean maximum of hottest month: 32°C or more
Mean minimum of coldest month: 3-5°C
Frosts: 5-20

Characteristics

Tree height in Australia: up to 30 m; usually a good trunk and an attractive crown
Bark type: ironbark type, almost black, impregnated with kino
Juvenile leaves: opposite first, then alternate, linear to oblong
Adult leaves: alternate, stalked, lanceolate
Wood: dark red, close interlocked grain, fine texture, very durable; density 1 060 kg/m^3
Buds and fruits: Figure a7-96 (541)
Viable seeds per gram: 232

Uses. Used for sleepers and general construction; form not usually good enough for poles

Prospects for planting. Adaptable to dry conditions and some frost. The range of natural occurrence is very wide. If planting countries need this type of wood in difficult dry sites, provenance trials should be made.

Success outside Australia. Reasonable to good success in Mediterranean countries, South Africa, Brazil, Zimbabwe, the Congo. In South Africa it is classed as a good coppicing species but difficult to debark in winter. It grows well on dry (375-400 mm) sites in Hawaii.

Refs. Blakely No. 371 Code MAKED FTA p. 186

E. sieberi L. Johnson (previously called E. sieberana and also E. sieberiana F. Muell.)

Common name in Australia. Silvertop ash

Regions of natural occurrence. Coastal areas of southern New South Wales and eastern Victoria, with a small occurrence on the coast of northeastern Tasmania. It occurs on coastal lowlands, on slopes with poor to fairly good soils; parent materials schists, sandstones and granites; soils including some clays, well drained.

Latitudinal range. 34°-42°S

Altitudinal range. Up to 500 m in Tasmania and up to 1 000 m on the mainland

Rainfall

Type: winter to uniform rainfall
Total: 750-1 000 mm
Dry season: 4 months, not severe

Temperature

Mean maximum of hottest month: 22-28°C
Mean minimum of coldest month: 2-9°C
Frosts: 10-20

Characteristics

Tree height in Australia: 30-35 m; a good trunk and an open crown
Bark type: persistent, fibrous, deeply fissured longitudinally on most of the trunk, decorticating and smooth on the branches
Juvenile leaves: opposite first, then alternate, stalks short or absent, elliptical to broadly lanceolate
Adult leaves: alternate, stalked, lanceolate and usually curved
Wood: brown or pink, frequently with interlocked grain, hard, strong but not durable; density 640-1 040 kg/m^3
Buds and fruits: Figure a7-97 (371)
Viable seeds per gram: 111

Uses. Widely used as a sawtimber and recently for woodchips

Prospects for planting. It is easy to handle and grows well on fairly poor soils. Its recent acceptance as a suitable wood for the paper industry makes it more attractive as a planting species.

Success outside Australia. Has grown well in several countries

E. smithii R.T. Bak.

Refs. Blakely No. 274 Code SPIKE FTA p. 140

Common name in Australia. Blackbutt peppermint

Regions of natural occurrence. Tablelands and scarps of southern New South Wales and eastern Victoria

Latitudinal range. 33.5°-37.75°S

Altitudinal range. Up to 500 m

Rainfall

Type: uniform rainfall
Total: 750-1 250 mm
Dry season: 3 months, not severe

Temperature

Mean maximum of hottest month: 22-28°C
Mean minimum of coldest month: 2-9°C
Frosts: nil to 20

Characteristics

Tree height in Australia: up to 40 m; a short stout trunk and a good crown
Bark type: rough, peppermint type on lower trunk; upper trunk and branches smooth
Juvenile leaves: opposite, sessile to amplexicaul, glaucous, narrow-lanceolate
Adult leaves: alternate, petiolate, narrow-lanceolate, acuminate

Wood: peppermint type; used occasionally for milling; used for woodchips
Buds and fruits: Figure a7-98 (274)
Viable seeds per gram: 187

Uses. A good valley tree for timber and honey production

Prospects for planting. Moderate

Success outside Australia. Useful specimens and stands in New Zealand and South Africa

Refs. Blakely No. 520 Code SUP:Q FTS No. 100

E. staigerana F. Muell. ex F.M. Bail. (previously spelt E. staigeriana)

Common name in Australia. Lemon-scented ironbark

Regions of natural occurrence. Far north Cape York Peninsula, Queensland, in the headwaters of the Palmer river

Latitudinal range. 16°S

Altitudinal range. 40-600 m

Rainfall

Type: summer rainfall
Total: 1 000-1 500 mm
Dry season: 7 months, can be severe

Temperature

Mean maximum of hottest month: 32°C
Mean minimum of coldest month: 13-15°C
Frosts: nil to rare

Characteristics

Tree height in Australia: up to 22 m; with a short bole frequently of poor form
Bark type: ironbark type to small branches
Juvenile leaves: opposite first on short stalks then alternate, stalked, ovate to elliptical, glaucous; odour of citronellal
Adult leaves: alternate, stalked, lanceolate, somewhat glaucous; odour of citronellal
Wood: red, strong and durable
Buds and fruits: Figure a7-99 (520)
Viable seeds per gram: 5

Uses. Few, as there are few people in the region of natural occurrence

Prospects for planting. Possibly for the essential oil citronellal, otherwise negligible

Success outside Australia. It has been planted experimentally for the oil, but no commercial enterprise has been reported

E. stoatei C.A. Gardn.

Refs. Blakely No. 161a Code SLOBA Chipp. p. 173

Common name in Australia. Scarlet pear gum

Regions of natural occurrence. A restricted area east of Kundip in southern Western Australia; usually in sandy or gravelly sandy loam in hilly country

Latitudinal range. 32°-33°S

Altitudinal range. Up to 100 m

Rainfall

Type: winter rainfall
Total: 400 mm
Dry season: up to 8 months, can be severe

Temperature

Mean maximum of hottest month: 38°C
Mean minimum of coldest month: 2-5°C
Frosts: few light frosts

Characteristics

Tree height in Australia: up to 6 m; a slender tree with erect branches and a narrow but dense crown
Bark type: smooth, grey and deciduous
Juvenile leaves: opposite at first, later stalked, alternate and ovate
Adult leaves: alternate, thick, oblong or elliptical-ovate with an abrupt sharp point
Wood: has not been used
Buds and fruits: Figure a7-100 (161a)
Viable seed per gram: about one

Uses. An attractive ornamental

Prospects for planting. As an ornamental

Success outside Australia. Not successful in Brazil

E. tereticornis Sm. (syn. E. umbellata (Gaertn.) Domin.)

Refs. Blakely No. 178 Code SNEEB FTA p. 92

Common name in Australia. Forest red gum

Regions of natural occurrence. A very wide latitudinal range from southern Victoria through New South Wales and Queensland to the savanna woodlands of the Papuan coast in Papua New Guinea

Latitudinal range. 6°-38°S

Altitudinal range. Near sea-level to 1 000 m in Australia and 800 m in Papua New Guinea

Rainfall

Type: summer to winter rainfall
Total: 500-1 500 mm
Dry season: varies greatly up to 7 months, can be severe in places over the wide range of occurrence

Temperature

Mean maximum of hottest month: 22-32°C
Mean minimum of coldest month: 2-12°C
Frosts: nil to 15

Characteristics

Tree height in Australia: up to 45 m or more; with an erect trunk and a fairly dense crown
Bark type: basically a smooth red-gum type, but sometimes a basal stocking of old remnants at base
Juvenile leaves: opposite first, then alternate, stalked, elliptical to broadly lanceolate
Adult leaves: alternate, stalked, narrowly lanceolate, often curved
Wood: red, hard, heavy; uniform texture and interlocked grain; strong and durable
Buds and fruits: Figure a7-101 (178)
Viable seeds per gram: 539

Uses. Widely used as a construction and mining timber in Australia; suitable for posts of all sizes

Prospects for planting. Very good, but provenance testing from over the enormous range of latitude 32° and from cool to equatorial conditions and from winter to summer rainfalls should be carried out. As with *E. camaldulensis,* provenances from the northern occurrences may prove important successes.

Success outside Australia. *E tereticornis* was introduced to a number of tropical or subtropical countries in the latter half of the nineteenth and the first half of the twentieth centuries, e.g., to Pakistan in 1867, to Ethiopia in 1895, to Zimbabwe in 1900, to the Philippines in 1910. In India it was first introduced into Mysore at an altitude of 830 m in 1919 and a further introduction was made into the Nandi Hills at 1 280 m in 1928 (Chaturvedi, 1976). Large-scale planting started in 1952 in Karnataka State. The species has now been planted in many parts of India and is easily the most important in terms of area. Including the land race variously known as "Mysore gum", "Mysore hybrid" or "Eucalyptus hybrid", *E. tereticornis* accounted for 415 000 ha out of the total area of eucalypts reported as planted in India in 1974. The most important planting States are Karnataka (130 000 ha) and Uttar Pradesh (70 000 ha). Planting in other countries has been less extensive and mostly more recent, but 3 500 ha have been reported by the Congo, 15 000 ha by Argentina, 700 ha by Colombia and 680 ha by Ghana. A combined total for *E. tereticornis* and *E. camaldulensis* of 39 000 ha is reported from Uruguay. Smaller areas or promising trials have been reported by many other countries.

E. tereticornis has been most successful in summer-rainfall conditions with a moderate to fairly severe dry season. It is considerably more drought resistant than *E. grandis*, but slightly less so than *E. camaldulensis*. It has a light, narrow crown and its form varies considerably according to provenance. Satisfactory straightness is reported by Papua New Guinea, Pakistan, Ghana and Uruguay (where it is reported to be superior to *E. camaldulensis* in this respect), but crookedness or forking from the Ivory Coast, Malaysia, Greece and Turkey. It coppices vigorously (99 percent reported from the Congo) and begins to produce seed at 3-6 years old in plantations; between 150 and 350 g per seed bearer can be expected.

Optimum rainfall appears to lie between 800 and 1 500 mm, but it has been planted in both lower rainfall (550 mm in Mozambique and Israel) and in considerably higher rainfall (1 900 mm in the Ivory Coast, 2 180 mm in Colombia, 3 060 mm in Sierra Leone and 3 500 mm in Papua New Guinea and the Solomon Islands). It is susceptible to frost. It will grow on a variety of soils, with a preference for deep, well-drained soils of fairly light texture, including alluvial soils, silts and sandy clays. It performs poorly on heavy clays in savanna in Ghana, but in Argentina it is reported to be more tolerant of clay soils than *E. camaldulensis*. A neutral or slightly acid pH is suitable, but not a strongly acid one.

As with *E. camaldulensis*, there is evidence of considerable differences between provenances. Local land races of good growth and form and adaptable to a variety of sites are the "Mysore gum", sometimes described as a hybrid but considered by Pryor (1973) as a form of *E. tereticornis*, although occasional hybridization has occurred with, e.g., *E. robusta*; the form 12ABL first described in Madagascar but planted widely in the Congo; and the *Eucalyptus* "C" from Zanzibar, planted in several East African countries. Still better provenances from Australia may be identified as the result of provenance trials (Martin, 1971).

The Forest Research Institute, Dehra Dun, has evolved two promising hybrid varieties of very fast-growing eucalypts by artificially crossing *E. tereticornis*, currently the most widely planted eucalypt in the plains of both north and south India, with *E. camaldulensis*, another closely related, faster growing and more adaptable species. These varieties, designated as F.R.I.-4 and F.R.I.-5, have displayed striking degrees of hybrid vigour in both height and diameter growth and have produced at the early age of 4 years nearly three times the volume of wood produced by *E. tereticornis*. These new varieties are expected to increase considerably the output of future fuelwood or pulpwood plantations in the country. F_2 breeder seed of these varieties now awaits multilocation testing. In the meantime, the work on breeding continues.

The F.R.I. has also produced *E. tereticornis* × *E. grandis* hybrids which, though not endowed with hybrid vigour, may prove useful from the point of view of resistance to the pink disease which causes high mortality of *E. grandis* in parts of Kerala State and for growing on drier and poorer sites where *E. grandis* itself cannot be expected to do well.

In Zambia the natural and artificial hybrid *E. tereticornis* × *E. grandis* has shown great promise (Hans, 1974). Growth is better than that of either parent and the form as good as that of *E. grandis*. It is more drought resistant than *E. grandis* but less so than *E. tereticornis*. Wood properties are intermediate between the two parents. Hybridization is possible with a number of other species, e.g., *E. robusta*, *E. botryoides*, *E. saligna*. In the Congo there is evidence of a striking heterosis effect in crosses between the form 12ABL and *E. saligna* — 35 m^3/ha/yr at 6 years in the hybrid compared with 12 m^3 in 12ABL and 6 m^3 in *E. saligna* (Chaperon, 1978a).

Vegetative propogation has been carried out successfully in India, from lignotuberous tissue, from branch cuttings from 2- to 3-year-old saplings and from epicormic shoots from older trees. In the Congo 60 percent rooting success has been obtained from cuttings (Chaperon and Quillet, 1978).

Rotation varies with site quality and the objects of management. In the Congo the rotation is 5-7 years. In Argentina it is 9-12 years, with a single thinning at about 7 or 8 years. In India it varies from 7 to 15 years. In Pakistan rotations are 15-30 years, with thinning every five years. In Uruguay a rotation of 16 years, with two thinnings at ages 5-7 and 10-11, is used for sawlog production; for smallwood production a rotation of 8-12 years is used, with no thinning.

Early height growth varies from 1 to 3 m a year and diameter growth from 1.3 to 2.6 cm a year. In the Solomon Islands diameter growth of line-planted trees, fertilized and weeded, is as high as 4 cm a year. On good sites a mean annual increment of 18-25 m^3/ha/yr is expected in the Congo, Argentina, the Ivory Coast, India and Uruguay. On poorer sandy soils in the Congo this drops to 12 m^3/ha/yr. In Uruguay on poor sites the MAI is only 6 m^3/ha/yr. In India yield may drop as low as 3.1 m^3/ha/yr on the poorest sites but an overall average of 10 m^3/ha/yr is expected. Volume tables have been published for India (Chaturvedi, 1973). The sensitivity of the species to site quality and cultural treatment may be judged by the fact that even within the single Indian State of Tamil Nadu the range of MAI (overbark at 8 years) is from 2.3 m^3 to 40 m^3/ha/yr.

In general, *E. tereticornis* has proved fairly free from pests and diseases. In India the most serious disease has been the canker caused by the fungus *Corticium salmonicolor*. In many areas termites attack young plants if insecticide is not used at planting. Other pests and diseases reported are the fungi *Ganoderma lucidum* and *Cylindrocladium quinqueseptatum* (India), the climber *Merremia* and the insect *Ambleypelta cocophaga* (Solomon Islands), the snout beetle *Gonipterus scutellatus* and the fungus *Mycosphaerella molleriana* (South Africa), and mole crickets (the Congo). In many countries *E. tereticornis* is considered relatively fire resistant among the eucalypts.

The wood has been used for a variety of purposes: fuelwood, charcoal, paper, poles, stakes and fenceposts, mining timber, fibre- and particle board. In Argentina, it is used for manufacture of hardboard for export and it has been sawn for construction timber in Argentina, India and Zambia. It has been used for tannin extraction in the Congo and for oil extraction in the Philippines. The wood of "Mysore gum" is hard and heavy and is satisfactory for boxwood, props, poles, posts and bridge-timber, but not for furniture, doors or window-frames (Jain, 1969). The most important use in India, however, is likely to be for pulp and paper. Strength properties of paper improve when the age of the trees exceeds 9 years (Guha *et al.*, 1973), but the dark colour of the heartwood, in comparison with some other eucalypts, is a disadvantage. Experiments have been undertaken by the F.R.I. in India to study the percentage yield and physico-chemical properties of leaf oil from this species.

E. tereticornis is under trial for establishment of a forest cover on copper-mine tailings in Bougainville, Papua New Guinea (Hartley, 1977).

E. tessellaris F. Muell.

Refs. Blakely No. 16 Code BAA:A FTA p. 20

Common name in Australia. Carbeen

Regions of natural occurrence. Much of eastern Queensland and part of northern New South Wales

Latitudinal range. 16°-30°S

Altitudinal range. Sea-level to 500 m

Rainfall

Type: summer rainfall
Total: 375-1 500 mm
Dry season: up to 7 months and severe

Temperature

Mean maximum of hottest month: 36-38°C
Mean minimum of coldest month: 4°C
Frosts: nil to 15

Characteristics

Tree height in Australia: up to 30 m or more; with a shortish trunk and a fairly dense crown
Bark type: persistent and tessellated on lower part of trunk, smooth above
Juvenile leaves: opposite first, then alternate, stalkless or shortly stalked, narrowly lanceolate or oblong
Adult leaves: alternate, shortly stalked, narrowly lanceolate to almost linear
Wood: brown to dark chocolate brown, hard and tough, rather greasy, strong with a close interlocked grain; not durable in contact with the ground;

density 960-1 000 kg/m³
Buds and fruits: Figure a7-102 (16)
Viable seeds per gram: 154

Uses. The wood dresses well; is used in construction work not in contact with the ground. An attractive tree.

Prospects for planting. Limited; not a fast-growing species

Success outside Australia. It has proved satisfactory in some dry areas of northeast Brazil and India

Refs. Blakely No. 7 Code EAC:A FTA p. 14

E. tetrodonta F. Muell.

Common name in Australia. Darwin stringybark

Regions of natural occurrence. Northern parts of Western Australia, Northern Territory and Queensland. Grows in association with *E. miniata* and a variety of bloodwoods.

Latitudinal range. 11°-17°S

Altitudinal range. Up to 300 m

Rainfall

Type: summer rainfall
Total: 750-1 500 mm
Dry season: 7 months, can be severe

Temperature

Mean maximum of hottest month: 35°C
Mean minimum of coldest month: 5°C
Frosts: nil or rare

Characteristics

Tree height in Australia: up to 30 m; a good trunk and an open crown
Bark type: stringybark type throughout
Juvenile leaves: opposite for many pairs, then shortly stalked, linear or narrowly oblong
Adult leaves: alternate, occasionally opposite, pendant on long stalks, broadly lanceolate, often curved
Wood: pale red, sapwood yellow, fairly hard, fissile, dense and moderately durable
Buds and fruits: Figure a7-103 (7)
Viable seeds per gram: 25

Uses. Not a high-quality wood, but one of the few species in its locality which produces millable logs. Used for poles and general house construction.

Prospects for planting. Limited. A possible species for very low latitudes.

Success outside Australia. No significant reports. Starting off well in northern Brazil.

E. torelliana F. Muell.

Refs. Blakely No. 49 Code CCB:A FTA p. 40

Common name in Australia. Cadaga, cadaghi

Regions of natural occurrence. Atherton tableland, Queensland, on the edge of rain forest. It grows on sandy loams and heavier loams of volcanic origin and requires permeable subsoils or good surface drainage.

Latitudinal range. 16°-19°S

Altitudinal range. 100-800 m

Rainfall

Type: summer rainfall
Total: 1 000-1 500 mm or more
Dry season: 3 months, not severe

Temperature

Mean maximum of hottest month: 29°C
Mean minimum of coldest month: 10-16°C
Frosts: nil to 1 or 2

Characteristics

Tree height in Australia: up to 30 m; a good trunk and a dense crown
Bark type: scaly and subfibrous at base and tessellated to about 5 m; smooth above
Juvenile leaves: opposite at first, peltate or shortly stalked; if stalks present they are minutely hairy; later leaves broadly lanceolate to nearly orbicular, stalks hairy
Adult leaves: alternate, stalked, ovate
Wood: brown, hard, strong, durable *above* ground, subject to gum veins
Buds and fruits: Figure a7-104 (49)
Viable seeds per gram: 263

Uses. It grows where there are many ornamental rain-forest timbers but few good eucalypts, so it is used in spite of gum veins

Prospects for planting. The crown of *E. torelliana* is probably the most dense crown of all the eucalypts. The species will shade out most undergrowth in plantations in suitable areas. The dense crown droops down at the edges of plantations and touches the ground, sweeping it when the wind blows. There are good production plantations in their own right in Queensland and the species may find a useful place in tropical forestry. It hybridizes rather readily with other bloodwoods and F_1 hybrids made with a light-crowned species may improve the ability of the light-crowned species to shade out undergrowth.

Success outside Australia. Successfully introduced into several low-latitude countries. In West Africa alternate rows of *E. citriodora* and *E. torelliana* have been grown to produce a continuous supply of F_1 hybrid seed. The resulting hybrid crop has a denser crown than the *E. citriodora* parent and controls the site better. *E. citriodora* is a very good species but thin-crowned. In southern India *E. torelliana* has shown some degree of resistance to the fungus *Corticium salmonicolor* and is excellent in shading out the dense weed growth which occurs in the local conditions of high rainfall.

E. torquata Luehm.

Refs. Blakely No. 159 Code SLI:M Chipp. p. 168

Common name in Australia. Coral gum

Regions of natural occurrence. Coolgardie to Norseman in Western Australia

Latitudinal range. 32°S

Altitudinal range. Up to 300 m

Rainfall

Type: winter rainfall or storm rains
Total: 200-300 mm
Dry season: 8 months, severe

Temperature

Mean maximum of hottest month: 38°C
Mean minimum of coldest month: 2-5°C
Frosts: up to 11

Characteristics

Tree height in Australia: up to 12 m; a shortish trunk and a rounded crown
Bark type: bark on main trunk rough
Juvenile leaves: opposite first, stalked, later alternate and lanceolate
Adult leaves: alternate, lanceolate or sometimes falcate, stalked
Wood: dark brown, hard and dense, mainly used as fuelwood
Buds and fruits: Figure a7-105 (159)
Viable seeds per gram: 90

Uses. Wood used as fuelwood; buds and flowers very ornamental

Prospects for planting. Good as an ornamental

Success outside Australia. Grown as an ornamental in California and Arizona

E. transcontinentalis Maid. (syn. E. oleosa F. Muell. ex Miq. var. glauca Maid.)

Refs. Blakely No. 581 Code SIT:K Chipp. p. 104

Common name in Australia. Redwood

Regions of natural occurrence. Southwest Western Australia, over much of the wheatbelt and goldfields area

Latitudinal range. 30°-34.5°S

Altitudinal range. Up to 300 m

Rainfall

Type: winter rainfall
Total: 250-380 mm
Dry season: 7-8 months, severe

Temperature

Mean maximum of hottest month: 38°C
Mean minimum of coldest month: 2-5°C
Frosts: up to 11

Characteristics

Tree height in Australia: up to 21 m; a mallee or small tree
Bark type: usually smooth, white or grey, sometimes with a basal stocking
Juvenile leaves: opposite, elliptical-lanceolate, stalkless with leaf edges continuing on to stem
Adult leaves: alternate, stalked, lanceolate, blue-grey or grey-green
Wood: red-brown, tough, hard and durable; used as firewood in the mining industry
Buds and fruits: Figure a7-106 (581)
Viable seeds per gram: 113

Uses. The markedly glaucous branches and blue-green leaves make it an attractive tree. Important to the mining industry as fuelwood.

Prospects for planting. Limited, but a good tree for near desert conditions, and a good ornamental tree

Success outside Australia. Mojave Desert and Colorado Desert in California, Cyprus, South Africa

E. urnigera Hook. f.

Refs. Blakely No. 240 Code SPINL FTS No. 66

Common name in Australia. Urn gum

Regions of natural occurrence. Southeastern Tasmania

Latitudinal range. 42.5°-43.5°S

Altitudinal range. 500-1 000 m

Rainfall

Type: winter rainfall
Total: 1 000-1 500 mm
Dry season: 3 months, not severe

Temperature

Mean maximum of hottest month: 16-18°C
Mean minimum of coldest month: 0°C or less
Frosts: 50-150

Characteristics

Tree height in Australia: from a mallee type to a tree up to 40 m high, with a good crown
Bark type: a gum type with bark decorticating in patches to leave a smooth surface
Juvenile leaves: opposite first, shortly stalked, then opposite to sub-opposite, sessile and stem-clasping, edge of leaf conspicuously crenulate
Adult leaves: alternate, stalked, lanceolate to broadly lanceolate
Wood: white and brittle
Buds and fruits: Figure a7-107 (240)
Viable seeds per gram: 273

Uses. An attractive ornamental for cold winter-rainfall areas

Prospects for planting. Limited except as an ornamental

Success outside Australia. A "noble tree" reported from Inverary on the west coast of Scotland

E. urophylla S.T. Blake (syn. E. decaisneana Bl.)

Refs. Blakely No...: Not given Code SNAAA FTS No. 214

Common name in Australia. Not an Australian species

Regions of natural occurrence. Timor and other islands in the eastern part of the Indonesian Archipelago

Latitudinal range. 8°-10°S

Altitudinal range. Up to 3 000 m

Rainfall

Type: summer rainfall
Total: probably 1 000-1 500 mm
Dry season: not severe

Temperature

Mean maximum of hottest month: 29°C
Mean minimum of coldest month: 8-12°C
Frosts: nil except at highest altitude

Characteristics

Tree height in Timor: up to 50 m
Bark type: sometimes fibrous and rough over most of tree; at other times the lower part only fibrous and the upper part smooth
Juvenile leaves: not known
Adult leaves: lanceolate and stalked
Wood: reddish, strong and durable
Buds and fruits: very similar to *E. alba*, Figure a7-3 (207)
Viable seeds per gram: 456

Uses. Used widely for heavy construction and bridging in Timor

Prospects for planting. Very promising; one of the best low-latitude eucalypts. Because of its wide range of altitudinal distribution in Timor and its occurrence on several other islands, it is a species which shows considerable provenance variation (Pryor, 1975) and provenance trials are essential if best use is to be made of the species.

Success outside the natural range. Seed was first collected and introduced into Java (where the species is not indigenous) by Dutch botanists in 1890. Two specimen trees, over 80 years old, still survive in the Bogor Botanic Garden. Plots of more recent introduction exist in East Java (1937), Bandung region (1952) and near Bogor (1960).

In 1919 Navarro de Andrade introduced the species to the Rio Claro Arboretum in Brazil. The seed came from Java, from the Bogor area, under the name *E. alba.* There were three plots, each of 400 trees planted at 2 × 2 m. Seed from these plots was used to plant extensive areas in Brazil and other countries between 1940 and 1970, usually under the name "Brazil *alba*". Much of this seed has since proved to be of hybrid origin, because of the readiness with which the Rio Claro trees, now identified as *E. urophylla*, hybridize with certain other species of eucalypt growing in the same arboretum. In many cases, the performance of the F_1 generation was excellent, but F_2 and subsequent generations have shown diminished vigour and excessive heterogeneity.

The species was introduced into Bali Island in 1935 and into Australia (New South Wales) in 1966. Many countries have established species or provenance trials in the present decade or are about to do so, e.g., Papua New Guinea, the Congo, Cameroon, the Ivory Coast, Malaysia, Madagascar, Réunion, French Guiana, Argentina. In the Congo an earlier introduction of "Brazil *alba*" had been made at Pointe-Noire and Loudima in 1957 and 1962.

The chief characteristics of *E. urophylla* are its rapid growth, good form and the ability of at least some of its provenances to grow well at a low altitude in low latitudes. It shows great promise in humid or subhumid, tropical or subtropical areas in Brazil, i.e., in areas with 1 100-1 500 mm rainfall and a dry season of 1-5 months in the coolest part of the year. A similar rainfall regime occurs in the Congo. It does not withstand frost (Argentina). In the Solomon Islands (2 400-3 500 mm and no dry season) it initially out-grows *E. deglupta* (4 m high in 20 months) but is so far thin-stemmed, liable to distortion by the climber *Merremia*, with a thin canopy inadequate to shade out weeds and grass.

Earlier seed collections are thought to have been made mainly in Timor and Flores. Brazil suggests best results are likely to be obtained from seed originating between 500 and 1 400 m altitude, where the native stands attain their best development. Most provenance trials are too young to give reliable results. One preliminary indication is available from Papua New Guinea, where a trial of four provenances established at 800 m had the following results at 14 months:

Table 14.9 Provenance data for *E. urophylla*

Locality	Altitude (m)	Trial plot results in Papua New Guinea	
		Height (m)	Survival %
East Timor	580	2.73	100
East Timor	1 100	0.85	50
West Timor	1 250	—	0
Flores	430	1.55	50

The low survival in some provenances was attributed in part to lack of weeding. In the case of a provenance trial in São Paulo, Brazil, no significant differences were found at 4½ years in height, diameter and volume growth between several different origins at different altitudes in Timor and the Rio Claro "Brazil *alba*" origin (Pasztor, 1978b). As mentioned above, *E. urophylla* hybridizes freely.

The "Brazil *alba*" is considered to consist mainly of hybrids between *E. urophylla* mother trees and male parents of either *E. tereticornis* or *E. saligna*. Some hybridization occasionally takes place in the natural range with *E. alba* (Pryor, 1975).

No data are available on yield, but data reported on early height and diameter growth are tabulated below. Since the data are mainly from trial plots, allowance may be needed for edge effect, e.g., in inflated figures for diameter growth.

Very little information is available on pests and diseases. In Brazil it is much more resistant to the fungus *Diaporthe cubensis* than either *E. grandis* or *E. saligna*. In the Solomon Islands, it is susceptible to stem damage by the climber *Merremia*.

Table 14.10 *E. urophylla* - early growth

Country/location	Age (yrs)	Dominant height (m)	Dominant diameter (cm)
Congo (Pointe-Noire; poor ochraceous, freely drained sandy soil)	2 1/2	7.84	—
Congo (Loudima; non-calcareous clay of good structure, poor in exchangeable bases, pH 4.7-5.0)	2	9.92	—
Papua New Guinea	4	11	22
Bali	5 1/2	15	17
East Java	7	27	22.8
Solomon Islands	1 2/3	4	—

It is too early to identify the full range of purposes for which the species could be used. It seems likely to be suitable for pulp production, as well as for the same general purposes as *E. globulus* and *E. grandis*.

For an excellent recent account of this species, readers should refer to Martin and Cossalter (1975/76).

E. viminalis Labill.

Refs. Blakely No. 277 Code SPIKKA FTA p. 142

Common name in Australia. Manna gum

Regions of natural occurrence. Occurs in the tablelands and adjacent valleys of the Great Dividing Range in New South Wales, with a small extension into Queensland, and in Victoria. There are widespread occurrences in Tasmania and a relatively small one in the Mount Lofty ranges in South Australia.

Latitudinal range. 28.5°-43.5°S

Altitudinal range. Near sea-level to 1 500 m

Rainfall

Type: winter to summer rainfall
Total: 625-1 400 mm
Dry season: 4 months

Temperature

Mean maximum of hottest month: 21°C
Mean minimum of coldest month: 1-4°C
Frosts: 5-60

Characteristics

Tree height in Australia: up to 30 or even 55 m
Bark type: rough, grey and persistent stocking on lower trunk; smooth above, decorticating in long ribbons
Juvenile leaves: opposite, sessile, sometimes amplexicaul, lanceolate or sometimes oblong
Adult leaves: alternate, stalked, lanceolate to narrowly lanceolate
Wood: pale yellow or pink, moderately hard but not strong or durable; grain straight and open; density 670-930 kg/m^3
Buds and fruits: Figure a7-108 (277)
Viable seeds per gram: 347

Uses. Not a favourite wood in Australia but now used in light construction and for wide boards; used for paper

Prospects for planting. A good planting species. Coppices well but does not debark easily in winter. There is a wide latitudinal range and many provenances; the species is a useful enough one to justify extensive provenance trials.

Success outside Australia. Successful in several countries from the high altitude tropics and the subtropics to cool temperate localities. It has given promising results in areas where frosts are relatively common and where faster-growing species such as *E. grandis* are unsuited. It is successfully planted or promising under trial in Argentina, Bolivia, Chile, France (Corsica), Greece, India, Lesotho, Peru, South Africa, Spain, Turkey and the United States (California and Hawaii). In Spain, several thousand hectares have been planted; in La Coruña at 450 m, on sites too cold for *E. globulus* subsp. *globulus*, it yields 12 m^3/ha/yr. In India, it does well on deeper soils at 1 200-2 000 m.

It is widely planted in the humid lower montane zone in southern Brazil. However, recent experience (Fishwick, 1976) suggests that other species, *E. dunnii, E. nitens, E. nova-anglica* and *E. globulus* subsp. *bicostata,* grow straighter and are equally frost resistant.

It has proved unsuitable in Uruguay and in the tropical moist zone of Madagascar.

Refs. Blakely No. 120 Code SIGAA FTA p. 80

E. wandoo Blakely (syn. E. redunca Schau. var. elata Benth.)

Common name in Australia. Wandoo

Regions of natural occurrence. Southwest Western Australia; on wheatbelt soils east of the jarrah forest

Latitudinal range. 31°-34°S

Altitudinal range. Up to 300 m

Rainfall

Type: winter rainfall
Total: 500-1 000 mm
Dry season: 6 to 7 months, severe

Temperature

Mean maximum of hottest month: 35°C
Mean minimum of coldest month: 2-4°C
Frosts: 5-20

Characteristics

Tree height in Australia: up to 30 m; with a good trunk and a compact crown
Bark type: usually smooth throughout
Juvenile leaves: opposite first then alternate; shortly stalked; broadly lanceolate to ovate
Adult leaves: alternate, stalked, narrow-lanceolate
Wood: yellow to light reddish brown; close textured; wavy to interlocked grain; hard and durable; density 1 100 kg/m^3; wood and bark contain 10-12 percent tannin
Buds and fruits: Figure a7-109 (120)
Viable seeds per gram: 317

Uses. Wood used where strength and durability are necessary; formerly used for wheelwright work and wagon construction. A feature of the wood is that there is no chemical interaction between the wood and metal fastenings. Wood and bark used for tannin extraction.

Prospects for planting. Probably limited. Tannins can be obtained more easily from acacias and other trees. Other special properties do not call for a substantial supply.

Success outside Australia. Unenthusiastic reports from North Africa, South Africa, Brazil, Chile, Kenya and India

E. woollsiana R.T. Bak. (incl. E. microcarpa)

Refs. Blakely No. 482 Code SUL:DA FTA p. 232

Common name in Australia. Grey box

Regions of natural occurrence. Inland New South Wales, southern Queensland, Victoria and South Australia. Grows on a wide variety of soils.

Latitudinal range. 30°-38°S

Altitudinal range. 80-400 m

Rainfall

Type: winter through uniform to summer rainfall
Total: 500-625 mm
Dry season: 7 months, severe

Temperature

Mean maximum of hottest month: 29-35°C
Mean minimum of coldest month: 4-5°C
Frosts: 5-20

Characteristics

Tree height in Australia: up to 25 m; with a good trunk and rounded crown
Bark type: box type down to small branches
Juvenile leaves: opposite first, then sub-opposite to alternate, narrow-lanceolate, shortly stalked
Adult leaves: narrow to broadly lanceolate, stalked
Wood: heavy, hard, tough, very durable
Buds and fruits: Figure a7-110 (482)
Viable seed per gram: 1 181

Uses. Limited supplies in farming country, mainly used in round or hewn for fencing and railway sleepers. An excellent fuelwood.

Prospects for planting. Probably limited as the boxwood properties are not in strong demand and fuelwood can be better supplied by other species

Success outside Australia. Planted in several countries; growth slower than other available eucalypts

Brief notes on minor species

The notes which follow give information in condensed form on a number of species which are of less interest than those in the preceding monographs. They include (*a*) species which have been tried in plantations in the past but have been comparative failures, (*b*) species which have scarcely been tried at all but which could be of interest for special, difficult sites of limited extent.[1]

The key to the numbered headings for each species is as follows:

1. The botanical name and authority
2. The number of the species in Blakely's *A key to the eucalypts*
3. The code letters in Pryor and Johnson's *A classification of the eucalypts*
4. A reference to a description of the species in *Forest trees of Australia* (FTA), the Forest Tree Series of numbered descriptive sheets (FTS) or Chippendale's *Eucalypts of the Western Australian goldfields*
5. The regions of natural occurrence, using the following abbreviations (taken from Pryor and Johnson):
   Q = Queensland
   N = New South Wales

[1] NOTE: * indicates trees with sound heartwood. Most other trees in the same area are hollow, heartwood having been eaten by termites.

V = Victoria
T = Tasmania
S = South Australia
W = Western Australia south of latitude 20°S
K = Western Australia north of latitude 20°S
Y = Northern Territory
M = Eastern Indonesian Islands, Timor, Papua New Guinea and the Philippines (Mindanao)

6. Latitudinal range
7. Altitudinal range
8. Rainfall — annual precipitation followed by the type: winter (W), summer (S) or uniform (U)
9. Number of frosts
10. Remarks (uses, special characteristics, etc.)

TABULAR NOTES ON LESS SUCCESSFUL SPECIES

1. *E. aggregata* Deane & Maid.; 2. 215; 3. SPEAG; 4. FTA p. 108; 5. N, V; 6. 34°-38°S; 7. 600-900 m; 8. 500-750 mm W; 9. 60-80; 10. Cold, wet sites.

1. *E. albens* Benth.; 2. 486; 3. SUL:G; 4. FTA p. 236; 5. Inland N,V,S; 6. 27°-37°S; 7. 150-500 m; 8. 500-800 mm U to W; 9. 5-20; 10. Inland farm country.

1. *E. amplifolia* Naudin.; 2. 184; 3. SNEEA; 4. FTS No. 19; 5. Eastern N, southeast Q; 6. 28.5°-36°S; 7. 0-1 000 m; 8. 500-1 000 U to S; 9. Up to 50; 10. Occurs on poor soils.

1. *E. amygdalina* Labill.; 2. 408; 3. MATEH (syn. *E. salicifolia* Cav.); 4. FTA p. 206; 5. Eastern T.; 6. 41°-43.5°S; 7. 0-800 m; 8. 500-1 200 W; 9. 5-90; 10. Poles, sawnwood and split shingles.

1. *E. apodophylla* Blakely & Jacobs; 2. 286a; 3. SNADE; 4. FTS No. 165; 5. K,Y; 6. 12°-13°S; 7. <100 m; 8. 625-1 500 mm S; 9. Nil; 10. Not a good tree in Australia, but it lives on low-latitude cracking soils which are flooded in the wet season.

1. *E. argillacea* W.V. Fitzg.; 2. 290; 3. SUADC; 4. FTS No. 105; 5. Q, W,K,Y; 6. 14°-22°S; 7 <500 m; 8. 375-750 mm S; 9. Nil to rare; 10. A fair tree in very open, dry tropical woodland.

1. *E. behriana* F. Muell.; 2. 480; 3. SUDGA; 4. FTS No. 60; 5. N,V,S; 6. 31°-36.5°S; 7. 30-250 m; 8. 500-625 mm W to U; 9. 1-20; 10. A southern inland mallee.

1. *E. bigalerita* F. Muell.; 2. 209 (as *E. pastoralis*); 3. SNABE; 4. FTS No. 119; 5. K,Y; 6. 11.5°-17.5°S; 7. <100 m; 8. 625-1 500 mm S; 9. Nil; 10. On good soils near streams it makes one of the better trees of northwest Australia.

1. *E. blaxlandii* Maid. & Camb.; 2. 336; 3. MAHCD; 4. FTS No. 10; 5. N (Blue Mts); 6. 33°-34.5°S; 7. <1 000 m; 8. 875-1 250 U to S; 9. 10-30; 10. A smallish stringybark.

1. *E. brevifolia* F. Muell.; 2. 206; 3. SNABGA; 4. FTS No. 164; 5. K,Y; 6. 14°-20°S; 7. 100-700 m; 8. 250-750 mm S; 9. Nil; 10. A small tree <12 m growing on plains, slopes and "breakaway" topography in open woodlands.

1. *E. caesia* Benth.; 2. 88; 3. SIVCG; 4. Chipp. p. 119; 5. Inland W; 6. 29°-30°S; 7. <100 m; 8. 200-300 W; 9. Up to 10; 10. Attractive ornamental.

1. *E. caleyi* Maid.; 2. 539; 3. SUV:K; 4. FTS No. 144; 5. Northern N, Southern Q; 6. 28°-33°S; 7. 160-1 000 m; 8. 630-750 S; 9. 20-60; 10. Rural durable ironbark.

1. *E. campaspe* S. Moore; 2. 90; 3. SIK:C; 4. Chipp. p. 80; 5. Inland W; 6. 32°S; 7. <100 m; 8. 250-300 W; 9. Up to 10; 10. Ornamental.

1. *E. camphora* R.T. Bak.; 2. 212; 3. SPEAA; 4. FTS No. 56; 5. Cold wet uplands in Q,N,V; 6. 28°-37°S; 7. 300-1 500 m; 8. 625-1 000 mm W to U; 9. Very many; 10. Environmental uses in places where few species survive.

1. *E. capitellata* Sm. [syn. *E. baxteri* (Benth.) Maid. & Blakely ex J.M. Black var. *baxteri*]; 2. 340; 3. MAHCF; 4. FTS No. 11; 5. Central N.; 6. 32°-36°S; 7. 300-500 m; 8. 875-1 250 mm U to S; 9. 0-5; 10. Sawn when available.

1. *E. cneorifolia* DC.; 2. 567; 3. SIP:K; 4. FTS No. 130; 5. S; 6. 36°S; 7. 10-30 m; 8. 500 mm W; 9. Few; 10. Good oil species.

1. *E. coccifera* Hook.f; 2. 418; 3. MATES; 4. FTA p. 196; 5. Central and southern T; 6. 41°-43°S; 7. 730-1 300 m; 8. 500-1 000 W; 9. 100-150; 10. Protection in cold areas.

1. *E. consideniana* Maid.; 2. 373; 3. MAKEA; 4. FTA p. 188; 5. Coastal and tablelands, southeast N and northeast V; 6. 33°-38°S; 7. 0-1 000 m; 8. 750-1 150 mm U; 9. 10-40; 10. Wood used for general purposes.

1. *E. cordata* Labill.; 2. 244; 3. SPINO; 4. FTS No. 53; 5. Southeast T; 6. 42°-43°S; 7. 150-750 m; 8. 630-1 200 mm W; 9. 20-50; 10. Ornamental.

1. *E. cosmophylla* F. Muell.; 2. 85; 3. SECGB; 4. FTS No. 126; 5. Southern S; 6. 34°-36°S; 7. 0-500 m; 8. 500-750 mm W; 9. 10-20; 10. Farm uses.

1. *E. cullenii* Camb.; 2. 512; 3. SUP:K; 4. FTS No. 99; 5. York Peninsula, Q; 6. 12°-17°S; 7. 80-700 m; 8. 875-1 500 mm S; 9. Nil; 10. A good low-latitude ironbark. It could be an interesting species for trial.

1. *E. dealbata* A. Cunn ex Schau.; 2. 189; 3. SNEEJ; 4. FTA p. 96; 5. Southern Q,N; 6. 26°-35°S; 7. 150-1 000 m; 8. 500-700 mm W to U; 9. Several; 10. Good fuelwood.

1. *E. dumosa* A. Cunn. ex Schau.; 2. 141; 3. SLE:GA; 4. FTS No. 131; 5. Western N, northeast V,S; 6. 30.5°-36.5°S; 7. 0-300 m; 8. 150-300 mm U; 9. Up to 20; 10. Ornamental.

1. *E. foecunda* Schau.; 2. 442; 3. SIZ:B; 4. Chipp. p. 138; 5. N,V,S,W; 6. South of 26°S; 7. <300 m; 8. 250-500 mm W to U; 9. Few; 10. Protection.

1. *E. froggattii* Blakely; 2. 454; 3. SUNEF; 4. FTS No. 80; 5. North-central V; 6. 36.5°S; 7. 400-800 m; 8. 400-500 mm W; 9. 10; 10. Protection.

1. *E. gillii* Maid.; 2. 582; 3. SIT:N; 4. FTS No. 135; 5. N,S,Y; 6. 30.5°-32°S; 7. 150-450 m; 8. 150-250 mm weakly W; 9. 1-5; 10. Protection, cineole.

1. *E. globoidea* Blakely; 2. 346; 3. MAHEF; 4. FTA p. 174; 5. Coastal N and northeast V; 6. 31°-38.5°S; 7. <300 m in south to 1 000 m in north; 8. 625-1 000 mm U to S; 9. 0-5; 10. Useful pole, sawlog and for chipwood.

1. *E. gracilis* F. Muell.; 2. 564; 3. SIX:A; 4. Chipp. p. 132; 5. N,V,S,W; 6. 30°-36°S; 7. <100 m; 8. 250-450 W; 9. Up to 8; 10. Protection.

1. *E. grandifolia* R.Br. ex Benth.; 2. 18; 3. BAA:D; 4. FTS No. 61; 5. Q,K,Y; 6. 11°-18°S; 7. <200 m; 8. 750-1 500 S; 9. 0-few (inland); 10. Environmental.

1. *E. intermedia* R.T. Bak.; 2. 46; 3. CAFID; 4. FTS No. 13; 5. Q,N; 6. 15°-33°S; 7. <800 m; 8. 750-2 000 mm S; 9. Few, not severe; 10. Useful hardwood, except for gum veins.

1. *E. jacobsiana* Blakely; 2. 52a; 3. CAJ:A; 4. FTA p. 42; 5. K,Y; 6. 12°-14°S; 7. 200-500 m; 8. 1 100-1 200 mm S; 9. Nil to rare; 10. Rhizomes on roots.

1. *E. jensenii* Maid.; 2. 519; 3. SUP:U; 4. FTS No. 49; 5. K,Y; 6. North of 15°S; 7. <300 m; 8. 625-1 500 mm S; 9. Nil; 10. A solid* small tree.

1. *E. johnstonii* Maid.; 2. 269; 3. SPIJAC; 4. FTS No. 69; 5. Southern T; 6. 42°-43°S; 7. 500-1 000 m; 8. 1 000-2 000 mm W; 9. 50-90; 10. Good wood; slow growing.

1. *E. kruseana* F. Muell.; 2. 243; 3. SIM:A; 4. Chipp. p. 83; 5. Southeast W; 6. 32°S; 7. 100 m; 8. 200-250 mm W; 9. 8; 10. Ornamental, leaves used in ikebana floral arrangements.

1. *E. lanepoolei* Maid.; 2. 589; 3. SIVEA; 4. FTS No. 74; 5. Coastal W near Perth; 6. 32°-34°S; 7. 30-100 m; 8. 750-1 000 mm W; 9. Few; 10. Ornamental.

1. *E. lesouefii* Maid.; 2. 157; 3. SLE:N; 4. Chipp. p. 155; 5. Around Kalgoorlie, W; 6. 32°-33°S; 7. <300 m; 8. 200-350 mm W; 9. Up to 8; 10. Good fuel, ornamental.

1. *E. nitida* Hook. f.; 2. 410; 3. MATEJ; 4. FTS No. . . .; 5. T; 6. 37°-44°S; 7. <100 m; 8. 500-750 mm W; 9. Numerous; 10. Environmental and ornamental.

1. *E. nortonii* (Blakely) L. Johnson; 2. 230; 3. SPIFC; 4. FTS No. 22; 5. N,V; 6. 31°-37°S; 7. 1 000 m; 8. 1 250 mm U; 9. Numerous; 10. Environmental and ornamental.

1. *E. notabilis* Maid.; 2. 72; 3. SECCB; 4. FTS No. 27; 5. Southeast Q,N.; 6. 28°-34°S; 7. 150-1 000 m; 8. 1 250-1 500 mm U; 9. 5-20; 10. Used locally.

1 *E. ochrophloia* F. Muell.; 2. 476; 3. SUJ:B; 4. FTS No. 25; 5. Southwest Q; 6. 22°-26°S; 7. <400 m; 8. 250-500 mm U to S; 9. 1-10; 10. Close to *E. thozetiana*. Both are solid* trees growing in arid zones and even on stony hills.

1. *E. odorata* Behr. & Schlecht; 2. 455; 3. SUNEBA; 4. FTA p. 224; 5. V,S; 6. 31°-37°S; 7. <600 m; 8. 375-750 mm W; 9. 5-15; 10. Cineole in leaves.

1. *E. oligantha* Schau.; 2. 491; 3. SUABE; 4. FTS No. 48; 5. K.Y; 6. 11.5°-18°S; 7. <150 m; 8. 625-1 500 mm S; 9. Nil; 10. A small box eucalypt making a solid* tree in a low latitude.

1. *E. parvifolia* Camb.; 2. 218; 3. SPIBA; 4. FTS No. 91; 5. N; 6. 36°-36.5°S; 7. 1 000-1 100 m; 8. 600-700 mm; 9. 100; 10. Marked cold resistance —> –15°C.

1. *E. patellaris* F. Muell.; 2. 490; 3. SUABC; 4. FTS No. 47; 5. W,K,Y; 6. 13°-16°S with outlier to 23°S; 7. <100 m; 8. 225-1 000 mm U to S; 9. Nil; 10. Growing on better soils, and one of the better trees in its area.

1. *E. peltata* Benth. subsp. *peltata*; 2. 48; 3. CCA:AA; 4. FTS No. 106; 5. North-central Q; 6. 17°-25°S; 7. <500 m; 8. 475-725 mm S; 9. Nil to rare; 10. Grows on poor soils in tropical woodland; a strong wood (a bloodwood).

1. *E. perriniana* F. Muell. ex Rodway; 2. 242; 3. SPINN; 4. FTS No. 123; 5. N,V,T; 6. 35°-42°S; 7. 800-1 800 m; 8. 1 000 m; 9. 200 — snow frequent; 10. Attractive ornamental. The connate leaf-pairs loosen and spin on the stem.

1. *E. phoenicea* F. Muell.; 2. 13; 3. EFC:B; 4. FTS No. 41; 5. K,Y; 6. 11°-17°S; 7. <300 m; 8. 675-1 500 mm S; 9. Nil; 10. Of little promise as a wood but in flower one of the most beautiful trees.

1. *E. piperita* Sm. subsp. *piperita*; 2. 427; 3. MATHAA; 4. FTA p. 214; 5. N; 6. 30°-36°S; 7. < 1 000 m; 8. 1 000-1 200 mm U to S; 9. Up to 50; 10. Used but not a preferred species.

1. *E. porosa* F. Muell. ex Miq.; 2. 451; 3. SUNCC; 4. FTS No. 134; 5. N,V,S; 6. 31°-35°S; 7. <500 m; 8. 225-375 mm W; 9. 1-5; 10. Environmental, farm use.

1. *E. pruinosa* Schau.; 2. 525; 3. SUP:Y; 4. FTS No. 50; 5. Q,K,Y; 6. 14°-20°S; 7. <300 m; 8. 325-950 mm S; 9. Nil; 10. A small tree or mallee; foliage glaucous and attractive; not promising as a wood.

1. *E. redunca* Schau.; 2. 115; 3. SIGAC; 4. Chipp. p. 70; 5. Inland southwest W; 6. 32°-34°S; 7. <300 m; 8. 300-500 mm W; 9. Up to 30; 10. An attractive ornamental.

1. *E. risdonii* Hook.f.; 2. 420; 3. MATEB; 4. FTS No. 151; 5. T; 6. 43°S; 7. <100 m; 8. 650-900 mm W; 9. Up to 30; 10. Attractive small tree.

1. *E. rossii* R.T. Bak. & H.G. Sm.; 2. 435; 3. MATKF; 4. FTS No. 4; 5. Western slopes and tablelands, N; 6. 29°-37°S; 7. 300-1 000 m; 8. 375-625 mm U; 9. 10-50; 10. A useful street and farm tree but not a good timber tree.

1. *E. rubida* Deane & Maid.; 2. 235; 3. SPINF; 4. FTA p. 120; 5. Southern Q,N,V,T,S; 6. 28°-43°S; 7. 100-1 500 m; 8. 625-1 250 mm W to S; 9. 15-70; 10. A very handsome tree but not a good timber species.

1. *E. siderophloia* Benth.; 2. 516; 3. SUP:I; 4. FTS No. . . . .; 5. Southern Q, northern N; 6. 22°-32°S; 7. 0-500 m; 8. 625-1 250 mm S; 9. Few, up to 14; 10. Grows on poor and dry soils.

1. *E. spathulata* Hook.f. subsp. *spathulata*; 2. 103; 3. SIDCDA; 4. Chipp. p. 59; 5. Southwest W; 6. 32°-35°S; 7. <200 m; 8. 340-500 mm W; 9. Up to 20; 10. Environmental.

1. *E. stellulata* Sieb. ex DC.; 2. 398; 3. MAKMA; 4. FTA p. 198; 5. High wet places along Great Dividing Range in N,V; 6. 29°-37°S; 7. 600-1 600 m; 8. 625-1 000 mm U to S; 9. 60-160; 10. Environmental use.

1. *E. striaticalyx* W.V. Fitzg.; 2. 149; 3. SLE:F; 4. FTS No. 83; 5. W; 6. 26°-28°S; 7. 400-500 m; 8. 175-275 mm U to W; 9. Rare; 10. Withstands great heat and dryness; already tested in several countries.

1. *E. tenuiramis* Miq.; 2. 421; 3. MATEC; 4. FTS No. 70; 5. Southeast T; 6. 42°-43°S; 7. >500 m; 8. 750-1 500 mm W; 9. 2-50; 10. Pulpwood, environmental.

1. *E. thozetiana* F. Muell. ex R.T. Bak.; 2. 470; 3. SUJ:A; 4. FTA p. 226; 5. Central Q, MacDonnell Range Y; 6. 18°-30°S; 7. 150-600 m; 8. 300-625 mm S; 9. Up to 20; 10. With *E. ochrophloia* it makes a fair-sized solid* tree on arid plains and rocky slopes and ridges.

1. *E. trachyphloia* F. Muell.; 2. 40; 3. CAFUJ; 4. FTA p. 39; 5. Q,N; 6. 16°-33°S; 7. <300 m; 8. 500-1 000 mm S; 9. Up to 15 in south; 10. Used as sawnwood, mining timber, fencing and fuel but has many gum veins.

1. *E. vernicosa* Hook.f.; 2. 266; 3. SPIJAA; 4. FTS No. 67; 5. High, wet, cold sites in southern T; 6. 41°-43°S; 7. <1 400 m; 8. 1 250-2 500 mm W; 9. 150 or more; 10. Very small.

1. *E. viridis* R.T. Bak. var. *viridis*; 2. 465; 3.SUNEHA; 4. FTS No. 6; 5. Q,N,V,S; 6. 28°-37°S; 7. 200-300 m; 8. 400-500 mm U to S; 9. 1-10; 10. Roots are a valuable fuel; possible leaf harvesting for essential oils.

1. *E. woodwardii* Maid.; 2. 89; 3. SLE:A 4. Chipp. p. 143; 5. Inland southern W; 6. 32°-33°S; 7. <100 m; 8. 200-300 mm W; 9. Average 8; 10. A useful ornamental street tree.

1. *E. youmanii* Blakely & Mckie; 2. 334; 3. MAHAE; 4. FTS No. 138; 5. New England tableland, N; 6. 28°-32°S; 7. 800-1 500 m; 8. 750-1 250 mm U; 9. 40-70; 10. Leaves are a useful source of the drug rutin.

Appendix 1. Climatic tables for Australia

The tables which follow give climatic data for some meteorological stations representative of the various seasonal rainfall zones in Australia. The climatic data have been extracted from Forestry and Timber Bureau leaflet No. 114 (Hall, 1972); Fahrenheit temperatures have been converted to Celsius and points of rainfall to millimetres.

The seasonal rainfall zones are those shown in Figure III (Chapter 1). The alpine zone is based on altitude, the remaining zones on a combination of total annual rainfall and seasonal incidence. Seasonal incidence is determined from the ratio (greater/lesser) of the median rainfalls: November-April (Summer) and May-October (Winter). The zones are as follows:

	Annual rainfall	Seasonal incidence ratio
	..... *(mm)*	.....
Summer-rainfall zones (See Table A1.1)		
(1) Summer	> 1 200	> 1.3
(2) Summer	600 - 1 200	> 1.3
(3) Summer	350 - 600	> 1.3
(4) Summer arid AZ (SS)	< 350	> 3.0
(5) Summer arid AZ (S)	< 350	⩽ 3.0 > 1.3
Uniform-rainfall zones (See Table A1.2)		
(1) Uniform	> 800	⩽ 1.3
(2) Uniform	500 - 800	⩽ 1.3
(3) Uniform	250 - 500	⩽ 1.3
(4) Uniform arid AZ (U)	< 250	⩽ 1.3
Winter-rainfall zones (See Table A1.3)		
(1) Winter	> 800	> 1.3
(2) Winter	500 - 800	> 1.3
(3) Winter	250 - 500	> 1.3
(4) Winter arid AZ (W)	< 250	⩽ 3.0 > 1.3
Alpine zone (See Table A1.4)		

Table A1.1 Summer-rainfall zones

Locality	January temperatures (°C)		July temperatures (°C)		Temperature extremes recorded (°C)		No. of hot days		Frosts	Rainfall												Total	Extremes recorded	
	Mean maxi-mum	Mean mini-mum	Mean maxi-mum	Mean mini-mum	Highest	Lowest	>32°	>38°		J	F	M	A	M	Jn	Jl	A	S	O	N	D		Highest	Lowest
(1) Summer rainfall > 1 200 mm																								
										Millimetres														
Cape York, Queensland Lat. 10.7°S [1] Alt. 27 m [2]	31	24	28	22	37.5	14	?	0	0	377	350	404	278	66	24	19	8	5	9	41	200	1 781	2 733	842
Cairns, Queensland Lat. 16.9°S Alt. 5 m	31.2	23.3	25.6	16.3	43	6.1	32	1	0	421	422	460	264	110	72	39	42	43	50	98	203	2 224	4 434	1 119
Atherton, Queensland Lat. 17.3°S Alt. 752 m	29.5	19	22	10.5	39	—3	17	<1	1.4	297	313	249	108	60	46	29	24	23	27	75	174	1 427	2 416	498
Mackay, Queensland Lat. 21.1°S Alt. 14 m	30	21	22	12	41	—1	27	<1	0	360	335	304	156	95	66	38	28	36	47	74	163	1 702	3 455	632
Lismore, New South Wales Lat. 28.8°S Alt. 26.5 m	30	18	20	6.5	45	—5	33	3	0.5	167	182	188	127	114	92	89	59	56	68	94	111	1 347	2 213	545

[1] Lat. = latitude. — [2] Alt. = altitude.

Table A1.1 Summer-rainfall zones *(continued)*

Locality	January temperatures (°C)		July temperatures (°C)		Temperature extremes recorded (°C)		No. of hot days		Frosts	Rainfall												Total	Extremes recorded	
	Mean maxi-mum	Mean mini-mum	Mean maxi-mum	Mean mini-mum	Highest	Lowest	>32°	>38°		J	F	M	A	M	Jn	Jl	A	S	O	N	D		Highest	Lowest
										Millimetres														
Coff's Harbour, New South Wales Lat. 30.3°S Alt. 21.0 m	27	18.5	18.9	6.0	43.3	—3.3	14	<1	0	164	211	242	191	144	124	96	77	70	95	104	140	1 658	3 376	685
Darwin, Northern Territory Lat. 12.4°S Alt. 29.6 m	34	26	31	19.5	40.6	13.5	228	1	0	391	330	260	103	14	3	1	2	13	50	126	243	1 536	2 215	892
Yirrkala, Northern Territory Lat. 12.2°S Alt. not given	*Not available*				40.0	12.2	*Not available*			219	251	254	256	91	31	12	5	2	5	41	145	1 312	*Not given*	
(2) Summer rainfall 600-1 200 mm																								
Bundaberg, Queensland Lat. 24.9°S Alt. 15 m	30	21	22	9.5	40	—0.6	15	1	0	204	179	147	86	68	66	53	31	38	59	76	129	1 136	2 359	338

Table A1.1 Summer-rainfall zones *(continued)*

Locality	January temperatures (°C)		July temperatures (°C)		Temperature extremes recorded (°C)		No. of hot days		Frosts	Rainfall												Total	Extremes recorded	
	Mean maxi-mum	Mean mini-mum	Mean maxi-mum	Mean mini-mum	Highest	Lowest	>32°	>38°		J	F	M	A	M	Jn	Jl	A	S	O	N	D		Highest	Lowest
										. . . .					*Millimetres*						. . . .			
Tamworth, New South Wales Lat. 31.1°S Alt. 378 m	32.3	17.3	15.7	2.9	45.0	—6.7	58	6	20	75	70	51	44	42	53	45	47	49	59	66	73	674	1 105	358
Katherine, Northern Territory Lat. 14.1°S Alt. 114 m	38.3	24.6	30.3	13.0	43.9	3.3	280	3.3	0	232	201	156	34	6	2	1	1	6	30	84	199	952	1 496	439
Derby, Western Australia Lat. 17.3°S Alt. 16 m	36.5	26.7	29.5	14.4	46.1	5.6	254	38	0	180	148	108	35	24	12	8	2	1	3	18	89	628	1 448	112
(3) Summer rainfall 350-600 mm																								
Charleville, Queensland Lat. 26.4°S Alt. 294 m	36	22	20	4.4	47.8	—5	130	41	7	69	69	65	35	31	31	29	19	20	36	41	56	501	1 202	202

Table A1.1 Summer-rainfall zones *(concluded)*

Locality	January temperatures (°C)		July temperatures (°C)		Temperature extremes recorded (°C)		No. of hot days		Frosts	Rainfall												Total	Extremes recorded	
	Mean maxi-mum	Mean mini-mum	Mean maxi-mum	Mean mini-mum	Highest	Lowest	>32°	>38°		J	F	M	A	M	Jn	Jl	A	S	O	N	D		Highest	Lowest
										. . . . Millimetres														
Halls Creek, Western Australia Lat. 18.2°S Alt. 373 m	38	24	27	9	44.4	—1.1	*Not available*	80	1	132	115	66	17	9	6	7	3	1	13	33	76	478	1 068	214
(4) Summer rainfall: Arid Zone AZ(SS) < 350 mm																								
Mundiwindi, Western Australia Lat. 23.9°S Alt. 559 m	38	23.5	21	5	44.4	—5.8	166	74	5.5	44	46	47	22	21	19	8	8	3	8	11	26	263	816	26
(5) Summer rainfall: Arid Zone AZ(S) < 350 mm																								
Birdsville, Queensland Lat. 26.9°S Alt. 43 m	38	24	21	7	4.8	—2		*Not given*		20	24	18	10	10	11	10	5	7	11	13	14	153	542	33

Table A1.2 Uniform-rainfall zones

Locality	January temperatures (°C)		July temperatures (°C)		Temperature extremes recorded (°C)		No. of hot days		Frosts	Rainfall												Total	Extremes recorded	
	Mean maxi-mum	Mean mini-mum	Mean maxi-mum	Mean mini-mum	Highest	Lowest	>32°	>38°		J	F	M	A	M	Jn	Jl	A	S	O	N	D		Highest	Lowest
										(1) Uniform rainfall > 800 mm														
										. . . . Millimetres														
Newcastle, New South Wales Lat. 32.9°S Alt. 34 m	25.8	19.6	16.5	8.1	44.4	2.8	9	1	0	88	103	118	121	117	108	107	82	78	72	64	84	1 142	1 918	640
Wollongong, New South Wales Lat. 34.4°S Alt. 10 m	26	17	16.7	8.0	46.3	1.0	7	1	0	108	109	118	131	116	109	90	61	67	68	72	86	1 135	2 224	525
Robertson, New South Wales Lat. 34.6°S Alt. 825 m					*Not recorded*					148	161	180	155	153	190	148	111	96	114	91	118	1 665	3 127	799
Bateman's Bay, New South Wales Lat. 35.7°S Alt. 15 m					*Not recorded*					98	93	100	98	106	103	75	60	62	70	70	86	1 021	2 082	517

Table A1.2 Uniform-rainfall zones

Locality	January temperatures (°C)		July temperatures (°C)		Temperature extremes recorded (°C)		No. of hot days		Frosts	Rainfall												Total	Extremes recorded	
	Mean maxi-mum	Mean mini-mum	Mean maxi-mum	Mean mini-mum	Highest	Lowest	>32°	>38°		J	F	M	A	M	Jn	Jl	A	S	O	N	D		Highest	Lowest
										(1) Uniform rainfall > 800 mm														
										. . . . *Millimetres*														
Newcastle, New South Wales Lat. 32.9°S Alt. 34 m	25.8	19.6	16.5	8.1	44.4	2.8	9	1	0	88	103	118	121	117	108	107	82	78	72	64	84	1 142	1 918	640
Wollongong, New South Wales Lat. 34.4°S Alt. 10 m	26	17	16.7	8.0	46.3	1.0	7	1	0	108	109	118	131	116	109	90	61	67	68	72	86	1 135	2 224	525
Robertson, New South Wales Lat. 34.6°S Alt. 825 m	*Not recorded*									148	161	180	155	153	190	148	111	96	114	91	118	1 665	3 127	799
Bateman's Bay, New South Wales Lat. 35.7°S Alt. 15 m	*Not recorded*									98	93	100	98	106	103	75	60	62	70	70	86	1 021	2 082	517

Table A1.1 Summer-rainfall zones *(concluded)*

Locality	January temperatures (°C)		July temperatures (°C)		Temperature extremes recorded (°C)		No. of hot days		Frosts	Rainfall												Total	Extremes recorded	
	Mean maxi-mum	Mean mini-mum	Mean maxi-mum	Mean mini-mum	Highest	Lowest	>32°	>38°		J	F	M	A	M	Jn	Jl	A	S	O	N	D		Highest	Lowest
										. . . . Millimetres														
Halls Creek, Western Australia Lat. 18.2°S Alt. 373 m	38	24	27	9	44.4	—1.1	*Not available*	80	1	132	115	66	17	9	6	7	3	1	13	33	76	478	1 068	214
(4) Summer rainfall: Arid Zone AZ(SS) < 350 mm																								
Mundiwindi, Western Australia Lat. 23.9°S Alt. 559 m	38	23.5	21	5	44.4	—5.8	166	74	5.5	44	46	47	22	21	19	8	8	3	8	11	26	263	816	26
(5) Summer rainfall: Arid Zone AZ(S) < 350 mm																								
Birdsville, Queensland Lat. 26.9°S Alt. 43 m	38	24	21	7	4.8	—2	*Not given*			20	24	18	10	10	11	10	5	7	11	13	14	153	542	33

Table A1.2 Uniform-rainfall zones *(continued)*

Locality	January temperatures (°C)		July temperatures (°C)		Temperature extremes recorded (°C)		No. of hot days		Frosts	Rainfall												Total	Extremes recorded	
	Mean maxi-mum	Mean mini-mum	Mean maxi-mum	Mean mini-mum	Highest	Lowest	>32°	>38°		J	F	M	A	M	Jn	Jl	A	S	O	N	D		Highest	Lowest
(2) Uniform rainfall 500-800 mm																								
										Millimetres														
Dubbo, New South Wales Lat. 32.3°S Alt. 264 m	33.5	17.8	10.7	2.5	46.4	—8.5	63	11	11	57	53	48	46	45	52	43	44	41	45	51	49	574	1 329	287
Canberra, A.C.T. Lat. 35.3°S Alt. 580 m	28	13.5	11.0	0.9	42	—7.9	15	1	39	54	54	63	54	49	46	46	49	47	73	55	54	644	1 061	304
(3) Uniform rainfall 250-500 mm																								
Condobolin, New South Wales Lat. 35.1°S Alt. 199 m	34	18.5	15.5	3.6	48.9	—6.7	73	19	12	41	38	39	34	35	39	32	36	29	39	33	41	436	903	211

Table A1.2 Uniform-rainfall zones *(concluded)*

Locality	January temperatures (°C)		July temperatures (°C)		Temperature extremes recorded (°C)		No. of hot days		Frosts	Rainfall												Total	Extremes recorded	
	Mean maxi-mum	Mean mini-mum	Mean maxi-mum	Mean mini-mum	Highest	Lowest	>32°	>38°		J	F	M	A	M	Jn	Jl	A	S	O	N	D		Highest	Lowest
										(4) Uniform rainfall: Arid Zone AZ(U) < 250 mm														
										. . . . *Millimetres*														
Marree, South Australia Lat. 29.6°S Alt. 49 m	37.3	20.9	18.3	4.5	46.8	—2.8	11	50	4	13	16	15	11	14	16	9	8	10	12	12	18	154	408	54
Kalgoorlie, Western Australia Lat. 30.8°S Alt. 424 m	33.8	18.0	16.8	6.0	45.6	—8.3	82	25	1	18	23	26	21	28	28	24	22	13	15	14	15	247	485	121

Table A1.3 Winter-rainfall zones

Locality	January temperatures (°C)		July temperatures (°C)		Temperature extremes recorded (°C)		No. of hot days		Frosts	Rainfall												Total	Extremes recorded	
	Mean maxi-mum	Mean mini-mum	Mean maxi-mum	Mean mini-mum	Highest	Lowest	>32°	>38°		J	F	M	A	M	Jn	Jl	A	S	O	N	D		Highest	Lowest
(1) Winter rainfall > 800 mm																								
										Millimetres														
Pilot Hill, New South Wales Lat. 35.6°S Alt. 669 m	23.5	10.3	6.0	—1.5	38	—8.9	2	<1	100	74	75	101	102	124	167	171	158	129	140	98	80	1 419	2 062	749
Powelltown, Victoria Lat. 37.9°S Alt. 228 m	25.7	10.7	13.5	2.5	*Not avail-able*	—6.1	7	1	10.8	65	76	77	120	164	122	153	150	152	149	138	105	1 471	2 039	947
Zeehan, Tasmania Lat. 41.9°S Alt. 181 m	18	7	10.7	3.4	37.5	—6.5	<1	0	22.5	138	113	151	216	240	252	265	262	230	221	189	166	2 443	3 063	1 791
Stirling West, South Australia Lat. 35.0°S Alt. 495 m	25	12	10.7	4.5	41.5	—4.0	13	1	20	39	37	43	96	143	183	161	156	124	99	61	49	1 191	1 839	600
Manjimup, Western Australia Lat. 34.2°S Alt. 279 m	25.8	13.0	14.1	6.0	41.7	—2.8	14	1	0.2	20	20	33	63	144	183	185	155	111	84	44	27	1 069	1 761	650

Table A1.3 Winter-rainfall zones *(continued)*

Locality	January temperatures (°C)		July temperatures (°C)		Temperature extremes recorded (°C)		No. of hot days		Frosts	Rainfall												Total	Extremes recorded	
	Mean maxi-mum	Mean mini-mum	Mean maxi-mum	Mean mini-mum	Highest	Lowest	>32°	>38°		J	F	M	A	M	Jn	Jl	A	S	O	N	D		Highest	Lowest
										(2) Winter rainfall 500-800 mm														
										Millimetres														
Portland, Victoria Lat. 38.3°S Alt. 15.5 m	21.7	13.0	13.5	6.7	42.8	—2.8	6	<1	3.2	35	36	44	68	93	102	107	108	85	71	51	45	845	1 289	485
Adelaide, South Australia Lat. 34.9°S Alt. 43 m	29.7	16.4	15.0	7.0	47.6	0.0	40	11	0	20	19	24	44	69	74	66	62	51	45	31	26	531	786	288
										(3) Winter rainfall 250-500 mm														
Horsham, Victoria Lat. 36.7°S Alt. 138 m	30.0	13.3	13.3	3.5	48.9	—6.1	31	6	4.1	22	26	25	33	47	53	44	48	45	43	33	29	448	684	254
Ceduna, South Australia Lat. 32.1°S Alt. 13 m	27.6	15.0	17.0	6.4	47.2	—2.8	39	16	*Not available*	7	16	13	19	37	41	38	36	23	24	19	15	288	486	146

Table A1.3 Winter-rainfall zones *(concluded)*

Locality	January temperatures (°C)		July temperatures (°C)		Temperature extremes recorded (°C)		No. of hot days		Frosts	Rainfall												Total	Extremes recorded	
	Mean maximum	Mean minimum	Mean maximum	Mean minimum	Highest	Lowest	>32°	>38°		J	F	M	A	M	Jn	Jl	A	S	O	N	D		Highest	Lowest
										Millimetres														
Geraldtown, Western Australia Lat. 28.8°S Alt. 4 m	32.0	17.5	19.3	9.2	46.5	1.0	35	10	0	6	7	13	24	70	121	97	68	31	18	7	4	466	855	262
(4) Winter rainfall: Arid Zone AZ(W) < 250 mm																								
Eucla, Western Australia Lat. 31.7°S Alt. 5 m	25.0	16.7	17.9	7.0	50.8	2.2	26	12	0.6	15	18	20	27	31	27	23	23	18	19	16	13	250	433	112

Table A1.4 Alpine zone

Locality	January temperatures (°C)		July temperatures (°C)		Temperature extremes recorded (°C)		No. of hot days		Frosts	Rainfall												Total	Extremes recorded	
	Mean maxi-mum	Mean mini-mum	Mean maxi-mum	Mean mini-mum	Highest	Lowest	>32°	>38°		J	F	M	A	M	Jn	Jl	A	S	O	N	D		Highest	Lowest
										.... Millimetres														
Charlotte's Pass, New South Wales Lat. 36.4°S Alt. 1 750 m	17.1	4.7	1.0	—7.5	28.9	—22	0	0	215	126	121	165	167	201	224	220	256	203	268	205	165	2 321	3 328	1 468
Mt Buffalo, Victoria Lat. 36.7°S Alt. 1 327 m	19.4	11.0	3.6	—0.7	34.1	—7.8	<1	0	71	81	90	104	135	193	223	227	226	191	195	133	113	1 911	3 341	737
Cradle Valley, Tasmania Lat. 41.6°S Alt. 912 m	16.9	5.2	4.6	0.9	31.7	—10.3	0	0	*Not assessed*	150	141	157	221	276	274	311	297	265	251	223	182	2 748	4 086	2 024

Appendix 2. Comparative volume tables and form factors

The table which follows compares figures from several published eucalypt volume tables for four tree sizes: h10, d10; h15, d15; h20, d20; and h30, d30.

For the full tables, which it is impossible to reproduce here for reasons of space, the reader is referred to the original sources cited below. In every case the independent variables measured were d (diameter in cm at 1.3 m overbark (OB)) and h (total tree height in m). In addition to volumes, form factors have been calculated. A brief summary of the methods used in each case precedes the table.

1. CIANCIO AND HERMANIN, 1974: *E. occidentalis*

Area Calabria (Italy) *Number of trees* 624

Range of tree sizes h 4 - 18 m d 5 - 20 cm

Definition of volume Stem volume overbark to 5 cm (OB) top, excluding stump.

Volume formula

$$v = -0.000349604598\,d - 0.000063313776\,d^2 + 0.000032240111\,d^2h + 0.000142407443\,dh$$

2. CIANCIO, 1966: *E. globulus*

Area Italy (Piazza Armerina, Sicily) *Number of trees* 496

Range of tree sizes h 16 - 21 m d 6 - 32 cm

Definition of volume Stem volume overbark, top diameter not defined, stump excluded.

Volume formula Not stated

3. CIANCIO, 1966: *E. camaldulensis*

Area Italy (Piazza Armerina, Sicily) *Number of trees* 2 293

Range of tree sizes h 4 - 16 m d 6 - 24 cm

Definition of volume Stem volume, overbark, top diameter not defined, stump excluded.

Volume formula Not stated

4. CIANCIO, 1970: *E. camaldulensis*

Area Italy (Policoro commune, Matera province) *Number of trees* 212

Range of tree sizes h 4 - 16 m d 3 - 24 cm

Definition of volume Stem volume overbark to 5 cm (OB) top diameter, stump excluded.

Volume formula $v = -0.000860\ d + 0.000117\ d^2 + 0.000024\ d^2h + 0.000061\ dh$

5. KOLAR, 1961: *E. camaldulensis*

Area Afek forest plantation (Israel) *Number of trees* 594

Range of tree sizes h 6 - 17 m d 6 - 26 cm

Definition of volume Stem and branchwood volume to 3 cm (OB) top, stump (10-20 cm) excluded.

6. CHATURVEDI, 1973: *E.* "hybrid" (*E. tereticornis*)

Area India (Bihar, Haryana, West Bengal, Punjab, Uttar Pradesh, Madhya Pradesh, Kerala and Tamil Nadu). *Number of trees* 580

Range of tree sizes h 5 - 22 m d 5 - 29 cm

Definition of volume Stem volume overbark to 5 cm (OB) top, stump included. Published tables give underbark volumes also.

Volume formula $v = -0.0001 + 0.31145\ d^2h$

7. HEINSDIJK *et al.*, 1965: Mixed eucalypt species

Area Brazil (states of Paraiba, Pernambuco, Minas Gerais, Rio de Janeiro and São Paulo) *Number of trees* 260

Range of tree sizes d 5 - 60 cm

Species included Mainly *E. saligna, E. citriodora* and *E. robusta* with some *E. tereticornis, E. "alba", E. camaldulensis* and *E. grandis*

Definition of volume Stem volume overbark to tip, stump included.

Volume formula $\log v = -5.24057 + 1.86157 \log (\text{GOB}) + 1.02437 \log h$

where GOB = girth overbark

8. Chaturvedi and Pande, 1973: *E. grandis*

Area India (states of Kerala and Tamil Nadu) *Number of trees* 149

Range of tree sizes	h 9 - 35 m d 6 - 28 cm
Definition of volume	Stem volume overbark to 5 cm (OB) top, stump included. Published tables give underbark volumes also.
Volume formula	$v = -0.0009 + 0.3360\ d^2h$

9, 10. Pande and Jain, 1976: *E. grandis* age 6 (No. 9) and age 14 (No. 10)

Area India (states of Kerala and Tamil Nadu) *Number of trees* 233

Range of tree sizes	h 6 - 42 m d 5 - 34 cm
Definition of volume	Stem volume overbark to 5 cm (OB) top. Inclusion of stump not specified, assumed included in accordance with previous practice (see No. 8 above). Published tables include separate overbark and underbark tables for trees of ages 6, 8, 10, 12 and 14 years. Excerpts from the age 6 and age 14 tables are reproduced here.
Volume formula	$v = -0.037728 + 0.216865\ d^2h + 0.039256\ d^2h \log A + 0.003188\ h$ (where A = age in years)

11. Wattle Research Institute, 1972: *E. grandis*

Area South Africa	*Number of trees* Several hundreds
Range of tree sizes	h 10 - 26 m d 6 - 25 cm
Definition of volume	Stem volume underbark to 5 cm top, stump included.
Volume formula	Not stated

12. Kingston, 1972: *E. grandis*

Area Uganda	*Number of trees* 455
Range of tree sizes	h 3 - 45 m d 2 - 58 cm
Definition of volume	Stem volume overbark to tip, stump excluded.
Volume formula	$v = 0.00003805 - 0.00009789\ d^2 + 0.0001325\ dh + 0.00002967\ d^2h$

Published tables also give total underbark volumes and volumes to 10 cm and 20 cm top, both overbark and underbark. Extracts from these are reproduced here.

Table A2.1 Examples of eucalypt tree volumes (v)[1] and form factors (f)

Species and country		Tree size h10 d10	h15 d15	h20 d20	h30 d30
Volume of cylinder		.079	.266	.628	2.121
1. *E. occidentalis*, Italy (Calabria)	v	.037	.121	.283	—
	f	.468	.455	.451	—
2. *E. globulus*, Italy (Sicily)	v	.035	.108	.255	—
	f	.443	.406	.406	—
3. *E. camaldulensis*, Italy (Sicily)	v	.037	.110	—	—
	f	.468	.414	—	—
4. *E. camaldulensis*, Italy (Basilicata)	v	.033	.108	—	—
	f	.418	.406	—	—
5. *E. camaldulensis*, Israel (Afek)	v	.041	—	—	—
	f	.520	—	—	—
6. *E. tereticornis*, India	v	.031	.105	.249	—
	f	.392	.395	.396	—
7. *E.* mixed spp., Brazil	v[2]	(.037)	(.120)	(.279)	(.882)
	f	.468	.451	.444	.416
8. *E. grandis*, India (Kerala, Tamil Nadu)	v	.035	.114	.270	.908
Chaturvedi and Pande 1973	f	.443	.429	.430	.428
9. *E. grandis*, India (Kerala, Tamil Nadu)	v	.023	.107	.256	.833
Pande and Jain, 1976, age 6	f	.291	.402	.408	.393
10. *E. grandis*, same as No. 9, age 14	v	.026	.118	.282	.923
	f	.329	.444	.449	.435
11. *E. grandis*, South Africa	v[3]	(.028)	(.109)	(.282)	—
	f	.354	.410	.449	—
12. *E. grandis*, Uganda	v	.033	.108	.251	.832
	f	.418	.406	.400	.392
Ditto to 10 cm top (OB)	v	.012	.080	.225	.813
Ditto to 20 cm top (OB)	v	—	—	.064	.551
Ditto total volume (UB)	v	.029	.093	.217	.720
	f	.367	.350	.346	.339
Ditto "silvolume"[4] (UB)	v	.029	.097	.230	.777
	f	.367	.366	.366	.367

[1] All volumes are m^3 overbark except those (under *E. grandis*, Uganda) defined as underbark. — [2] Figures in parentheses have been derived from the published tables by interpolation. — [3] Overbark volumes derived from published underbark volume tables and bark percentages. — [4] Uses a conventional form factor of .3667, which is constant for all tree sizes, to convert the product of OB basal area and total height to UB stem volume to 5 cm top excluding stump.

Appendix 3. Examples of yield tables

Notes on symbols

In the yield tables, the definition of the symbols used is as shown below. Most of them are those recommended by the International Union of Forestry Research Organizations (IUFRO, 1965).
Mensurational symbols are expressed in capital letters only if they refer to total per hectare, e.g., G = total basal area per hectare, V = total volume per hectare.
Unless otherwise indicated, all measurements are overbark. Underbark measurements are indicated by the symbol $_u$. Thus G denotes overbark basal area per hectare, G_u underbark basal area per hectare.
Unless otherwise indicated, volume measurements are of stem volume only and exclude branch volume. The inclusion of branch volume is indicated by the symbol $_b$. Thus V_b denotes overbark volume per hectare of stem *and* branches.
The definition of stem volume varies from country to country as to whether (*a*) stump, (*b*) tip above a given diameter are included. This has been stated when known. In the absence of precise information, it may be reasonable to assume that the IUFRO definition — "from ground to tip of tree" has been followed, i.e., that volume of both stump and tip is included.

IUFRO SYMBOLS

d Diameter overbark at 1.3 m of a single tree (cm)

d_u Diameter underbark at 1.3 m of a single tree (cm)

$\bar{d}$ Arithmetic mean diameter at 1.3 m (cm)

d_g Diameter corresponding to mean basal area of stand (cm)

f Artificial form factor, the factor used to convert the product of basal area overbark at 1.3 m and total height to total stem volume overbark from ground to tip of tree, $f = \frac{v}{gh}$

g Basal area overbark at 1.3 m of a single tree (m^2)

G Total basal area overbark per hectare (m^2)

h Total height of a tree from ground to tip (m)

$\bar{h}$ Arithmetic mean height (m)

h_g Height corresponding to mean basal area of a stand (m)

h_{dom} Average height of dominant trees (m). The definition of "dominant" varies from one country to another and is not always clearly stated. In South Africa (van Laar, 1961) h_{dom} is the height corresponding to a diameter of $\bar{d}$ plus 1.5 standard deviations of d. In Uganda it is the height corresponding to the mean diameter of the 100 thickest (biggest diameter) trees per hectare.

N Number of trees per hectare

v Total stem volume overbark from ground to tip of tree (excluding branches, including stump and tip) of a single tree (m^3)

v_b Total volume overbark of stem and branches of a single tree (m^3)

v_u Total stem volume underbark of a single tree (m^3)

V Total stem volume overbark per hectare (m^3)

OTHER ABBREVIATIONS

CAI Current annual increment. Volume increment overbark per hectare in a single year (m^3)

MAI Mean annual increment. Average annual volume increment overbark per hectare over the life of the crop (m^3) = total overbark volume production, including thinnings, divided by the age

QC Quality class. A measure of the relative productive capacity of a site. In the following tables the number of QCs in an area varies from 1 to 6 and QC1 is the most highly productive class

SI Site Index. A measure of site quality based on the height of the dominant trees in a stand at a given age (usually 10 years)

S% Spacing percent. Average spacing between trees expressed as a percentage of the dominant height of the stand

Table A3.1

Species E. camaldulensis *Reference:* Country statement
Area Morocco (Mamora)
Stocking Spacing 3.5 × 3.5 m, therefore initially N = 800/ha
Volume Stem volume overbark. Inclusion/exclusion of tip and stump not specified.

Quality class I

Age *(years)*	h_g *(m)*	d_g *(cm)*	G *(m²)*	V *(m³)*	MAI *(m³)*	CAI *(m³)*	f
6	11.1	11.6	8.7	35.1	5.8	12.1	0.365
7	12.4	13.0	10.9	47.7	6.8	13.3	0.353
8	13.6	14.3	13.1	61.7	7.7	13.7	0.346
9	14.6	15.4	15.2	75.1	8.3	14.2	0.340
10	15.6	16.5	17.4	90.2	9.0	15.1	0.333
11	16.5	17.4	19.5	105.4	9.6	15.0	0.328
12	17.3	18.3	21.5	120.1	10.0	14.4	0.323
13	18.0	19.1	23.3	134.1	10.3	14.4	0.320
14	18.7	19.8	25.1	149.0	10.6	14.2	0.317
15	19.3	20.5	26.9	162.6	10.9	14.0	0.313
16	19.9	21.1	28.6	177.0	11.0	13.4	0.311

Quality class II

6	10.4	10.9	7.6	29.3	4.9	8.7	0.373
7	11.5	12.0	9.3	38.7	5.5	8.7	0.363
8	12.5	13.1	11.0	48.8	6.1	10.8	0.354
9	13.5	14.2	12.9	60.4	6.7	11.0	0.346
10	14.3	15.1	14.5	70.9	7.1	11.0	0.341
11	15.1	15.9	16.2	82.4	7.5	10.9	0.336
12	15.8	16.7	17.8	93.5	7.8	10.6	0.331
13	16.4	17.3	19.2	103.6	8.0	9.6	0.329
14	16.9	17.9	20.4	112.6	8.0	9.2	0.325
15	17.4	18.4	21.7	122.1	8.1	8.7	0.323
16	17.8	18.8	22.8	130.0	8.1	8.3	0.320

Table A3.1 *(concluded)*

Quality class III

Age *(years)*	h_g *(m)*	d_g *(cm)*	G *(m^2)*	V *(m^3)*	MAI *(m^3)*	CAI *(m^3)*	f
6	9.6	10.0	6.4	23.5	3.9	7.1	0.382
7	10.6	11.1	7.9	30.9	4.4	7.6	0.370
8	11.5	12.0	9.3	38.7	4.8	7.9	0.363
9	12.3	12.9	10.7	46.7	5.2	7.8	0.356
10	13.0	13.7	12.0	54.4	5.4	7.5	0.350
11	13.6	14.3	13.1	61.7	5.6	7.5	0.346
12	11.2	14.9	14.2	69.5	5.8	7.4	0.342
13	14.7	15.5	15.3	76.5	5.9	6.5	0.339
14	15.1	15.9	16.2	82.4	5.9	5.3	0.336
15	15.4	16.2	16.9	87.0	5.8	4.5	0.334
16	15.7	16.5	17.6	91.8	5.7	4.6	0.331

Quality class IV

6	8.9	9.2	5.5	19.1	3.2	5.8	0.393
7	9.7	10.1	6.5	24.2	3.5	5.6	0.382
8	10.5	10.9	7.7	30.1	3.8	5.4	0.372
9	11.1	11.6	8.7	35.1	3.9	5.3	0.368
10	11.7	12.3	9.6	40.7	4.1	5.2	0.361
11	12.2	12.8	10.5	45.6	4.1	4.6	0.356
12	12.6	13.2	11.2	49.9	4.2	4.4	0.354
13	13.0	13.7	12.0	54.4	4.2	3.4	0.350
14	13.2	13.9	12.3	56.8	4.1	2.4	0.348
15	13.4	14.1	12.7	59.2	3.9	2.4	0.347
16	13.6	14.3	13.1	61.7	3.8	2.0	0.346

Quality class V

6	8.1	8.4	4.5	14.7	2.5	4.3	0.404
7	8.8	9.1	5.4	18.5	2.6	3.8	0.393
8	9.4	9.8	6.1	22.2	2.8	3.7	0.388
9	10.0	10.4	6.9	26.3	2.9	3.5	0.379
10	10.4	10.9	7.6	29.3	2.9	2.5	0.373
11	10.7	11.2	8.0	31.7	2.9	2.5	0.370
12	11.0	11.5	8.5	34.3	2.8	2.1	0.368
13	11.2	11.7	8.8	36.0	2.7	1.7	0.365
14	11.4	11.9	9.1	37.8	2.7	1.3	0.363
15	11.5	12.0	9.3	38.7	2.6	0.9	0.362
16	11.6	12.1	9.5	39.7	2.5	0.7	0.361

Table A3.2

Species	*E. cloeziana*	*Reference:* Country statement (provisional yield table)
Area	Zambia (Copperbelt)	
Stocking	Initial N = 720/ha, thinned at ages 5 and 8, final N = about 250/ha	
Volume	Stem volume. Volume of thinnings shown separately, included in the calculation of MAI.	

Age *(years)*	$\bar{h}$ *(m)*	$\bar{d}$ *(cm)*	N	G *(m^2)*	V *(m^3)*	CAI *(m^3)*	MAI *(m^3)*	Roundwood volume *m^3 to:*			Roundwood volume *percent to:*			Assortment *percent*			
								10 cm	15 cm	20 cm	10 cm	15 cm	20 cm	Saw	Small poles	Pur-lins	Waste
1																	
2	9.0	8.5	720														
3	12.5	12.6	720														
4	14.2	14.2	720		51.8		13.0										
B[1] 5	16.5	16.3	720	15.0													
A[1]	(17.0)	17.0	494														
T[1]	15.0	15.0	226	4.0	19			12			66				44	28	18
6	18.8	19.2	494														
7	20.5	21.0	494														
B 8	22.0	22.7	494	20.0	130		18.6	114	78		88	60		47	15	26	13
A	(22.6)	23.3	247														
T	20.6	21.2	247	8.7	54			46	26		85	48		36	19	31	14
9	24.0	25.2	247														
10	25.5	27.0	247	14.1	105		17.8	95	83		91	79		60	5	11	14
11	27.0	28.7	247	16.0													
12	28.2	30.4	247	17.9	146		18.2	135	130		93	89		60	4	9	17

[1] B = before thinning; A = after thinning; T = thinnings.

Table A3.3

Species *E. globulus* ssp. *globulus* *Reference*: Country statement
Area Portugal (north of River Tagus)
Stocking N = 1 100/ha
Volume Stem volume overbark to tip, including stump

Quality class I

h_{dom} age 10 = 27 m — 1 100 trees/ha

Age *(years)*	h_{dom} *(m)*	$\bar{d}$ *(cm)*	V *(m^3)*	G *(m^2)*	MAI *(m^3)*
2	10	7.6	20	4.9	10.0
3	13	10.4	50	9.3	16.7
4	16	13.1	100	14.8	25.0
5	18	14.6	140	18.3	28.0
6	20	15.8	185	21.6	30.8
7	22	16.8	230	24.3	32.9
8	24	17.7	280	27.1	35.0
9	25.6	18.5	325	29.4	36.1
10	27.0	19.4	380	32.5	38.0
11	28.6	20.0	430	34.6	39.1
12	30.0	20.6	480	36.8	40.0
13	31.0	21.0	512	37.9	39.4
14	32.0	21.3	545	39.1	38.9
15	32.6	21.5	566	39.8	37.7
16	33.2	21.6	586	40.4	36.6
17	33.6	21.7	600	40.9	35.3
18	34.0	21.8	610	41.1	33.9
19	34.4	21.9	620	41.3	32.6
20	34.8	21.9	630	41.4	31.5

Quality class II

h_{dom} age 10 = 23 m — 1 100 trees/ha

2	8.6	6.4	12	3.5	6.0
3	11.0	8.5	28	6.2	9.3
4	13.4	10.6	54	9.7	13.5
5	15.4	12.5	88	13.5	17.6
6	17.0	13.9	120	16.7	20.0
7	18.8	15.2	160	20.0	22.9
8	20.4	16.0	194	22.2	24.3
9	21.6	16.6	220	23.7	24.4
10	23.0	17.3	255	25.8	25.5
11	24.2	17.8	286	27.4	26.0
12	25.4	18.4	322	29.3	26.3
13	26.6	19.1	364	31.6	28.0
14	27.6	19.7	400	33.4	28.6
15	28.2	19.9	418	34.2	27.9
16	28.8	20.2	440	35.2	27.5
17	29.2	20.3	454	35.8	26.7
18	29.6	20.5	465	36.1	25.8
19	30.0	20.6	480	36.8	25.3
20	30.4	20.7	492	37.2	24.6

Table A3.3 *(continued)*

Quality class III

h_{dom} age 10 = 19 m — 1 100 trees/ha

Age *(years)*	h_{dom} *(m)*	$\bar{d}$ *(cm)*	V *(m^3)*	G *(m^2)*	MAI *(m^3)*
2	6.4	5.6	6	2.7	3.0
3	9.0	6.7	14	3.9	4.7
4	11.0	8.5	28	6.2	7.0
5	12.8	10.0	46	8.7	9.2
6	14.2	11.3	66	11.1	11.0
7	15.6	12.6	90	13.7	12.9
8	17.0	13.9	120	16.7	15.0
9	18.0	14.6	140	18.3	15.6
10	19.0	15.1	160	19.8	16.0
11	20.0	15.8	185	21.6	16.8
12	21.0	16.4	210	23.3	17.5
13	22.0	16.8	230	24.3	17.7
14	23.0	17.1	250	25.3	17.9
15	23.6	17.5	270	26.6	18.0
16	24.2	17.9	288	27.6	18.0
17	24.8	18.1	304	28.4	17.9
18	25.2	18.4	318	29.2	17.6
19	25.6	18.6	330	29.8	17.4
20	26.0	18.7	340	30.2	17.0

Quality class IV

h_{dom} age 10 = 15 m — 1 100 trees/ha

2	4.6	5.4	4	2.5	2.0
3	7.0	5.9	8	3.0	2.7
4	8.6	6.4	12	3.5	3.0
5	10.0	7.6	20	4.9	4.0
6	11.2	8.7	30	6.5	5.0
7	12.4	9.5	40	7.8	5.7
8	13.4	10.6	54	9.7	6.7
9	14.4	11.6	70	11.6	7.8
10	15.0	12.1	80	12.7	8.0
11	16.0	13.1	100	14.8	9.1
12	17.0	13.9	120	16.7	10.0
13	17.6	14.2	130	17.4	10.0
14	18.3	14.7	145	18.6	10.4
15	18.9	15.2	160	19.9	10.7
16	19.4	15.6	173	20.9	10.8
17	20.0	15.8	185	21.6	10.9
18	20.4	16.1	195	22.3	10.8
19	20.8	16.3	205	23.0	10.8
20	21.2	16.5	214	23.5	10.7

Table A3.3 *(concluded)*

Quality class V

h_{dom} age 10 = 11 m — 1 100 trees/ha

Age *(years)*	h_{dom} *(m)*	$\bar{d}$ *(cm)*	V *(m^3)*	G *(m^2)*	MAI *(m^3)*
2	3.0	5.1	2	2.2	1.0
3	5.0	5.7	5	2.8	1.7
4	6.4	6.2	8	3.3	2.0
5	7.4	6.3	9	3.5	1.0
6	8.4	6.5	12	3.6	2.0
7	9.2	7.1	16	4.3	2.3
8	9.9	7.4	19	4.7	2.4
9	10.6	8.0	24	5.6	2.7
10	11.0	8.5	28	6.2	2.8
11	11.6	8.8	32	6.7	2.9
12	12.2	9.6	40	7.9	3.3
13	12.8	10.0	46	8.7	3.5
14	13.4	10.6	54	9.7	3.9
15	14.0	11.1	62	10.6	4.1
16	14.5	11.5	70	11.5	4.4
17	14.8	12.0	77	12.4	4.6
18	15.2	12.5	83	13.0	4.6
19	15.6	12.5	89	13.6	4.7
20	16.0	12.8	95	14.1	4.8

Table A3.4

Species *E. globulus* ssp. *globulus* *Reference:* Country statement
Area Portugal (south of River Tagus)
Stocking N = 1 100/ha
Volume Stem volume overbark to tip, including stump

Age *(years)*	**Quality class I** (h_{dom} age 10 = 18 m)		**Quality class II** (h_{dom} age 10 = 14 m)		**Quality class III** (h_{dom} age 10 = 10 m)	
	V *(m^3)*	MAI *(m^3)*	V *(m^3)*	MAI *(m^3)*	V *(m^3)*	MAI *(m^3)*
4	34	8.5	18	4.5	6	1.5
6	83	13.8	44	7.3	19	3.2
8	148	18.5	83	10.4	36	4.5
10	202	20.2	123	12.3	54	5.4
12	246	20.5	149	12.4	72	6.0

Table A3.5

Species *E. globulus* var. *globulus* *Reference:* Pita Carpenter, 1966
Area Northern Spain (provinces of Santander, Pontevedra, Oviedo and La Coruña) *Number of sample plots* 48
Stocking N varies from 3 000/ha (age 4, QC IV) to 2 400/ha (age 16, QC I)
Volume Stem volume overbark from ground level to tip

Quality class I

Age *(years)*	$\bar{h}$ *(m)*	h_{dom} *(m)*	N	$\bar{d}$ *(cm)*	G *(m²)*	V *(m³)*	f	MAI *(m³)*	CAI *(m³)*
4	11.1	15.5	2 700	9.2	17.7	110	0.560	27.5	
6	15.8	20.9	2 651	11.4	27.3	226	0.524	37.7	58.0
8	19.2	24.7	2 604	12.9	34.1	336	0.513	42.0	55.0
10	22.0	27.9	2 557	14.0	39.6	443	0.508	44.3	53.5
12	24.2	30.4	2 511	14.9	43.9	537	0.505	44.8	47.0
14	25.9	32.3	2 466	15.6	47.3	617	0.504	44.1	40.0
16	27.3	33.9	2 421	16.2	50.0	687	0.503	42.9	35.0

Quality class II

Age *(years)*	$\bar{h}$ *(m)*	h_{dom} *(m)*	N	$\bar{d}$ *(cm)*	G *(m²)*	V *(m³)*	f	MAI *(m³)*	CAI *(m³)*
4	10.8	15.2	2 800	8.8	17.1	104	0.563	26.0	
6	14.5	19.4	2 750	10.7	24.7	190	0.531	31.7	43.0
8	17.0	22.2	2 700	11.9	29.7	262	0.519	32.8	36.0
10	19.0	24.5	2 652	12.7	33.7	329	0.514	32.9	33.5
12	20.4	26.1	2 604	13.3	36.4	380	0.512	31.7	25.5
14	21.5	27.3	2 557	13.8	38.6	423	0.510	30.2	21.5
16	22.5	28.5	2 511	14.3	40.6	463	0.507	28.9	20.0

Quality class III

Age *(years)*	$\bar{h}$ *(m)*	h_{dom} *(m)*	N	$\bar{d}$ *(cm)*	G *(m²)*	V *(m³)*	f	MAI *(m³)*	CAI *(m³)*
4	10.2	14.5	2 900	8.3	15.8	93	0.577	23.3	
6	13.0	17.7	2 848	9.8	21.6	152	0.541	25.3	29.5
8	14.7	19.6	2 797	10.7	25.1	195	0.528	24.4	21.5
10	16.0	21.1	2 746	11.3	27.7	232	0.523	23.2	18.5
12	16.9	22.1	2 697	11.8	29.5	259	0.520	21.6	13.5
14	17.7	23.0	2 648	12.2	31.1	286	0.518	20.4	13.0
16	18.2	23.6	2 601	12.5	32.1	301	0.515	18.8	8.0

Quality class IV

Age *(years)*	$\bar{h}$ *(m)*	h_{dom} *(m)*	N	$\bar{d}$ *(cm)*	G *(m²)*	V *(m³)*	f	MAI *(m³)*	CAI *(m³)*
4	9.2	13.4	3 000	7.6	13.7	75	0.595	18.8	
6	11.1	15.5	2 946	8.8	17.7	110	0.560	18.3	17.5
8	12.2	16.8	2 893	9.4	20.0	134	0.549	16.8	12.0
10	13.0	17.7	2 841	9.9	21.6	152	0.541	15.2	9.0
12	13.6	18.4	2 790	10.2	22.9	167	0.536	13.9	7.5
14	14.0	18.8	2 740	10.5	23.7	177	0.533	12.6	5.0
16	14.4	19.3	2 690	10.8	24.5	187	0.530	11.7	5.0

Table A3.6

Species	*E. globulus* ssp. *globulus*
Reference	Data made available by courtesy of Servicio de Producción Forestal de la Dirección de la Producción Agraria del Ministerio de Agricultura, Madrid
Area	Southwest Spain, sandy soils
Stocking	N varies from about 600/ha in QC I to 400/ha in QC IV
Volume	Stem volume overbark

Quality class I

Age *(years)*	h_g *(m)*	N	d_g *(cm)*	G *(m^2)*	V *(m^3)*	MAI *(m^3)*	CAI *(m^3)*
3	5.2	604	6.1	1.8	4.0	1.3	—
6	11.3	604	11.0	5.7	28.7	4.8	8.2
9	16.0	604	14.7	10.3	73.8	8.2	15.0
12	19.5	594	17.5	14.3	125.1	10.4	17.1
15	22.2	575	19.8	17.7	176.3	11.8	17.1

Quality class II

Age *(years)*	h_g *(m)*	N	d_g *(cm)*	G *(m^2)*	V *(m^3)*	MAI *(m^3)*	CAI *(m^3)*
3	3.5	549	5.0	1.1	1.5	0.5	—
6	8.6	549	9.1	3.6	13.7	2.3	4.1
9	13.0	549	12.6	6.8	39.5	4.4	8.6
12	16.5	549	15.4	10.2	75.4	6.3	12.0
15	19.4	542	17.7	13.3	115.7	7.7	13.4

Quality class III

Age *(years)*	h_g *(m)*	N	d_g *(cm)*	G *(m^2)*	V *(m^3)*	MAI *(m^3)*	CAI *(m^3)*
3	2.6	490	4.5	0.8	0.7	0.2	—
6	6.5	490	7.6	2.2	6.2	1.0	1.8
9	10.0	490	10.4	4.2	18.6	2.1	4.1
12	12.9	490	12.7	6.2	35.7	3.0	5.7
15	15.4	487	14.7	8.3	57.2	3.8	7.2

Quality class IV

Age *(years)*	h_g *(m)*	N	d_g *(cm)*	G *(m^2)*	V *(m^3)*	MAI *(m^3)*	CAI *(m^3)*
3	1.9	415	4.4	0.6	0.3	0.1	—
6	4.6	415	6.6	1.4	2.7	0.5	0.8
9	7.0	415	8.5	2.4	7.3	0.8	1.5
12	8.9	415	10.0	3.3	13.0	1.1	1.9
15	10.4	407	11.3	4.1	18.9	1.3	2.0

Table A3.7

Species	*E. globulus* ssp. *globulus*
Reference	Data made available by courtesy of Servicio de Producción Forestal de la Dirección de la Producción Agraria del Ministerio de Agricultura, Madrid
Area	Southwest Spain, soils derived from slates and shales
Stocking	N varies from about 600/ha (age 3, QC I) to about 400/ha (age 15, QC V)
Volume	Stem volume overbark

Quality class I

Age *(years)*	h_g *(m)*	N	d_g *(cm)*	G *(m^2)*	V *(m^3)*	MAI *(m^3)*	CAI *(m^3)*
3	5.8	597	5.5	1.4	3.9	1.3	—
6	13.5	597	13.0	7.9	45.7	7.6	13.9
9	20.0	597	19.4	17.1	145.6	16.2	33.3
12	25.1	597	24.4	26.0	277.3	23.1	43.9
15	29.1	534	28.4	33.8	417.8	27.9	46.8

Quality class II

Age *(years)*	h_g *(m)*	N	d_g *(cm)*	G *(m^2)*	V *(m^3)*	MAI *(m^3)*	CAI *(m^3)*
3	4.5	559	4.3	0.8	2.0	0.6	—
6	11.1	559	10.8	5.1	24.5	4.1	7.5
9	17.0	546	16.6	11.8	85.6	9.5	20.4
12	21.8	534	21.3	19.0	176.2	14.7	30.2
15	25.8	510	25.2	25.4	278.5	18.6	34.1

Quality class III

Age *(years)*	h_g *(m)*	N	d_g *(cm)*	G *(m^2)*	V *(m^3)*	MAI *(m^3)*	CAI *(m^3)*
3	3.7	522	3.7	0.6	1.4	1.4	—
6	9.2	522	9.0	3.3	13.3	2.2	4.0
9	14.0	511	13.7	7.5	45.0	5.0	10.6
12	17.9	493	17.6	12.0	91.6	7.6	15.5
15	21.1	482	20.8	16.4	147.3	9.8	18.6

Quality class IV

Age *(years)*	h_g *(m)*	N	d_g *(cm)*	G *(m^2)*	V *(m^3)*	MAI *(m^3)*	CAI *(m^3)*
3	2.8	474	3.0	0.3	0.8	0.3	—
6	7.0	474	7.0	1.8	5.8	1.0	1.7
9	11.0	470	10.9	4.4	21.0	2.3	5.1
12	14.3	458	14.2	7.3	44.7	3.7	7.9
15	17.1	444	17.0	10.1	73.7	4.9	9.7

Quality class V

Age *(years)*	h_g *(m)*	N	d_g *(cm)*	G *(m^2)*	V *(m^3)*	MAI *(m^3)*	CAI *(m^3)*
3	2.2	432	2.5	0.2	0.6	0.2	—
6	5.3	432	5.5	1.0	2.7	0.5	0.7
9	8.0	420	8.2	2.2	7.9	0.9	1.7
12	10.1	405	10.4	3.4	15.0	1.3	2.4
15	11.8	390	12.1	4.5	23.0	1.5	2.7

Table A3.8

Species	*E. globulus* ssp. *globulus*	*Reference:*	Country statement and Streets, 1962
Area	India (Nilgiri Hills)		
Volume	Overbark volume, derived from stacked volume of firewood by use of reducing factor 0.625		

Quality class I

Age *(years)*	h_{dom} *(m)*	d_{dom} *(cm)*	V *(m^3)*	MAI *(m^3)*
5	21.9	21.0	155.3	31.1
6			193.5	32.3
7	26.2	25.9	227.4	32.5
8			262.4	32.8
9	29.6	29.9	296.3	32.9
10			329.1	32.9
11	32.9	33.1	359.7	32.7
12			385.9	32.2
13	35.4	37.2	411.1	31.6
14			434.1	31.0
15	37.8	39.6	454.8	30.3
16			474.5	29.7
17			494.2	29.1
18			512.8	28.5
19			530.3	27.9
20			547.8	27.4

Quality class II

Age *(years)*	h_{dom} *(m)*	d_{dom} *(cm)*	V *(m^3)*	MAI *(m^3)*
5	16.2	15.4	113.7	22.7
6			141.0	23.5
7	20.1	19.4	166.2	23.7
8			191.3	23.9
9	23.8	23.5	215.4	23.9
10			239.4	23.9
11	26.5	26.7	262.4	23.9
12			283.2	23.6
13	29.0	29.9	303.9	23.4
14			321.4	23.0
15	31.1	32.3	336.8	22.5
16			352.1	22.0
17			367.4	21.6
18			382.6	21.3
19			394.7	20.8
20			410.0	20.5

Table A3.8 *(concluded)*

Quality class III

Age *(years)*	h_{dom} *(m)*	d_{dom} *(cm)*	V *(m^3)*	MAI *(m^3)*
5	11.3	12.1	72.1	14.4
6			88.6	14.8
7	14.6	15.4	104.9	15.0
8			120.3	15.0
9	17.7	18.6	135.6	15.1
10			150.9	15.1
11	20.1	21.8	166.2	15.1
12			180.4	15.0
13	22.3	23.5	192.4	14.8
14			207.8	14.8
15	24.4	25.9	218.7	14.6
16			229.6	14.4
17			240.2	14.1
18			251.4	14.0
19			261.3	13.8
20			272.3	13.6

Table A3.9

Species *E. grandis* *Reference:* Uganda Forest Department Technical Note 193/72 (Kingston, 1972)
Area Uganda
Stocking N = 1 680/ha (assumes full stocking)
Volume "Silvolume" = stem volume underbark to 5 cm top excluding stump, derived from the product of height times overbark basal area by multiplying by the conventional form factor 0.3667 for all sizes of tree.

Silvolume yield table for ***E. grandis***

SITE INDEX (SI)

Age (years)	20				25				30				35				40			
	h_{dom} (m)	CAI (m^3)	MAI (m^3)	V_u (m^3)	h_{dom} (m)	CAI (m^3)	MAI (m^3)	V_u (m^3)	h_{dom} (m)	CAI (m^3)	MAI (m^3)	V_u (m^3)	h_{dom} (m)	CAI (m^3)	MAI (m^3)	V_u (m^3)	h_{dom} (m)	CAI (m^3)	MAI (m^3)	V_u (m^3)
4	15.90		23.87	95.48	18.21		26.20	104.78	20.50		36.07	144.29	22.81		43.80	175.21	25.11		50.23	200.90
5	16.20	7.66	20.63	103.14	19.83	20.40	25.04	125.18	22.79	31.98	35.25	176.27	25.77	45.40	44.12	220.61	28.74	60.50	52.28	261.49
6	17.39	9.13	18.71	112.27	20.89	19.62	24.13	144.80	24.37	26.42	33.78	202.69	27.87	38.90	43.25	259.51	31.34	52.70	52.35	314.10
7	18.01	7.35	17.09	119.62	21.95	18.50	23.33	163.30	25.87	25.50	32.60	228.19	29.82	36.50	42.29	296.01	33.74	49.00	52.40	366.80
8	18.67	8.06	15.96	127.68	23.01	17.50	22.73	181.80	27.33	24.50	31.71	253.69	31.67	34.35	41.56	332.51	35.98	46.75	51.98	415.80
9	19.34	8.42	15.12	136.10	24.04	16.70	22.14	199.30	28.70	23.59	30.91	278.19	33.40	33.63	40.66	366.13	38.06	45.00	51.39	462.55
10	20.00	8.53	14.46	144.63	25.00	15.80	21.51	215.10	30.00	23.24	30.14	301.43	35.00	32.38	39.85	391.51	40.00	43.71	50.76	507.55
11	20.64	8.85	13.95	153.48	25.94	14.50	20.87	229.60	31.21	22.38	29.44	323.81	36.51	31.69	39.11	430.20	41.78	41.64	49.93	549.19
12	21.25	7.93	13.45	161.41	26.81	14.10	20.49	245.90	32.34	21.54	28.78	345.35	37.90	30.12	38.36	460.32	43.43	39.91	49.09	589.10
13	21.84	8.21	13.05	169.62	27.64	13.96	19.99	259.86	33.40	20.78	28.16	366.13	39.20	28.99	37.64	489.31	44.96	38.12	48.25	627.22
14	22.39	7.82	12.67	177.44	28.41	13.26	19.51	273.12	34.39	19.89	27.57	386.02	40.41	27.70	36.93	517.01	46.39	36.60	47.42	663.82
15	22.92	7.68	12.34	185.12	29.14	12.84	19.06	285.96	35.32	19.12	27.01	405.14	41.54	26.48	36.23	543.49	47.72	34.87	46.58	698.69
16	23.42	7.38	12.03	192.50	29.82	12.20	18.64	298.16	36.19	18.25	26.46	423.39	42.60	25.28	35.55	568.87	48.97	33.50	45.76	732.19
17	23.89	7.05	11.74	199.55	30.47	12.01	18.25	310.17	37.01	17.53	25.94	440.92	43.59	24.17	34.88	593.04	50.14	31.99	44.95	764.18
18	24.34	6.86	11.47	206.41	31.08	11.20	17.85	321.37	37.79	16.98	25.44	457.90	44.53	23.34	34.24	616.38	51.23	30.36	44.14	794.54
19	24.77	6.65	11.21	214.06	31.66	10.95	17.49	332.32	38.57	17.26	25.01	475.16	45.41	22.26	33.61	638.64	52.27	29.45	43.37	823.99
20	25.17	6.28	10.97	219.34	32.21	10.52	17.14	342.84	39.20	14.15	24.47	489.31	46.24	21.30	33.00	659.94	53.24	27.90	42.59	851.99

Note: SI 20 data from 4-6 years are very unreliable.

Table A3.10

Species	*E. grandis* *Reference:* van Laar, 1961, courtesy of the author
Area	South Africa (Transvaal) *Number of sample plots* 242
Stocking	N = 1 100/ha
Volume	Stem volume underbark to 7.5 cm top, including stump
Remarks	Yield table assumes 100 percent stocking. For planning purposes the author recommends reducing yields by 10 percent to allow for less than full stocking. Site Index I (the best) does not occur in the Transvaal. Over the whole area SI IV was considered as occupying approximately 80 percent of the area and SI VI 20 percent. Original published tables have been converted from imperial to metric.

Volume yield table for unthinned stands in the Transvaal

Site Index II

Age *(years)*	h_{dom} *(m)*	$\bar{h}$ *(m)*	$\bar{d}$ *(cm)*	G *(m^2)*	V_u *(m^3)*	CAI_u *(m^3)*	MAI_u *(m^3)*
3	19.1	16.9	11.9	11.7	57.4		19.1
4	23.3	20.8	14.3	17.0	112.7	55.3	28.1
5	27.1	24.3	16.1	21.6	172.1	59.5	34.4
6	30.6	27.5	17.4	25.4	236.5	64.4	39.4
7	33.7	30.2	18.5	28.8	299.5	63.0	42.9
8	36.3	32.6	19.2	31.0	356.1	56.7	44.5
9	38.7	34.8	19.8	33.1	409.3	53.2	45.5

Site Index III

Age *(years)*	h_{dom} *(m)*	$\bar{h}$ *(m)*	$\bar{d}$ *(cm)*	G *(m^2)*	V_u *(m^3)*	CAI_u *(m^3)*	MAI_u *(m^3)*
3	16.9	15.1	11.4	10.7	44.1		14.7
4	20.7	18.5	13.5	15.1	85.4	41.3	21.3
5	24.1	21.6	15.1	19.1	131.9	46.5	26.4
6	27.2	24.4	16.4	22.5	180.9	49.0	30.2
7	30.0	26.9	17.4	25.3	229.9	49.0	32.8
8	32.3	29.0	18.2	27.7	276.7	46.9	34.6
9	34.4	30.9	18.8	29.8	320.5	43.7	35.6
10	36.0	32.3	19.4	31.5	360.3	39.9	36.0
11	37.8	34.0	19.8	33.0	395.0	34.6	35.9
12	39.0	35.1	20.1	34.1	424.7	29.7	35.4

Table A3.10 *(continued)*

Volume yield table for unthinned stands in the Transvaal

Site Index IV

Age *(years)*	h_{dom} *(m)*	$\bar{h}$ *(m)*	$\bar{d}$ *(cm)*	G *(m^2)*	V_u *(m^3)*	CAI_u *(m^3)*	MAI_u *(m^3)*
3	14.8	13.1	10.7	9.4	32.2		10.7
4	18.1	16.1	12.5	13.0	60.9	28.7	15.3
5	21.1	18.8	14.1	16.5	97.3	36.4	19.3
6	23.8	21.3	15.3	19.7	135.7	38.5	22.6
7	26.2	23.5	16.4	22.4	173.5	37.8	24.8
8	28.3	25.4	17.2	24.7	209.2	35.7	26.2
9	30.1	27.0	17.8	26.6	242.8	33.6	27.0
10	31.7	28.4	18.3	28.2	273.6	30.8	27.4
11	32.9	29.6	18.7	29.3	301.6	28.0	27.4
12	34.1	30.7	19.1	30.5	326.8	25.2	27.2
13	35.1	31.5	19.3	31.4	349.9	23.1	26.9
14	36.0	32.3	19.6	32.2	371.5	21.7	26.5
15	36.9	33.2	19.7	32.8	390.4	18.9	26.0
16	37.5	33.7	19.9	33.3	406.5	16.1	25.4
17	38.4	34.5	20.0	33.7	420.5	14.0	24.8
18	39.0	35.1	20.1	34.1	432.4	11.9	24.0

Site Index V

Age *(years)*	h_{dom} *(m)*	$\bar{h}$ *(m)*	$\bar{d}$ *(cm)*	G *(m^2)*	V_u *(m^3)*	CAI_u *(m^3)*	MAI_u *(m^3)*
3	12.7	11.2	10.2	8.6	23.8		7.9
4	15.5	13.8	11.7	11.3	42.0	18.2	10.5
5	18.1	16.1	13.0	14.1	66.1	24.1	13.3
6	20.4	18.2	14.1	16.6	93.1	26.9	15.5
7	22.5	20.1	15.1	19.0	121.0	28.0	17.3
8	24.3	21.7	15.9	21.1	148.0	26.9	18.5
9	25.8	23.1	16.6	23.0	173.2	25.2	19.2
10	27.1	24.2	17.1	24.6	196.3	23.1	19.6
11	28.2	25.3	17.6	26.0	217.3	21.0	19.7
12	29.3	26.2	18.0	27.2	236.8	19.6	19.7
13	30.1	27.0	18.3	28.3	254.7	17.8	19.6
14	30.9	27.8	18.6	29.1	271.1	16.4	19.4
15	31.6	28.4	18.8	29.9	286.2	15.0	19.1
16	32.2	28.9	19.0	30.4	300.2	14.0	18.8
17	32.9	29.5	19.2	30.9	313.1	12.9	18.4
18	33.5	30.1	19.3	31.3	325.0	11.9	18.1
19	33.8	30.4	19.4	31.7	336.2	11.2	17.7
20	34.4	30.9	19.5	32.0	346.4	10.1	17.4

Table A3.10 *(concluded)*

Volume yield table for unthinned stands in the Transvaal

Site Index VI

Age *(years)*	h_{dom} *(m)*	$\bar{h}$ *(m)*	$\bar{d}$ *(cm)*	G *(m²)*	V_u *(m³)*	CAI_u *(m³)*	MAI_u *(m³)*
3	10.6	9.3	9.5	7.4	15.4		5.1
4	13.0	11.4	10.7	9.4	28.0	12.6	7.0
5	15.1	13.4	11.7	11.4	43.0	15.0	8.6
6	17.0	15.1	12.6	13.3	59.8	16.8	9.9
7	18.7	16.6	13.4	15.0	77.3	17.5	11.1
8	20.2	18.0	14.1	16.7	95.2	17.8	11.9
9	21.5	19.2	14.8	18.3	112.7	17.5	12.5
10	22.6	20.2	15.3	19.7	129.1	16.4	12.9
11	23.5	21.0	15.8	21.0	144.5	15.4	13.2
12	24.4	21.8	16.3	22.1	159.2	14.7	13.3
13	25.1	22.5	16.6	23.1	172.5	13.3	13.3
14	25.8	23.1	16.9	24.1	185.1	12.6	13.2
15	26.3	23.6	17.2	24.9	196.3	11.2	13.1
16	26.9	24.0	17.5	25.6	206.4	10.1	12.9
17	27.4	24.5	17.7	26.2	215.5	9.1	12.7
18	27.8	24.9	17.9	26.7	223.9	8.4	12.5
19	28.2	25.3	18.0	27.2	231.6	7.7	12.2
20	28.7	25.7	18.1	27.5	238.6	7.0	12.0

Table A3.11

Species	*E. grandis*	*Reference:* van Laar, 1961, courtesy of the author
Area	South Africa (Transvaal)	
Stocking	Initial N = about 1 100/ha, heavily thinned at ages 3½, 5, 8 and 12 to final N = about 110/ha	
Volume	Stem volume underbark to 7.5 cm top, including stump	
Remarks	Original published tables have been converted from imperial to metric.	

Yield table for heavily thinned stands in the Transvaal

Age (years)	h_{dom} (m)	Remaining stand N	G (m^2)	$\bar{d}$ (cm)	$\bar{h}$ (m)	V_u (m^3)	S%	Thinnings N	$\bar{d}$ (cm)	$\bar{h}$ (m)	V_u (m^3)	Total stand N	G (m^2)	$\bar{d}$ (cm)	$\bar{h}$ (m)	V_u (m^3)	S%	Sum of thinnings (m^3/ha)	Total production (m^3/ha)	Total vol. of thinnings as per cent of total production
Site Index III																				
3½	18.8	638	9.78	14.2	17.2	52.9	21.0	487	10.2	13.7	12.2	1 125	13.13	12.4	16.8	65.1	15.9	12.2	65.1	18.7
5	24.1	356	9.09	18.3	23.3	72.2	22.0	282	14.0	21.0	27.7	638	13.22	16.5	22.7	99.9	16.4	39.9	112.1	35.6
8	32.3	183	10.63	27.3	30.2	115.0	22.9	173	24.1	28.7	80.4	356	18.76	25.9	29.6	195.4	16.4	120.3	235.2	54.0
12	39.0	114	12.97	38.1	36.9	166.9	24.2	69	33.0	35.7	73.9	183	18.94	36.3	36.3	240.8	19.0	194.2	361.0	53.8
Site Index IV																				
4	18.1	687	8.70	13.0	16.6	44.5	21.0	437	9.7	13.4	9.4	1 124	13.13	12.4	16.2	53.9	16.5	9.4	53.9	17.4
6	23.8	363	9.55	18.5	22.3	73.1	22.0	324	14.7	19.8	32.9	687	14.72	16.8	21.6	106.0	16.0	42.3	115.4	36.6
9	30.1	208	11.16	26.2	27.7	108.9	23.1	157	21.8	27.1	55.2	365	15.93	23.9	28.3	164.1	17.4	97.5	206.4	47.3
13	35.0	143	12.08	32.8	32.9	141.3	23.9	64	29.5	32.3	58.5	207	17.24	32.5	32.6	199.8	19.8	156.0	297.3	52.5
18	39.0	109	13.59	39.9	36.6	170.9	24.5	34	34.5	35.7	40.6	143	16.67	38.5	36.3	211.5	21.5	196.6	367.5	53.3

Table A3.12

Species *E. grandis*
Area Zambia (Copperbelt)
Stocking Initial N = 720/ha, thinned at ages 2, 5 and 9, final N = 220/ha
Volume Stem volume
Volume of thinnings shown separately, included in calculation of MAI

Reference: Country statement

Age *(years)*	$\bar{h}$ *(m)*	$\bar{d}$ *(cm)*	N	G *(m²)*	V *(m³)*	CAI *(m³)*	MAI *(m³)*	Roundwood volume *m³ to:*			Roundwood volume *percent to:*			Assortment *percent*			
								10 cm	15 cm	20 cm	10 cm	15 cm	20 cm	Saw	Small poles	Pur-lins	Waste
1																	
B[1] 2	10.0	9.2	720	5.0	23.0		11.5										
A[1]	10.0	9.2	496	3.45	15.0												
T[1]	10.0	9.2	224	1.55	8.0			—	—	—	—	—	—		40	4	56
3	15.0	13.8	496	7.8	47	27.0	18.3										
4	19.2	17.0	496	11.6	87	40.0	23.7										
B 5	22.0	19.2	496	15.0	127	40.0	27.0										
A	23.0	20.1	329	10.8	95												
T	20.1	17.5	167	4.2	32	29.0		28	8		87	25	—	14	14	32	40
6	25.5	22.5	329	13.4	124		27.4										
7	27.5	24.5	329	15.8	157	33.0	28.2										
8	28.8	26.3	329	18.1	191	34.0	29.0							63	4	8	25
B 9	30.1	27.9	329	20.4	222	31.0	29.1										
A	30.4	28.5	220	14.3	156												
T	29.5	26.7	109	6.1	66			60	52	31	92	80	47	65	5	7	23
10	31.3	30.3	220	16.1	183	27.0	28.8	172	157	119	94	86	65	75	2	4	19
11	32.3	31.9	220	17.9	211	28.0	28.8	200	189	151	95	90	72	76	1	3	19
12	33.0	33.5	220	19.8	234	23.0	28.4	224	215	177	96	92	76	78	1	3	18

[1] B = before thinning; A = after thinning; T = thinnings.

Table A3.13

Species *E. microtheca* — *Reference:* Ahmed, 1977

Area Sudan (Gezira) — *Number of sample plots* 70

Stocking Initial N varies from about 1 600 to 1 900 trees/ha, reduced to between 670 and 780 trees/ha by age 12. Many trees multi-stemmed, with average between two and three stems per tree.

Volume Stem plus branch volume overbark to 5 cm top, excluding stump.

Quality class I

Age *(years)*	N	h_{dom} *(m)*	$\bar{d}$ *(cm)*	V_b *(m^3)*	MAI_b *(m^3)*	CAI_b *(m^3)*
1	1 610	3.35	2.2	0	0	0
2	1 250	6.00	4.1	3.69	1.85	3.69
3	1 050	8.35	5.8	11.86	3.95	8.17
4	910	10.40	7.4	24.91	6.23	13.05
5	830	12.05	8.8	45.33	9.07	20.42
6	771	13.30	10.2	76.91	12.82	31.58
7	730	14.70	11.5	136.67	19.52	59.76
8	710	15.60	12.6	185.67	23.21	49.00
9	693	16.35	13.6	209.39	23.27	23.72
10	686	16.90	14.4	222.77	22.28	13.38
11	679	17.25	15.1	230.05	20.91	7.28
12	674	17.45	15.6	235.39	19.62	5.34

Quality class I/II

Age *(years)*	N	h_{dom} *(m)*	$\bar{d}$ *(cm)*	V_b *(m^3)*	MAI_b *(m^3)*	CAI_b *(m^3)*
1	1 795	2.60	1.6	0	0	0
2	1 424	4.70	3.0	0	0	0
3	1 219	6.55	4.4	4.71	1.57	4.71
4	1 064	8.15	5.6	13.05	3.26	8.34
5	957	9.60	6.8	25.24	5.05	12.19
6	886	10.30	7.9	43.79	7.30	18.55
7	829	11.90	8.9	69.79	9.97	26.00
8	788	12.80	9.9	107.15	13.39	37.36
9	755	13.55	10.7	126.88	14.10	19.73
10	736	14.15	11.5	137.36	13.74	10.48
11	719	14.60	12.2	142.76	12.98	5.40
12	707	14.90	12.7	146.19	12.18	3.43

Quality class II

Age *(years)*	N	h_{dom} *(m)*	$\bar{d}$ *(cm)*	V_b *(m^3)*	MAI_b *(m^3)*	CAI_b *(m^3)*
1	1 924	1.95	1.2	0	0	0
2	1 605	3.55	2.3	0	0	0
3	1 376	5.60	3.3	0	0	0
4	1 209	6.40	4.2	3.86	0.97	3.86
5	1 110	7.70	5.2	11.86	2.37	8.00
6	1 007	8.80	6.0	22.14	3.69	10.28
7	945	9.80	6.9	35.79	5.11	13.65
8	895	10.60	7.7	51.33	6.42	15.54
9	850	11.30	8.4	61.64	6.85	10.31
10	820	11.80	9.0	67.31	6.73	5.67
11	798	12.28	9.6	70.31	6.39	3.00
12	781	12.40	10.0	71.07	5.92	0.76

Table A3.14

Species	*E. occidentalis*	*Reference:*	Ciancio and Hermanin, 1976
Area	Italy (Calabria)	*Number of sample plots*	36
Stocking	N = 970/ha		
Volume	Stem volume overbark to 5 cm top, excluding stump		
Remarks	Sample plots were distributed systematically throughout the plantation area and can therefore be considered as representative of yields to be expected. Their distribution between quality classes was: QC I 33%, QC II 50%, QC III 17%.		

Quality class I

Age *(years)*	$\bar{h}$ *(m)*	V *(m³)*	G *(m²)*	$\bar{d}$ *(cm)*	CAI *(m³)*	MAI *(m³)*
5	5.93	10.200	3.4371	6.7	7.664	2.040
6	7.24	17.864	5.1115	8.2	8.990	2.977
7	8.42	26.854	6.8218	9.5	9.840	3.836
8	9.48	36.694	8.5095	10.6	9.941	4.587
9	10.40	46.635	10.7578	11.9	9.733	5.182
10	11.20	56.368	11.5326	12.3	8.946	5.637
11	11.87	65.314	12.8005	13.0	7.599	5.938
12	12.40	72.913	13.8380	13.5		6.076

Quality class II

Age *(years)*	$\bar{h}$ *(m)*	V *(m³)*	G *(m²)*	$\bar{d}$ *(cm)*	CAI *(m³)*	MAI *(m³)*
5	4.69	5.059	2.0919	5.2	4.036	1.012
6	5.70	9.095	3.1692	6.4	4.846	1.516
7	6.62	13.941	4.2884	7.5	5.376	1.992
8	7.45	19.317	5.4024	8.4	5.625	2.415
9	8.19	24.942	6.4742	9.2	5.516	2.771
10	8.83	30.458	7.4581	9.9	5.234	3.046
11	9.38	35.692	8.3444	10.5	4.735	3.245
12	9.84	40.427	9.1138	10.9	3.934	3.369
13	10.20	44.361	9.7334	11.3		3.412

Quality class III

Age *(years)*	$\bar{h}$ *(m)*	V *(m³)*	G *(m²)*	$\bar{d}$ *(cm)*	CAI *(m³)*	MAI *(m³)*
6	4.16	3.451	1.5957	4.6	2.020	0.575
7	4.81	5.471	2.2111	5.4	2.288	0.782
8	5.40	7.759	2.8320	6.1	2.441	0.970
9	5.93	10.200	3.4371	6.7	2.534	1.133
10	6.41	12.734	4.0219	7.3	2.476	1.273
11	6.83	15.210	4.5611	7.7	2.452	1.383
12	7.21	17.662	5.0705	8.2	2.153	1.472
13	7.52	19.815	5.5007	8.5	1.987	1.524
14	7.79	21.802	5.8859	8.8	1.541	1.557
15	7.99	23.343	6.1774	9.0		1.556

Table A3.15

Species	Mixed species including, in descending order of frequency, *E. citriodora, E. saligna, E. robusta, E. tereticornis, E.* Brazil "*alba*", *E. camaldulensis and E. grandis*
Reference	Heinsdijk *et al.*, 1965
Area	Brazil *Number of sample plots* 981
Stocking	Average N varies from about 2 800/ha (QC 6, age 4) to 700/ha (QC 1, age 25)
Volume	Stem volume overbark to tip, including stump. Volume of thinnings shown separately, included in calculation of MAI.
Remarks	Mean site quality was 3 to 4. Distribution of plots over four years old was found to be QC 1 36, QC 2 87, QC 3 255, QC 4 325, QC 5 195, QC 6 21.

Quality class 1

Age *(years)*	N	h_{dom} *(m)*	$\bar{h}$ *(m)*	$\bar{d}$ *(cm)*	V (total crop) *(m³)*	V (thinnings) *(m³)*	MAI *(m³)*
4	1 640	22.1	15.3	10.2	135	—	33.8
5	1 337	26.7	18.9	12.4	211	32	42.2
8	983	35.2	26.0	16.6	412	30	55.5
11	855	40.0	30.0	19.1	558	23	56.4
14	790	43.0	32.5	20.4	664	18	53.5
17	750	45.0	33.9	21.3	743	14	49.8
20	724	46.5	35.8	22.3	804	17	46.1
25	695	48.3	37.3	22.9	879	13	40.5

Quality class 2

4	1 688	19.1	12.9	10.0	93	—	23.3
5	1 375	23.0	16.0	11.8	146	22	29.2
8	1 012	30.4	22.0	15.9	285	20	38.4
11	880	34.5	25.4	18.1	386	16	38.9
14	813	37.1	27.6	19.4	460	13	37.0
17	772	38.9	29.1	20.4	515	10	34.5
20	745	40.2	30.3	21.0	557	12	31.9
25	715	41.7	31.6	22.0	609	9	28.1

Quality class 3

4	1 759	15.6	10.6	9.2	63	—	15.8
5	1 434	19.3	13.1	11.1	99	15	19.8
8	1 055	25.5	18.0	15.0	193	14	26.0
11	918	29.0	20.8	16.9	261	11	26.4
14	847	31.2	22.6	18.1	311	9	25.1
17	805	32.6	23.8	19.1	347	6	23.3
20	776	33.7	24.7	19.7	376	8	21.6
25	745	35.0	25.8	20.7	411	6	19.0

Table A3.15 *(concluded)*

Quality class 4

Age *(years)*	N	h_{dom} *(m)*	$\bar{h}$ *(m)*	$\bar{d}$ *(cm)*	V (total crop) *(m^3)*	V (thinnings) *(m^3)*	MAI *(m^3)*
4	1 878	12.9	8.2	8.3	41	—	10.3
5	1 530	15.5	10.2	10.2	63	9	12.6
8	1 126	20.5	14.0	13.4	124	9	16.6
11	980	23.3	16.2	15.3	168	7	16.9
14	904	25.0	17.6	16.6	200	6	16.1
17	859	26.2	18.5	17.5	224	5	15.0
20	829	27.1	19.3	18.1	242	5	13.9
25	795	28.1	20.1	18.8	264	3	12.2

Quality class 5

Age *(years)*	N	h_{dom} *(m)*	$\bar{h}$ *(m)*	$\bar{d}$ *(cm)*	V (total crop) *(m^3)*	V (thinnings) *(m^3)*	MAI *(m^3)*
4	2 112	9.6	5.9	7.0	24	—	6.0
5	1 721	11.5	7.3	8.6	37	6	7.4
8	1 266	15.3	10.0	11.1	72	5	9.8
11	1 101	17.3	11.6	12.7	97	4	9.8
14	1 017	18.6	12.5	14.0	116	3	9.4
17	966	19.5	13.2	14.6	130	3	8.7
20	932	20.1	13.8	15.0	140	3	8.1
25	894	20.9	14.1	15.6	153	2	7.1

Quality class 6

Age *(years)*	N	h_{dom} *(m)*	$\bar{h}$ *(m)*	$\bar{d}$ *(cm)*	V (total crop) *(m^3)*	V (thinnings) *(m^3)*	MAI *(m^3)*
4	2 777	6.1	3.5	4.5	10	—	2.5
5	2 263	7.3	4.4	5.7	16	3	3.2
8	1 665	9.7	6.0	7.6	30	2	4.1
11	1 448	11.0	6.9	8.6	41	1	4.2
14	1 337	11.9	7.5	9.2	49	1	3.9
17	1 270	12.4	8.0	9.6	55	1	3.7
20	1 225	12.8	8.3	9.9	59	1	3.4
25	1 176	13.3	8.6	10.5	65	1	3.0

Appendix 4. Quick reference tables of species characteristics and climatic requirements

Australia and East Indies

Table A4.1 summarizes the climatic zones in which occur naturally 60 eucalypt species of actual or potential importance for planting. The seasonal rainfall zones are those shown in Figure IV, and meteorological data for representative stations in the zones are shown in Appendix 1. Further subdivision has been made in accordance with mean annual temperature (MAT). The climatic zones indicated in the column headings are thus a combination of the following:

Three seasonal rainfall zones

S = summer rainfall U = uniform rainfall W = winter rainfall.

Humid	=	rainfall	> 1 200 mm(S)	> 800 mm (U, W)
Subhumid	=	”	600-1 200 mm(S)	500-800 mm (U, W)
Semi-arid	=	”	350- 600 mm(S)	250-500 mm (U, W)
Arid	=	”	< 350 mm(S)	< 250 mm (U, W)

Five temperature zones

1 = MAT > 25°C (tropical)

2 = MAT 20-25°C (subtropical)

3 = MAT 15-20°C (warm temperate)

4 = MAT 10-15°C (cool temperate)

5 = MAT < 10°C (cold)

It will be seen that a number of combinations do not occur, or at least do not contain eucalypts of importance for planting. Columns for these combinations are omitted. For example, temperature zones 1 (tropical) and 2 (subtropical) are missing throughout the uniform and winter-rainfall zones, while temperature zone 5 (cold) occurs only in the humid and subhumid portions of the uniform and winter-rainfall zones.

The table is intended as an aid to the initial selection of species for planting, or for testing, in a given climate in an introducing country. After a number of possible species have been chosen from the columns which most nearly match the climate of the area to be planted, more detailed information should be obtained from the species monographs in Chapter 14 in order to improve the precision of matching. For example, length and severity of dry season may be more critical than total annual rainfall, minimum temperature of the coldest month than mean annual temperature. Some species occur in many different zones, an indication that it may be more important to match a particular provenance to the climate of the planting area than the species as a whole.

Information on climate is supplemented in Table A4.2 by information on the uses and characteristics of the same species in their natural range. The symbol + signifies that the species is a preferred one for the use indicated. The column headed "Productivity class" is an attempt to estimate the comparative productivity of the various species when grown in plantation, based on plantation experience in many countries, not just Australia. There are five classes, A-E. Although their primary purpose is to *compare* the productivity of different species, they may be considered as roughly equivalent to MAIS of A = > 20 m^3/ha/yr, B = 15-20, C = 10-15, D = 5-10, E = < 5 m^3/ha/yr, provided the following conditions are met:

— MAI refers to total stem volume overbark from ground to tip but excludes branchwood.

— The appropriate provenance is used and planted in a climatic zone to which it is suited.

— Within the climatic zone the MAI quoted is the average for soils of median quality, which usually account for the greatest proportion of a planting area. (Yield on the best soils may be as much as twice that on median soils and yield on the poorest soils only half as much.)

— The MAI is that expected as an average from large planting blocks.

— The plantations are 80-100 percent stocked.

— Special treatment, such as fertilization, irrigation, is excluded.

It should be stressed that the productivity class refers to *volume* production. If *weight* production is more important, the considerable differences between eucalypt species in specific gravity may alter their comparative ratings. For data on specific gravity see Table 10.6 on page 276 and species monographs in Chapter 14.

For reasons of space this appendix is limited to 60 species. Tabulated information has been published on many more species in Australia (Jacobs, 1961; Hall *et al.*, 1972).

Table A4.1 Natural occurrence of principal eucalypt species by climatic zones

Species	SUMMER				UNIFORM				WINTER			
	Humid 1 2 3	Sub-humid 1 2 3 4	Semi-arid 1 2 3	Arid 1 2 3	Humid 3 4 5	Sub-humid 3 4 5	Semi-arid 3 4	Arid 3	Humid 3 4 5	Sub-humid 3 4 5	Semi-arid 3 4	Arid 3
E. andrewsii		++										
astringens										+	+	
botryoides					++	++						
brassiana	++											
calophylla									+	+		
camaldulensis		++	+++	++			+	+		+	++	+
citriodora		++										
cladocalyx										++	++	
cloeziana	+	+										
coccifera									+			
crebra		++	++									
dalrympleana					++				++			
deglupta	+											
delegatensis					+				++			
diversicolor									+			
drepanophylla	+	+										
dunnii	++	++										
elata					++	++						
exserta		++	++									
fastigata					++	++			++	++		
ficifolia									+			
globulus ssp. *bicostata*		+			+	+			+	+		
globulus ssp. *globulus*					+				+			
globulus ssp. *maidenii*					+	+						

Table A4.1 *(continued)*

Species	SUMMER Humid 1 2 3	SUMMER Sub-humid 1 2 3 4	SUMMER Semi-arid 1 2 3	SUMMER Arid 1 2 3	UNIFORM Humid 3 4 5	UNIFORM Sub-humid 3 4 5	UNIFORM Semi-arid 3 4	UNIFORM Arid 3	WINTER Humid 3 4 5	WINTER Sub-humid 3 4 5	WINTER Semi-arid 3 4	WINTER Arid 3
E. gomphocephala									+	+		
grandis	++	++										
gunnii									+			
intertexta			+	+			+	+				
johnstonii									++			
macarthurii		+			+	+						
maculata	++	++			+	+						
melliodora		+	+			++	++			++	++	
microcorys	++	++										
microtheca		+	++	++								
nitens					++	++			++	++		
obliqua		+			++	++			++	++		
occidentalis										+	+	
ochrophloia			+	+								
ovata						+			+	+		
paniculata	+	+			+							
patens									+	+		
pellita	+++											
pilularis	++	++			+							
propinqua	++	++			+							
regnans									++	+		
resinifera	++	++			+							
robusta	++	++			+							
rudis									+	+	+	

Table A4.1 *(concluded)*

Species	SUMMER Humid 1 2 3	SUMMER Sub-humid 1 2 3 4	SUMMER Semi-arid 1 2 3	SUMMER Arid 1 2 3	UNIFORM Humid 3 4 5	UNIFORM Sub-humid 3 4 5	UNIFORM Semi-arid 3 4	UNIFORM Arid 3	WINTER Humid 3 4 5	WINTER Sub-humid 3 4 5	WINTER Semi-arid 3 4	WINTER Arid 3
E. saligna	++	++			+			+			+	+
salmonophloia											+	
sargentii										++	++	
sideroxylon		+	+			+	+					
sieberi					++	++				+		
tereticornis	+++	+++			+	++						
tetrodonta	+	+										
thozetiana			+	+								
torelliana	+								++			
urnigera												
urophylla	++					+			++	+		
viminalis		+										

Note: 1 = tropical > 25°C; 2 = subtropical 20-25°C; 3 = warm temperate 15-20°C; 4 = cool temperate 10-15°C; 5 = cold < 10°C.

Table A4.2 Uses and characteristics of principal eucalypt species within natural distribution

Species	Description		Main uses in regions of origin								Special characteristics
	Productivity class	Mature height (m) (countries of origin)	Shelter & windbreaks	Amenity planting	Sawlogs	Pulpwood	Firewood	Poles	Fencing material	Honey	
E. andrewsii	B	30 +			+			+			Occurs inland of, and in a drier climate than, *E. pilularis*
E. astringens	E	20			+		+				Good for tool handles
E. botryoides	B	30 +	+	+	+			+	+	+	Suitable for coastal planting, withstands saline winds
E. brassiana	C										Closely related to *E. tereticornis*, but on Australian mainland extends into lower latitude. Also occurs in Papua New Guinea.
E. calophylla	C	30				+	+	+	+	+	Resistant to *Phytophthora*
E. camaldulensis	B/C/D	20-40	+		+			+	+		Great variation between provenances in climatic requirements and in height growth in natural stands. Needs seasonal flooding or high water table wherever rainfall is less than 350 mm. Withstands flooding.
E. citriodora	C/D	30			+			+	+		Source of citronellal oil
E. cladocalyx	D	15-30	+	+				+	+	+	
E. cloeziana	B	40			+			+	+		Able to outgrow most other species in valleys devastated by fire or cyclones. Occurs in a number of separate localities.

Table A4.2 *(continued)*

Species	Description		Main uses in regions of origin								Special characteristics
	Productivity class	Mature height (m) (countries of origin)	Shelter & windbreaks	Amenity planting	Sawlogs	Pulpwood	Firewood	Poles	Fencing material	Honey	
E. coccifera	C/D	10-30	+	+			+				Growth and form vary greatly with site. One of the most cold-resistant eucalypts
E. crebra	C/D	25	+				+	+	+	+	
E. dalrympleana	C	30	+		+				+		
E. deglupta	A	60-70		+	+	+			+		Occurs both sides of the equator, from 11°S - 9°N. Rainfall in excess of 2 500 mm with no dry season. Colonizes stream sandbanks and young volcanic soils
E. delegatensis	B	50 +	+		+	+		+			
E. diversicolor	B	50 +	+		+	+		+		+	
E. drepanophylla	C	25 +			+		+	+	+	+	
E. dunnii	A	30-50			+						Seed supplies present a problem. Very fast-growing
E. elata	C	25 +	+	+		+					
E. exserta	C	25			+		+		+	+	
E. fastigata	B	35 +	+		+	+					
E. ficifolia	D	10	+	+						+	Outstanding flowering tree

Table A4.2 *(continued)*

Species	Description		Main uses in regions of origin								Special characteristics
	Productivity class	Mature height (m) (countries of origin)	Shelter & windbreaks	Amenity planting	Sawlogs	Pulpwood	Firewood	Poles	Fencing material	Honey	
E. globulus ssp. *bicostata*	B	40 +	+	+		+		+	+	+	Occurs in a number of widely separated provenances from 31°S-41°S. Tolerates colder and drier conditions than ssp. *globulus*
ssp. *globulus*	A/B	50	+	+		+		+	+	+	
ssp. *maidenii*	A/B	40-70	+	+		+		+	+	+	Tolerates colder and drier conditions than ssp. *globulus*
E. gomphocephala	C/D	30			+		+			+	Tolerates calcareous soils
E. grandis	A	40-55		+	+	+					Able to outgrow other species in valleys devastated by fire or cyclones. More trials needed of lower latitude coastal provenances.
E. gunnii	C/D	20	+	+							
E. intertexta	E	20	+				+	+	+	+	In western New South Wales considered an indicator of acid, light-textured soils
E. johnstonii	C/D	40	+	+							
E. macarthurii	C	25-40	+	+							Leaves produce geraniol oil
E. maculata	C	30 +	+	+	+					+	
E. melliodora	D	25	+	+			+	+	+	+	Outstanding honey producer

Table A4.2 *(continued)*

Species	Description		Main uses in regions of origin								Special characteristics
	Productivity class	Mature height (m) (countries of origin)	Shelter & windbreaks	Amenity planting	Sawlogs	Pulpwood	Firewood	Poles	Fencing material	Honey	
E. microcorys	B/C	30-50	+		+		+	+	+	+	
E. microtheca	D	20	+				+			+	Tolerant of heavy clays and of periodic flooding
E. nitens	B	40		+	+	+					
E. obliqua	B/C	50	+		+	+	+	+	+	+	
E. occidentalis	E	20		+			+		+		Tolerates clay soils and flooding
E. ochrophloia	E	20	+				+		+	+	
E. ovata	D	10-20			+						Tolerates frost hollows and impeded drainage on swamp margins
E. paniculata	C	30 +	+		+		+	+	+	+	
E. patens	C	30	+		+	+	+	+	+	+	Underestimated. Resistant to *Phytophthora*.
E. pellita	B/C	30	+		+			+			Two widely separated occurrences in *(a)* north Queensland coast *(b)* southern Queensland and New South Wales coast. More trials needed of north Queensland coastal provenances.
E. pilularis	B/C	40-60	+	+	+	+	+	+	+	+	
E. propinqua	C	30	+		+		+	+	+	+	

Table A4.2 *(continued)*

Species	Description		Main uses in regions of origin								Special characteristics
	Productivity class	Mature height (m) (countries of origin)	Shelter & windbreaks	Amenity planting	Sawlogs	Pulpwood	Firewood	Poles	Fencing material	Honey	
E. regnans	A	60-80		+	+	+			+	+	
E. resinifera	B	30-50	+		+			+			
E. robusta	C	25	+		+				+		Tolerates clay soils and swampy conditions. Resistant to saline winds in coastal areas.
E. rudis	C/D	10-15	+	+			+	+	+		Tolerates clay soils and periodic flooding
E. saligna	A	40 +	+	+	+	+					
E. salmonophloia	E	25	+	+			+	+	+	+	
E. sargentii	E	10	+	+							Extremely tolerant of soil salinity
E. sideroxylon	D	25	+	+			+	+	+	+	
E. sieberi	B/C	30-40	+		+	+					
E. tereticornis	C/D	30-40	+	+	+	+	+	+	+	+	Wide latitudinal and climatic range, from winter to summer rainfall. Choice of provenance important.
E. tetrodonta	E	20-25			+		+		+		Combines a 5 months dry season with a fairly high annual rainfall.
E. thozetiana	E	20	+				+	+	+		

Table A4.2 *(concluded)*

Species	Description		Main uses in regions of origin								Special characteristics
	Productivity class	Mature height (m) (countries of origin)	Shelter & windbreaks	Amenity planting	Sawlogs	Pulpwood	Firewood	Poles	Fencing material	Honey	
E. torelliana	B/C	30	+	+	+			+	+		Has the densest crown of any eucalypt. Able to colonize the edge of rain forest.
E. urnigera	C/D	10-40	+	+			+				Variable size and form according to site
E. urophylla	A	40-50	+	+	+	+	+	+	+	+	Altitudinal variation occurs, in addition to possible variation between different islands in the Sunda archipelago
E. viminalis	B	30-60		+	+	+				+	A wide range and many provenances

Tables A4.3 and A4.4 and explanatory notes have been extracted from *Characteristics and uses of trees and shrubs* (Poynton, 1972), by courtesy R.J. Poynton, Department of Forestry, Republic of South Africa.

Explanatory note on Table A4.3 (recommended silvicultural zones)

This table should be read in conjunction with the silvicultural map of southern Africa (Figure A4.1).

The map itself is largely self-explanatory and takes into account the two principal climatic factors which limit the establishment and growth of trees in southern Africa, namely drought and frost. The humidity zones have been computed by means of a formula which embraces rainfall, potential loss of moisture to the atmosphere through evaporation and transpiration, and the occurrence of seasonal dry periods (Thornthwaite, 1948). This gives an indication of the amount of moisture available to vegetation throughout the year for sustaining life and growth. The temperature zones represent average intensities of killing frost.

The various zones for which the different species can be recommended are indicated in this table by the symbol x. Where the symbol is printed in CAPITALS (X), the species may be established in the zone concerned *under plantation conditions* for utility or commercial purposes.

The silvicultural zones indicated in the column headings of the table are a combination of the following:

— *Three humidity zones* A = humid, B = subhumid, C = semi-arid. The fourth humidity zone, D = arid, is excluded from the table as unsuitable for tree-planting except with irrigation.

— *Three seasonal rainfall zones* w = winter rainfall, u = uniform rainfall, s = summer rainfall.

— *Four temperature zones* 1 = frost severe, 2 = frost moderately severe, 3 = frost light, 4 = frost virtually absent.

It should be reiterated that these recommendations have been drawn up on the assumption that the trees will not be watered or protected from frost once properly established (no allowance being made for abnormal growing conditions such as excessively shallow soil, localized frost hollows or undue exposure to cold winds). It follows, therefore, that all or most of the species can be grown on a small scale for ornamental purposes under harsher conditions than those for which they have been recommended, provided that adequate steps are taken to protect them against the vagaries and inclemencies of the climate.

Explanatory notes, Table A4.4

The table of characteristics and uses of species which follows these notes comprises a number of columns. The scope and contents of the different columns are discussed below in the same sequence as that in which the latter appear in the table, and, wherever possible, quantitative values are assigned to the various symbols used.

Attention is invited to the fact that information given about a species in each individual column of the table applies strictly to the particular characteristic or use under immediate consideration. Thus, for instance, although a species may receive a very high rating for converted timber, it does not necessarily follow that it can be planted profitably on a commercial scale for sawtimber production, because its rate of growth may be too low. Due consideration must therefore be given to all the factors involved before finally deciding upon the suitability of a species for a particular purpose.

Name of species

1. *Botanical name*

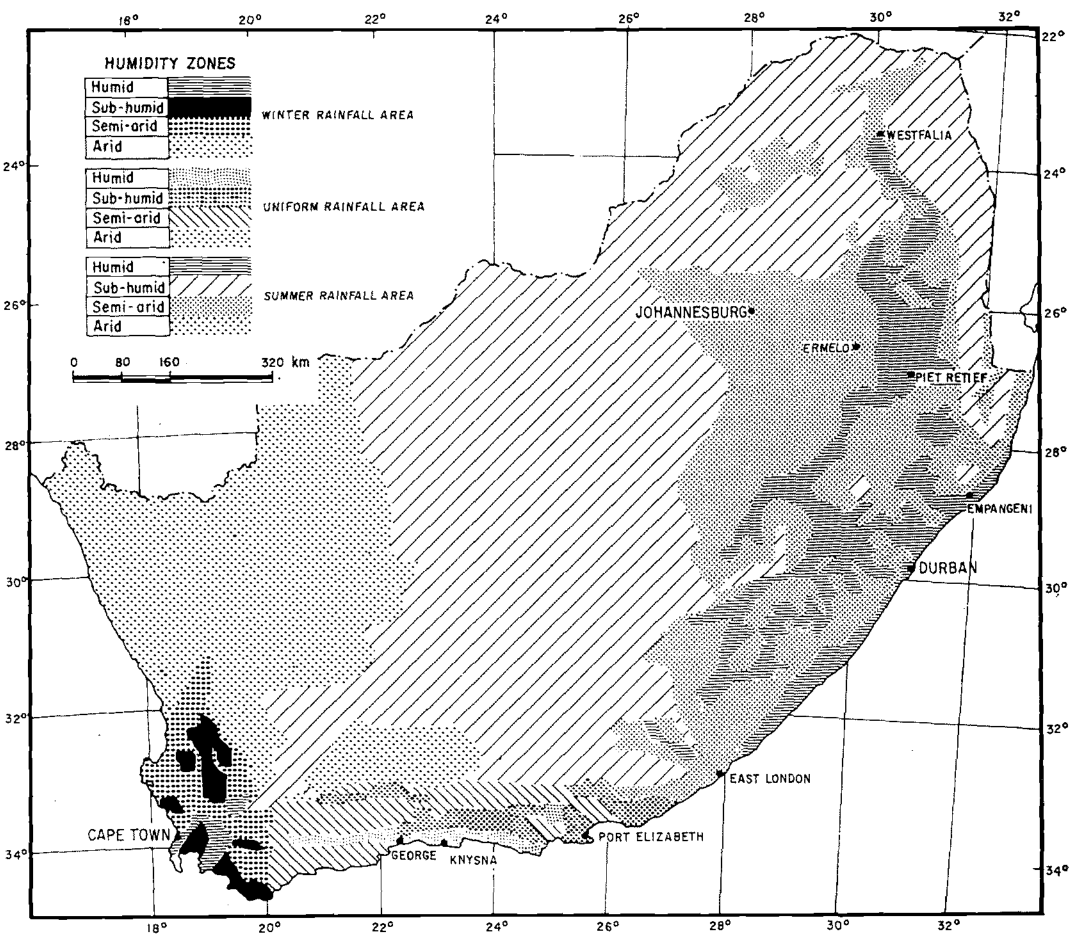
The botanical or scientific name of a species, in contrast to its common name or names, is accepted universally and is written in Latin.

Description

2. *Usual height attained and greatest height recorded in South Africa*

The usual height attained by a species under "average" conditions in South Africa is given first in this column, followed by the maximum height thus far recorded. The figure for maximum height may be taken to represent the potential size of the species at maturity under particularly favourable conditions in this country.

A4-1. Silvicultural maps of southern Africa, including the Republic of South Africa, Lesotho, and Swaziland. *This page*, humidity zones; *opposite*, frost-hazard zones



In assessing the probable eventual height of a species in a particular locality, its requirements, especially with regard to temperature and rainfall, must be taken into account. These can be gauged, to a large extent, from columns 8 and 9 of the table. Thus, a species which is clearly adapted to a cool, moist climate is unlikely to reach its maximum development in a warm, dry area. The converse usually holds equally well.
Soil depth and fertility also exercise a marked effect on the ultimate height attained by a tree.

3. *Form of crown*

The shape of the crown of a more or less free-growing tree at maturity is indicated in this column.
The three broad classes into which crowns have been grouped for present purposes may be defined as follows:

- Spreading — Crown breadth equalling or exceeding crown length at maturity.
- Intermediate — Crown length exceeding crown breadth at maturity by as much as four times.
- Narrow — Crown length exceeding crown breadth at maturity by more than four times.

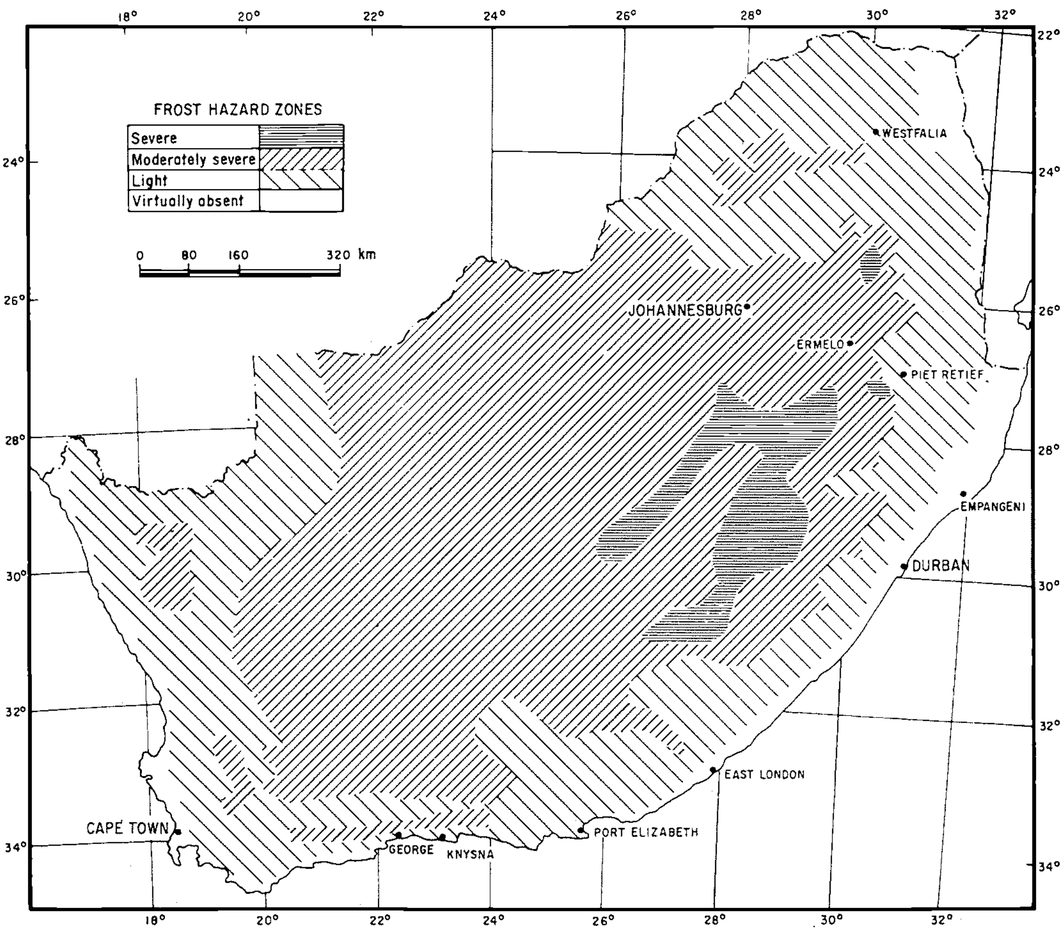


Table A4.3 Recommended silvicultural zones in southern Africa

Botanical name	SILVICULTURAL ZONES																																		
	Aw1	Au1	As1	Aw2	Au2	As2	Aw3	Au3	As3	Aw4	Au4	As4	Bw1	Bu1	Bs1	Bw2	Bu2	Bs2	Bw3	Bu3	Bs3	Bw4	Bu4	Bs4	Cw1	Cu1	Cs1	Cw2	Cu2	Cs2	Cw3	Cu3	Cs3	Cw4	Cu4	Cs4
E. alba							x	x	X	x	x	X							x	x	x	x	x	x												
bosistoana				x	x	X	x	x	X	x	x	X				x	x	x	x	x	x	x	x	x												
botryoides							X	X	X	X	X	X							x	x	x	x	x	x												
bridgesiana	x	x	x	x	x	x	x	x	x	x	x	x	x	X	X	x	X	X	x	X	X	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
calophylla							x	x	x	x	x	x							x	x	x	x	x	x												
camaldulensis				x	x	x	x	x	x	x	x	x				X	X	X	X	X	X	X	X	X				X	X	X	X	X	X	X	X	X
cinerea	x	x	x	x	x	x	x	x	x	x	x	x	x	x	X	x	x	X	x	x	x	x	x	x												
citriodora				x	x	X	x	x	X	x	x	X				x	x	X	x	x	X	x	x	X				x	x	X	x	x	X	x	x	X
cladocalyx				X	X	x	X	X	x	X	X	x				X	X	x	X	X	X	X	X	X				X	X	x	X	X	x	X	X	x
cloeziana							x	x	X	x	x	X							x	x	x	x	x	x												
cornuta							X	X	x	X	X	x							x	x	x	x	x	x												
crebra				x	x	x	x	x	x	x	x	x				x	x	X	x	x	X	x	x	X				x	x	X	x	x	X	x	x	X
dalrympleana	x	X	X	x	X	X	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x												
delegatensis				X	X	X	X	X	X	x	x	x				x	x	x	x	x	x	x	x	x												
diversicolor							X	X	x	X	X	x								x			x													
dives	X	X	X	X	X	X	X	X	X	x	x	x	X	X	X	X	X	X	X	X	X	x	x	x												
elata				x	x	X	x	x	X	x	x	x				x	x	x	x	x	x	x	x	x												
fastigata				x	X	X	x	x	x							x	x	x	x	x	x															
ficifolia							x	x	x	x	x	x							x	x	x	x	x	x												
fraxinoides				x	X	X	x	X	X	x	x	x																								
globoidea				X	X	X	X	X	X	x	x	x				x	x	x	x	x	x	x	x	x												
globulus				X	X	X	X	X	X	x	x	x				x	x	x	x	x	x	x	x	x												
gomphocephala							x	x	x	x	x	x							x	x	x	x	x	x												
grandis							X	X	X	X	X	X							x	x	x	x	x	x												
gummifera							X	X	X	X	X	X							x	x	x	x	x	x												
lehmannii							x	x		x	x								x	x		x	x								x	x		x	x	
macarthurii	x	X	X	x	X	X	x	X	X				x	x	x	x	x	x	x	x	x															

Table A4.3 *(concluded)*

Botanical name	SILVICULTURAL ZONES Aw1	Au1	As1	Aw2	Au2	As2	Aw3	Au3	As3	Aw4	Au4	As4	Bw1	Bu1	Bs1	Bw2	Bu2	Bs2	Bw3	Bu3	Bs3	Bw4	Bu4	Bs4	Cw1	Cu1	Cs1	Cw2	Cu2	Cs2	Cw3	Cu3	Cs3	Cw4	Cu4	Cs4
E. maculata							x	X	X	x	X	X							x	x	x	x	x	x												
maidenii				x	x	x	x	x	x							x	x	x	x	x	x															
marginata							X	X	x	X	X	x							x	x	x	x	x	x												
melliodora	x	x	x	x	x	x	x	x	x	x	x	x	x	X	X	x	X	X	x	X	X	x	x	x	x	X	X	x	X	X	x	X	X	x	x	x
microcorys							x	X	X	x	X	X							x	x	x	x	x	x												
muellerana				X	X	X	X	X	X	X	X	x				x	x	x	x	x	x	x	x	x												
nitens	X	X	X	X	X	X	X	X	X	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x												
obliqua				X	X	X	X	X	X	x	x	x				x	x	x	x	x	x	x	x	x												
oreades				x	X	X	x	X	X	x	x	x				x	x	x	x	x	x	x	x	x												
paniculata							x	X	X	x	X	X							x	X	X	x	X	X							x	x	x	x	x	x
pauciflora	x	x	x	x	x	x	x	x	x				x	x	x	x	x	x	x	x	x															
pilularis							X	X	X	X	X	X							x	x	x	x	x	x												
polyanthemos				x	x	x	x	x	x	x	x	x				X	X	X	X	X	X	x	x	x				X	X	X	X	X	X	x	x	x
punctata							X	X	X	X	X	X							x	x	x	x	x	x												
quadrangulata							x	X	X	x	X	X							x	x	x	x	x	x												
radiata				X	X	X	x	x	x	x	x	x				x	x	x	x	x	x	x	x	x												
resinifera				X	X	X	X	X	X	X	X	X				x	x	x	x	x	x	x	x	x												
robusta							x	x	x	x	x	x							x	x	x	x	x	x												
rubida	X	X	X	X	X	X	x	x	x	x	x	x	X	X	X	X	X	X	x	x	x	x	x	x												
sideroxylon				x	x	x	x	x	x	x	x	x				X	X	X	X	X	X	X	X	X				X	X	X	X	X	X	X	X	X
sieberi				X	X	X	X	X	X	X	X	x				x	x	x	x	x	x	x	x	x												
smithii				x	x	x	x	x	x	x	x	x				x	x	x	x	x	x	x	x	x												
torquata				x	x	x	x	x	x	x	x	x				x	x	x	x	x	x	x	x	x				x	x	x	x	x	x	x	x	x
viminalis	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x												

4. *Colour of foliage*

This information is given mainly as an aid to the creation of interesting landscape effects, and for this reason an attempt has been made to convey an impression of the colour of the crown as a whole rather than that of an individual leaf.

5. *Colour of flowers or fruits*

In this column the colour of the flowers or fruits borne by a species is indicated, the information being given in roman type when the display is showy and visible from a distance and in italics when it is not very conspicuous. Cognizance of the ornamental value of flowers and fruits is also taken in column 16 — Uses, Ornament.

Optimum rate of growth

6, 7. *Fast; Medium*

The rate of growth of a species under favourable (though more or less natural) conditions in South Africa is given in these columns. The data are thus directly applicable only in localities well suited to the species concerned, growth elsewhere being less rapid. Forced growth, induced by heavy manuring and watering, finds no place in the present assessment.

It should be borne in mind that, because the requirements of different species vary to a considerable degree, no one site can sustain the optimum growth of every species. An approximation of the probable rate of growth of a tree in a particular locality can be arrived at only by taking into account the conditions to which it is best suited (see explanatory note on column 2 — Usual height attained and greatest height recorded in South Africa).

The limits assigned in these columns are as follows:

6. *Fast*	x:	Growth 1.0 m per year
	xx:	Growth 1.2 m per year
	xxx:	Growth 1.5 m or more per year
7. *Medium*	x:	Growth 0.6 m per year

In trees with a life span of some decades the rate of growth indicated is the mean annual height increment for the first five to ten years after establishment.

Hardiness to drought and frost

8. *Drought* (see Figure A4-1)

The drought-resisting capacity of a species can not be assessed accurately over a short period of time, but should be judged rather by its ability to grow to maturity under specified climatic conditions without being watered. Not only are trees, once established, exposed to periodic fluctuations in the rainfall, but they may, if planted close together in the form of stands or shelterbelts, also have to face mounting competition for the available soil moisture as they grow. For this reason it has been found necessary, in the case of species which may be established under plantation conditions, to differentiate between the amount of drought which they will withstand when planted as single, free-growing specimens for ornamental purposes and that which they can be expected to survive in closed stands or in broad shelterbelts. This has been done, as in previous columns, by introducing CAPITALS, an example of the use of which is given below.

Comparative drought-hardiness is indicated in this column by the allocation of symbols as follows:

- xxx Very resistant; suitable for planting in the semi-arid, interior regions of the northern and northeastern Cape Province, the dry midlands of Natal, the western Orange Free State and the western and extreme eastern Transvaal (see map). Drought hardy (though not necessarily frost hardy), for example, at Queenstown, Weenen, Bloemfontein and Lichtenburg. Also suitable for drier areas if abundant soil moisture is present.
- xx Moderately resistant; unable to survive in the semi-arid areas mentioned above unless a plentiful supply of seepage water is available, but suitable for planting throughout the subhumid parts of the central plateau and coastal plain. Drought hardy (but not necessarily frost hardy) at Humansdorp, Ladysmith, Bethlehem and in the Pretoria-Witwatersrand area.
- x Slightly resistant; undependable in subhumid areas except on selected sites where supplementary soil moisture is available. Drought hardy (though not necessarily frost hardy) at George, Cedara, Van Reenen and Piet Retief.

Where the above symbols are given in the table in CAPITALS, drought hardiness under plantation conditions is indicated. Thus, for example, where the symbols appear as follows:

xXX

the species should be understood to be very hardy when planted as a free-growing tree for ornament but only moderately hardy when planted at a relatively close espacement for commercial or utility purposes.

It may be noted that, in practice, the ability of a tree to withstand prolonged drought is often influenced to a great extent by the depth and texture of the soil in which it is growing as well as by the amount of seepage water available.

9. *Frost* (see Figure A4-1)

The great majority of trees tend to become increasingly frost resistant as they grow in size. This is especially the case during the first few years after planting. Trees are most sensitive to frost while their vulnerable, growing shoots are still at ground level (where temperatures at night are lowest) and before their bark has developed sufficiently to insulate the living tissues

from excessive cold. In this column, the comparative frost hardiness of a species is thus assessed according to its ability to withstand cold, without protection and without suffering serious injury, in the period immediately after establishment.
The symbols used here should be understood as follows:

xxx Very hardy; suitable for planting in the cold mountain ranges of the Cape Province and Natal and in the eastern highveld regions of the Orange Free State and Transvaal (see map). Frost hardy (but not necessarily drought hardy), for example, at Barkly East, Bergville, Harrismith and Belfast, though localized frost hollows in these districts should be avoided if possible.

xx Moderately hardy; undependable in the coldest areas, mentioned above, and in frost hollows or on sites exposed to very cold winds, but otherwise suitable for planting throughout the remainder of the cool, mountain and highveld regions of the country. Frost hardy (though not necessarily drought hardy) at Kokstad, Howick, Kroonstad and the Witwatersrand.

x Slightly hardy; best suited to the warmer parts of the interior plateau and coastal plains where frosts are comparatively mild. Frost hardy (though not necessarily drought hardy) at Grahamstown, Pietermaritzburg and Pretoria north of the Magaliesberg.

Not hardy; undependable except in subtropical areas where frosts are rarely experienced.

Uses

10. *Converted timber*

The term "Converted timber" is often used in a broad sense to include sawtimber, veneers and turned articles. However, in column 10 species have been rated simply according to their value as sawtimber.
In assessing the value of a species for sawtimber, the following essential requirements have been taken into consideration:

— size and form of logs
— ease of sawing and seasoning
— excellence or versatility of the product, irrespective of actual use.

The following interpretation should be placed on the symbols used in this column:

xxx Very useful sawtimber
xx Moderately useful sawtimber
x Indifferent sawtimber
Not worth sawing into boards

It should be noted that, from the point of view of commercial afforestation, it is desirable that a species should combine usefulness as a sawtimber with rapid growth.

11. *Poles*

The symbols used in this column should be understood in the following sense:

xxx Eminently suitable for use as telephone and transmission poles

xx Moderately suitable for use as telephone and transmission poles

x Unsuitable for use as telephone or transmission poles though nevertheless yielding a pole which can be utilized for many other purposes.

The particular properties stipulated in the specifications laid down for telephone and transmission poles are adequate size, a high degree of strength, good form, comparative freedom from end-splitting and amenability to impregnation with wood preservatives.

12. *Firewood*

The calorific or thermal value of a dry wood is more or less proportional to its density (resinous woods excepted), hence equal weights of different woods are able, theoretically, to generate approximately the same amount of heat. However, although all woods can be burned, not all give satisfaction in the hearth or kitchen range.

The property chiefly looked for in a good firewood is a capacity for prolonged, steady burning, without emitting sparks, until only ash remains. Light, resinous woods, which are rapidly consumed in a fire, are not in this sense regarded as particularly good firewood, although they may be very useful as kindling.

The quality of firewood yielded by different species is indicated in this column as follows:

xxx Very good

xx Moderately good

x Somewhat indifferent

Unfortunately, the information available on this subject tends to be rather meagre.

13. *Honey*

Species are designated in this column by the symbols "N" and "P" according to whether they yield an appreciable supply of nectar or pollen or both.

As before, the symbols are given in CAPITALS if the supply of nectar or pollen is abundant and in lower case if the yield does not warrant the planting of a species specifically for honey production or if the quality of the honey itself is inferior.

Again, the information on this subject is still far from complete.

14. *Shelterbelts and windbreaks*

It is advisable to give rather more careful consideration to the choice of species when establishing a shelterbelt in close proximity to cultivated lands than is usually necessary if the belt is bordered on both sides by grazing paddocks. The reasons for this are twofold, namely:

(1) crop yields in the vicinity of the belt will be adversely affected by species which have a superficial, ramifying root system. The breadth of the zone to either side of the belt which is liable to be affected by root competition may be taken at any stage as one and a half times the height of the trees forming the belt;
(2) arable land may be invaded by regeneration as a result of planting species whose roots tend to sucker when injured or severed during the course of cultivating the soil.

Broadly speaking, it is inadvisable to plant the majority of eucalypts in close proximity to cultivated lands as their root systems extend for a considerable distance and compete vigorously with the crop for soil moisture and nutrients. Most *Eucalyptus* species have not been rated highly for windbreaks on this account and also for the reason that their tall, shaft-like boles are generally devoid of side branches for much of their length. The latter disadvantage can, however, be overcome to a large extent by establishing belts consisting of two or more rows of trees and by felling these in rotation, allowing the coppice to grow up and fill in the gap below the crowns of the larger trees. Alternatively, a shorter, more bushy, evergreen species can be planted in one or more of the outer rows of the belt.
The symbols in this column are used in the following sense:

xxx Very effective as a windbreak
xx Moderately effective as a windbreak
x Somewhat indifferent as a windbreak but can be used for the purpose.

15. *Reclamation of driftsands*

Species which can be recommended for the reclamation of sand dunes, particularly in coastal areas, are indicated thus:

xxx Very suitable; xx Moderately suitable; x Somewhat indifferent.

16. *Ornament*

The assessment of the ornamental value of a species made in this column is, of necessity, a broadly based one, covering form, beauty of foliage and fruiting characteristics. No account has been taken of the ultimate size attained by the species.
As before, relative merit is denoted by the use of repetitive symbols, the most ornamental species being designated "xxx".

17. *Miscellaneous*

Certain miscellaneous characteristics are indicated in this column by the digits "1" to "4", as detailed below. Where the characteristic is developed to a marked degree, the digit is in italics.
The characteristics here considered are the following:

1. — tolerant of sea breezes
2. — tolerant of brak (saline) soils
3. — resistant to termites
4. — resistant to snout beetle.

Table A4.4 Characteristics and uses of eucalypts in South Africa

Botanical name	Description: Usual height attained and greatest height recorded in S.A. (m)	Description: Form of crown: (S)preading (I)ntermediate (N)arrow	Description: Foliage Colour: (D)ark green (L)ight green (G)rey-green	Colour of (Fl)owers or (Fr)uits	Optimum rate of growth per year: Fast (1.0 m or more)	Optimum rate of growth per year: Intermediate (0.6 m)	Hardiness to drought and frost: Drought	Hardiness to drought and frost: Frost	Uses: Converted timber	Uses: Poles	Uses: Firewood	Uses: Honey (N)ectar (P)ollen	Uses: Shelterbelts and windbreaks	Uses: Reclamation of driftsands	Uses: Ornament	Uses: Miscellaneous
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
E. alba	15, 24	I	L	Fl cream	x		xX	x	x		xx		x		x	4
bosistoana	20, 30	I	L	Fl cream	xx		xX	xx	x	x	x	N P	x		x	4
botryoides	25, 50	I	D	Fl cream	xxx		xX	x	xx	x	x	n p	xx		xx	1 2 3 4
bridgesiana	18, 31	I	L	Fl cream	xxx		xXX	xxx		x	x	N p	xx		x	4
calophylla	15, 29	I	D	*Fl white*	x		xX	x	x	x	xx	n p	xx	x	xx	1 4
camaldulensis	18, 40	I	L	Fl cream	xx		XXX	xx	x	xx	xx	N P	x		x	1 2 4
cinerea	10, 27	I	G	Fl cream	xx		XX	xxx		x	x	n p	xxx		xx	4
citriodora	20, 44	I	D	Fl cream	xxx		XXX	xx	xxx	xxx	xxx	N p	x		x	4
cladocalyx	15, 44	I	L	Fl cream	xxx		XXX	xx	x	xxx	xx	N p	x	x	x	1 2 3 4
cloeziana	25, 48	I	L	Fl cream	xxx		xX	x	xxx	xxx	x	n p	x		x	4
cornuta	20, 37	S	L	Fl yellowish	xx		xX	x	xx	x	x	N p	xx		x	1 4
crebra	20, 42	I	L	Fl cream	xx		XXX	xx	x	xx	xx	n p	xx		xxx	4
dalrympleana	20, 27	S/I	L	Fl yellowish	xx		xX	xxx		xx	x	n p	x		x	
delegatensis	25, 41	I	D	Fl cream	xxx		xX	xx	x	xx	x	n p	xx		xxx	4
diversicolor	25, 58	I	L	Fl cream	xxx		xX	x	xxx	xx	x	N p	xx		x	4

Table A4.4 *(continued)*

Botanical name	Description: Usual height attained and greatest height recorded in S.A. (m)	Description: Form of crown (S)preading (I)ntermediate (N)arrow	Description: Foliage Colour (D)ark green (L)ight green (G)rey-green	Colour of (Fl)owers or (Fr)uits	Optimum rate of growth per year: Fast (1.0 m or more)	Optimum rate of growth per year: Intermediate (0.6 m)	Hardiness to drought and frost: Drought	Hardiness to drought and frost: Frost	Uses: Converted timber	Uses: Poles	Uses: Firewood	Uses: Honey (N)ectar (P)ollen	Uses: Shelterbelts and windbreaks	Uses: Reclamation of driftsands	Uses: Ornament	Uses: Miscellaneous
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
E. dives	15, 28	I	L	Fl cream	xx		XX	xxx	Distillation of essential oil							4
elata	20, 36	I	D	Fl cream	xxx		xX	xx		xx	x	n p	xx		x	4
fastigata	25, 50	I	D	Fl cream	xxx		xX	xx	xx	xx	xx	n	xx		x	4
ficifolia	8, 19	I	D	*Fl red, pink, orange*		x	xx	x			x	N p	xx	x	xxx	*1* 4
fraxinoides	25, 46	I	D	Fl cream	xxx		X	xx	xx	xx	x	n p	x		x	4
globoidea	20, 36	I	D	Fl cream	xxx		xX	xx	x	xx	x	n p	x		x	4
globulus	25, 61	S/I	D	Fl cream	xxx		xX	xx	xx	xx	x	n p	xx		x	
gomphocephala	18, 34	I	L	Fl cream	x		XX	x	x	x	x	n P	xx	xx	x	*1* 2 3 4
grandis	25, 72	I	D	Fl cream	xxx		xX	x	xxx	xxx	x	N P	x		x	1 4
gummifera	25, 30	S/I	D	*Fl white*	xxx		xX	x	x	xx	x	N p	xx		xx	1 4
lehmannii	10, 19	S	L	*Fl cream*		x	xXX	x			x	N p	xxx	xx	x	*1* 4
macarthurii	18, 32	I	D	Fl yellow	xxx		xX	xxx		xx	xx	n p	xxx		xx	4

Table A4.4 *(continued)*

Botanical name	Description: Usual height attained and greatest height recorded in S.A. (m)	Form of crown: (S)preading (I)ntermediate (N)arrow	Foliage Colour: (D)ark green (L)ight green (G)rey-green	Colour of (Fl)owers or (Fr)uits	Optimum rate of growth per year: Fast (1.0 m or more)	Intermediate (0.6 m)	Hardiness to drought and frost: Drought	Frost	Uses: Converted timber	Poles	Firewood	Honey: (N)ectar (P)ollen	Shelterbelts and windbreaks	Reclamation of driftsands	Ornament	Miscellaneous
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
E. maculata	20, 55	I	D	Fl cream	xxx		xX	x	xxx	xxx	xxx	N p	x		x	1 *4*
maidenii	20, 59	I	D	Fl cream	xxx		xX	xxx	x	xxx	xx	n p	x		x	
marginata	13, 21	I	L	Fl cream	x		xX	x	xxx	xx	x	n P				*4*
melliodora	18, 29	I	D	Fl cream	x		XXX	xxx	xx	xx	xxx	N	xx		x	*3* 4
microcorys	20, 60	I	D	Fl cream	xxx		xX	x	xxx	xxx	xx	n p	xxx		xx	*4*
muellerana	20, 42	I	D	Fl cream	xxx		xX	xx	xxx	xx	x	n p	x		x	*4*
nitens	25, 43	I	D	Fl cream	xxx		xX	xxx	xx	xx	x		x		x	*4*
obliqua	25, 49	I	D	Fl cream	xxx		xX	xx	xx	xx	x	n P	xx		x	*4*
oreades	20, 44	I	D	Fl cream	xxx		xX	xx	xx	xxx	x		x		x	*4*
paniculata	20, 50	I	D	Fl cream	xxx		xXX	x	xx	xxx	xxx	N p	xx		x	3 *4*
pauciflora	9, 27	S/I	L	Fl cream	xx		xx	xxx		x	xx	n p	xx		xx	4
pilularis	25, 62	I	L	Fl reddish	xxx		xX	x	x	xx	x	n p			x	*4*

Table A4.4 *(concluded)*

Botanical name	Description: Usual height attained and greatest height recorded in S.A. (m)	Description: Form of crown: (S)preading (I) ntermediate (N)arrow	Description: Foliage Colour: (D)ark green (L)ight green (G)rey-green	Colour of (Fl)owers or (Fr)uits	Optimum rate of growth per year: Fast (1.0 m or more)	Optimum rate of growth per year: Intermediate (0.6 m)	Hardiness to drought and frost: Drought	Hardiness to drought and frost: Frost	Uses: Converted timber	Uses: Poles	Uses: Firewood	Uses: Honey (N)ectar (P)ollen	Uses: Shelterbelts and windbreaks	Uses: Reclamation of driftsands	Uses: Ornament	Uses: Miscellaneous
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
E. polyanthemos	15, 24	I	G	Fl cream	xx		XXX	xx	x	x	xxx	n	xx		x	1 2 *4*
punctata	20, 34	S/I	D	Fl yellowish	xxx		xX	x	x	x	x	n p	xx		x	1 4
quadrangulata	25, 42	I	D	Fl yellowish	xxx		xX	x	xx	x	xxx		x		x	4
radiata	18, 39	S/I	D	Fl cream	xx		xX	xx		xx	x	n	xx		x	*4*
resinifera	20, 46	I	D	Fl red	xxx		xX	xx	x	xx	x	n p	x		x	*4*
robusta	15, 36	I	D	Fl cream	xxx		xX	x	x	xx	x	n p	xx	x	xx	1 2 3 4
rubida	18, 32	I	L/G	Fl yellow	xxx		XX	xxx	x	xx	x	n p	x		x	3 4
sideroxylon	15, 29	I	D	*Fl red, cream*	x		XXX	xx	x	xx	x	N p	xx		xx	1 2 *4*
sieberi	20, 43	S/I	D	Fl cream	xxx		xX	xx	xx	xx	xx	n p	x		x	2 *4*
smithii	20, 35	I	D	Fl cream	xxx		xX	xx		x	x	n p	x		x	
torquata	6, 9	S/I	L	*Fl, Fr reddish*		x	XXX	xx					x		xx	*4*
viminalis	15, 32	S/I	L	Fl cream	xxx		XX	xxx	x	xx	xx	N P	xx		x	*2*

Appendix 5. Area of eucalypt plantations

Table A5.1 summarizes information available on the extent of eucalypt plantations in each country or area. The information was mainly provided by the replies to a questionnaire distributed by FAO in early 1975 and refers to plantation areas at the end of 1973. Where replies were not available, information was derived from other sources. The source is indicated in each case.

The total area in Table A5.1 is just under 4 million ha. Brazil has easily the largest area, with over one million ha. Four countries (India, Spain, South Africa, Portugal) have between a quarter and half a million ha each.

Relatively few countries have reported the current or planned annual rate of eucalypt planting, but they include most of the important eucalypt-growing areas. Such information as is available is summarized in Table A5.2. It can be seen that the average annual planting area in the listed countries and areas is about 5 percent of the total, but there is great variation from the 2-3 percent of the older plantation countries to the 20, 50 or 100 percent of countries at the beginning of their planting programme. If this 5 percent average annual increase could be applied to the world total of 4 million ha, the resulting world expansion rate would be 200 000 ha a year.

Considerable variation in the reliability of the estimates must be recognized. In some cases they may refer to the area of fully stocked plantations, in others to the total area planted, in still others to an area equivalent to the number of plants raised in nurseries.

Table A5.1 Area of eucalypt plantations

Country or area	Total area planted to end of 1973 (hectares)	Total area planted and date, other than 1973 (hectares)	Source of information
Algeria		28 200 (1965)	FAO, 1967a
Angola		100 600 (1970)	Persson, 1975
Argentina	80 000		Questionnaire
Australia		26 400 (1972)	FORWOOD, 1974
Belize	Trials only		Questionnaire
Bolivia	5 000		Questionnaire
Brazil	1 052 000		Questionnaire
British Solomon Islands	Trials only		Questionnaire
Brunei	Trials only		Questionnaire
Burundi	18 627		Questionnaire
Cameroon		2 000 (1972)	Persson, 1975
Central African Republic	Trials only		Questionnaire
Chad	223		Questionnaire
Chile		31 052 (1966)	Questionnaire
China		52 000 (1977) [1]	FAO (in press)
Colombia	13 800		Questionnaire
Comoros	638		Questionnaire
Congo	5 500		Questionnaire
Costa Rica		Trials and farm woodlots	Gewald, 1977
Cuba	36 000		Questionnaire
Cyprus	2 000		Questionnaire
Dominican Republic	Trials and ornamentals		Questionnaire
Ecuador		17 716 (1975)	Narvaez, 1976
Ethiopia	42 300		Questionnaire
Fiji	Trials only		Questionnaire
France		1 130 (1961)	2nd World Eucalyptus Conference
Ghana	900		Questionnaire
Greece	100		Questionnaire
Guyana	Trials only		Questionnaire
Honduras		300 (1972)	Troensegaard *et al.*, 1973

Table A5.1 *(continued)*

Country or area	Total area planted to end of 1973 (hectares)	Total area planted and date, other than 1973 (hectares)	Source of information
Hong Kong	Trials only		Questionnaire
India	450 000		Questionnaire
Indonesia	Trials only		Questionnaire
Iran	Trials only		Questionnaire
Iraq	3 000		Questionnaire
Ireland	20		Questionnaire
Israel	10 022		Questionnaire
Italy		38 000 (1975)	Questionnaire
Ivory Coast	150		Questionnaire
Jordan	10		Questionnaire
Kenya	11 296		Questionnaire
Kuwait	Ornamentals		Questionnaire
Lesotho	360		Questionnaire
Libya		26 000 (1965)	FAO, 1967a
Madagascar	180 000		Questionnaire
Malawi		9 600 (1976)	Questionnaire
Malaysia	40		Questionnaire
Mali	Trials only		Questionnaire
Malta	Ornamentals		Questionnaire
Mauritius		3 000 (1970)	Persson, 1975
Mexico		2 000 (1967)	Reynders, 1970a
Morocco	177 743		Questionnaire
Mozambique	8 000		Questionnaire
Nepal	Trials only		Questionnaire
New Zealand	12 659		Questionnaire
Niger	40		Questionnaire
Nigeria	4 000		Questionnaire
Pakistan	1 000		Questionnaire
Panama	Trials and ornamentals		Questionnaire
Papua New Guinea	1 348		Questionnaire
Paraguay		2 900 (1972)	Persson, 1974
Peru		92 882 (1975)	Questionnaire
Philippines		7 070 (1975)	Domingo, 1977
Portugal	250 000		Questionnaire
Puerto Rico	840		Questionnaire

Table A5.1 *(concluded)*

Country or area	Total area planted to end of 1973 (hectares)	Total area planted and date, other than 1973 (hectares)	Source of information
Rwanda		23 000 (1970)	Persson, 1975
Senegal		50 (1965)	FAO, 1967a
Sierra Leone	Trials only		Questionnaire
Somalia	Trials only		Questionnaire
South Africa	347 464		South Africa, 1974
Spain	390 277		Questionnaire
Sri Lanka	8 296		Questionnaire
Sudan		7 560 (1969)	Persson, 1975
St. Kitts-Nevis-Anguilla	Ornamentals		Questionnaire
Swaziland	2 943		Questionnaire
Tanzania	2 744		Questionnaire
Thailand		100 (1965)	FAO, 1967a
Trinidad and Tobago	Trials only		Questionnaire
Tunisia		42 000 (1974)	Questionnaire
Turkey	10 770		Questionnaire
Uganda		11 528 (1975)	Questionnaire
United Kingdom	Ornamentals		Questionnaire
United States	110 000		Questionnaire; Skolmen, 1976
Upper Volta		933 (1976)	Questionnaire
Uruguay	111 123		Questionnaire
USSR		2 300 (1957)	Linnard, 1969
Western Samoa	Trials only		Questionnaire
Yemen Arab Republic		Windbreaks, woodlots	Beskok, 1974
Yemen, People's Dem. Republic of		Trials, windbreaks	Bilaidi, 1977
Zaire		5 000 (1965)	FAO, 1967a
Zambia	7 556		Questionnaire
Zimbabwe		25 000 (1965)	Barret & Mullin, 1968
Total	3 358 789	558 321	
Grand total	3 917 110		

[1] Area of plantations in Kwantung Province. Does not include areas planted in other provinces.

Table A5.2 Annual eucalypt planting rate in certain countries

Country or area	Total area planted (ha)	Current or planned annual planting rate (ha)	Annual increase (percent)	Source of information
Argentina	80 000 (1973)	3 000-6 000 (1973)	3.75-7.5	Questionnaire
Brazil	1 052 000 (1973)			Questionnaire
		65 000 (1972)	6.2	Pulpwood survey, 1972 [1]
Colombia	13 800 (1973)	2 500 (1973)	18.1	Questionnaire
Ethiopia	42 300 (1973)	1 770 (1973)	4.2	Questionnaire
India (part) [2]	189 000 (1972)	6 000 (1972)	3.2	Pulpwood survey, 1972 [1]
Lesotho	360 (1973)	400-800 (1973)	110-220	Questionnaire
Morocco	177 743 (1973)			Questionnaire
		5 000 (1971)	2.8	Pulpwood survey, 1972 [1]
Nigeria	4 000 (1973)	800 (1973)	20.0	Questionnaire
Papua New Guinea	1 348 (1973)	900 (1973)	66.8	Questionnaire
Portugal	250 000 (1973)	15 000 (up to 1973)	6.0	Questionnaire
South Africa	347 464 (1973)	10 426 (1973)	3.0	South Africa, 1974
Sri Lanka	8 296 (1973)	400 (1973)	4.8	Questionnaire
Tunisia	42 000 (1974)			Questionnaire
		500-800 (1971)	1.2-1.9	Pulpwood survey, 1972 [1]
Turkey	10 770 (1973)	250 (1973)	2.3	Questionnaire
Total	2 219 081	111 946-115 646	5.0-5.2	

[1] FAO survey of eucalypt plantations for pulpwood in selected countries, 1972 (unpublished). — [2] Figures applicable to part of India only, i.e.: Bihar, Gujarat, Maharashtra, Kerala, U.P., Punjab, Andaman and Nicobar Islands, Goa Daman and Din, Armachal Pradesh, Dadra and Nagar Davali.

Appendix 6. Calculating profitability of plantations

Table A6.1 illustrates one method of comparing the profitability of eucalypt plantations in three hypothetical cases. In every case costs and revenue refer to one hectare of plantation over a period of 24 years and at a discount rate of 10 percent.

In order to make the examples as simple as possible, it is assumed that establishment costs are all incurred during the first year (year 0) of the operation of the project. This is possible with an optimum combination of circumstances (minimum clearing of vegetation, intensive site preparation and weeding, a fast-growing species and a high-quality site), when four months for nursery work and site preparation and eight months from planting to canopy closure should be sufficient. More frequently, however, establishment costs may be spread over several years of the project, e.g., land clearing in year 0, soil cultivation, nursery work and planting in year 1 and weeding in year 2. In such cases a different discount factor must be used for the cost of operations in each year.

In the examples it is assumed that establishment costs do not include the cost of land. Where government forest departments operate in government forest reserves, it is justifiable to omit cost of land from calculations. Where private land must be purchased, or could be sold for profit as an alternative to being used for eucalypt planting, it should be included as a cost at the start of the project and its future sale value included as an item of revenue at the end of the project. It is assumed that the cost of thinning and felling is borne by the buyer and that stumpage value represents the value to the grower of the standing crop.

Cases 1 and 2 represent two species being grown on a pulp rotation of 8 years. Seedling crops of both species grow at the same rate (MAI 20 m^3/ha/yr over 8 years) and have the same value as pulpwood ($10 per m^3). Case 1 regenerates readily from coppice, Case 2 must be replanted. Case 1 can therefore be regenerated more cheaply at ages 9 and 17. In addition the MAI of Case 1 in the first coppice rotation (24 m^3/ha/yr) is 20 percent higher than in the seedling rotation. In the second coppice rotation the MAI reverts to 20 m^3. Case 1 is clearly the more profitable. Its net present value or net discounted revenue is over twice as high as that of Case 2.
Case 3 represents a species, of similar growth rate as Cases 1 and 2, being grown primarily for sawlogs and large poles, but with a market available for early thinnings. Because of the longer rotation, the MAI is considered to

be 17.5 m³/ha/yr. The unit price of sawlogs is considered to be over twice that of pulpwood. The net present value or net discounted revenue at 10 percent discount rate falls midway between those of Cases 1 and 2.
The table also shows the internal rate of return (IRR) — the rate of interest at which discounted costs are exactly equal to discounted revenues — for each case. Case 1 remains the most profitable of the three, with an IRR of 14.8 percent. The IRR of Cases 2 and 3 are the same, 12.4 percent, even though Case 3 shows a higher profit at 10 percent interest rate. This is because the adverse effect of increased interest rates on profitability weighs more heavily on projects like Case 3, in which the greatest part of revenue is concentrated at the end of the project, than on projects where revenues are more evenly spread in time (Cases 1 and 2). On the other hand, a reduction in interest rates would favour a project like Case 3; at 5 percent interest Case 3 is more profitable than Case 1.

Table A6.1 Calculation of net present value (in US$) at 10 percent discount rate for 1 ha of eucalypt plantation, and the internal rate of return

Year	Item	Case 1			
		Remarks	Value	Discount factor	Dis-counted value
	COSTS				
0	Establishment		520	1.0	520
9	Regeneration	By coppice	40	0.424	17
17	Regeneration	By coppice	40	0.198	8
0-24	Annual protection/ overheads		40	9.077	363
	Total discounted costs				908
	REVENUE				
5	Stumpage value (thinning)				
8	Stumpage value (clear-fell)	160 m³ at $10	1 600	0.467	747
10	Stumpage value (thinning)				
15	Stumpage value (thinning)				
16	Stumpage value (clear-fell)	192 m³ at $10	1 920	0.218	419
24	Stumpage value (clear-fell)	160 m³ at $10	1 600	0.102	163
	Total discounted revenue				1 329
	Net discounted revenue or "Net present value"				421
	Internal rate of return (percent)				14.8

Table A6.1 *(continued)*

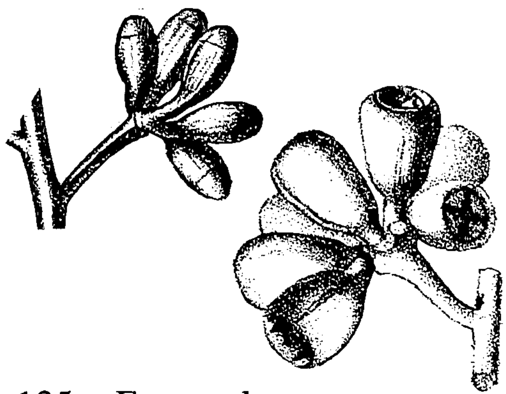
Year	Item	Case 2			
		Remarks	Value	Discount factor	Discounted value
	COSTS				
0	Establishment		520	1.0	520
9	Regeneration	By replanting	300	0.424	127
17	Regeneration	By replanting	300	0.198	59
0-24	Annual protection/ overheads		40	9.077	363
	Total discounted costs				1 069
	REVENUE				
5	Stumpage value (thinning)				
8	Stumpage value (clear-fell)	160 m³ at $10	1 600	0.467	747
10	Stumpage value (thinning)				
15	Stumpage value (thinning)				
16	Stumpage value (clear-fell)	160 m³ at $10	1 600	0.218	349
24	Stumpage value (clear-fell)	160 m³ at $10	1 600	0.102	163
	Total discounted revenue				1 259
	Net discounted revenue or "Net present value"				190
	Internal rate of return (percent)				12.4

Year	Item	Case 3			
		Remarks	Value	Discount factor	Discounted value
	COSTS				
0	Establishment		520	1.0	520
9	Regeneration				
17	Regeneration				
0-24	Annual protection/ overheads		40	9.077	363
	Total discounted costs				879
	REVENUE				
5	Stumpage value (thinning)	40 m³ at $5	200	0.621	124
8	Stumpage value (clear-fell)				
10	Stumpage value (thinning)	60 m³ at $10	600	0.386	232
15	Stumpage value (thinning)	80 m³ at $15	1 200	0.239	287
16	Stumpage value (clear-fell)				
24	Stumpage value (clear-fell)	240 m³ at $22	5 280	0.102	539
	Total discounted revenue				1 182
	Net discounted revenue or "Net present value"				303
	Internal rate of return (percent)				12.4

Appendix 7. Eucalypt buds and fruits

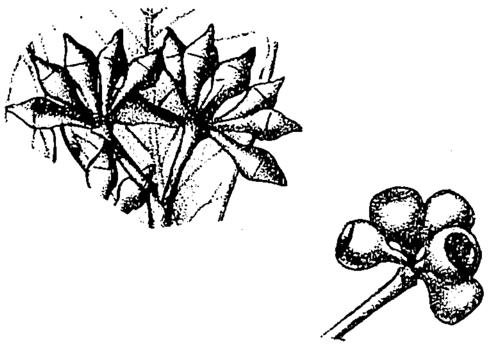
In the following illustrations, the number preceding the species name below each pair of drawings is the Blakely number. In each pair, the left-hand drawing is the bud and the right-hand the fruit. The drawings, which are life-size, are reproduced from "*Eucalyptus* buds and fruits," by G.M. Chippendale, 1968, with the permission of the Australian Government Publishing Service, Canberra, Australia. The Blakely nomenclature has been retained in all cases (see "Note on nomenclature," p. viii).

a7-1



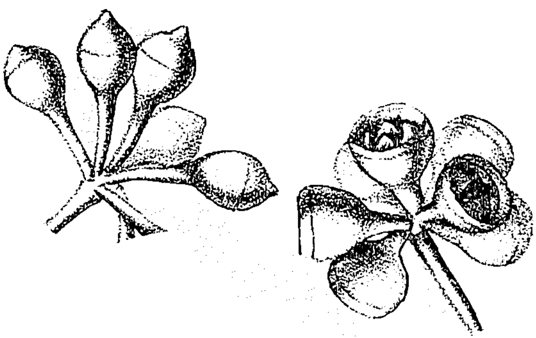
125 *E. accedens*

a7-2



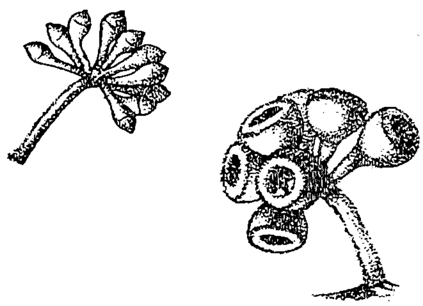
313 *E. acmenioides*

a7-3



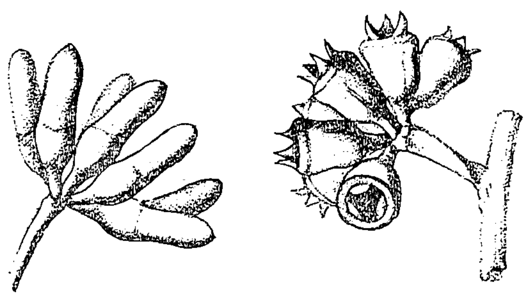
207 *E. alba*

a7-4



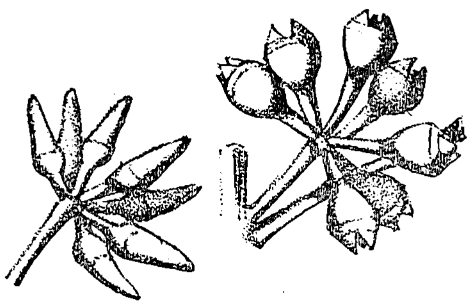
422 *E. andrewsii*

a7-5



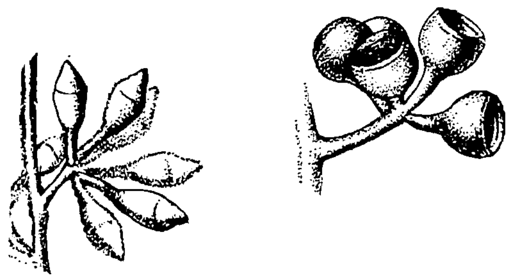
112 *E. astringens*

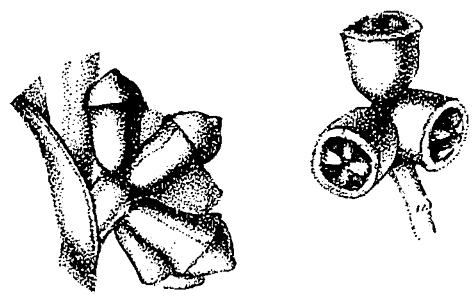
a7-6



186 *E. blakelyi*

a7-7



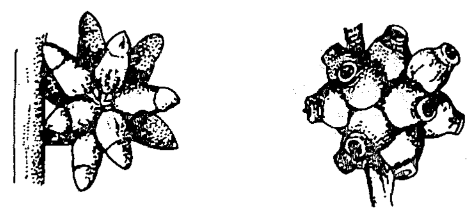


a7-8

479 *E. bosistoana*

64 *E. botryoides*

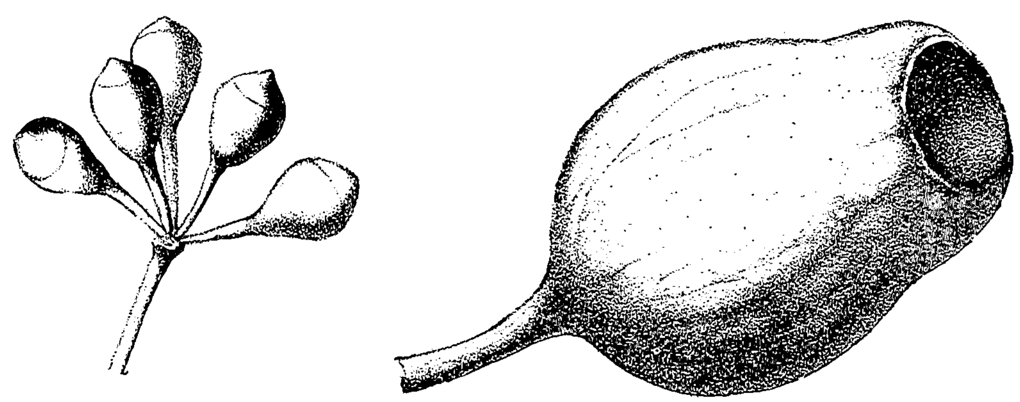
a7-9



a7-10

225 *E. bridgesiana*

584a *E. brockwayi*



a7-11

32 *E. calophylla*

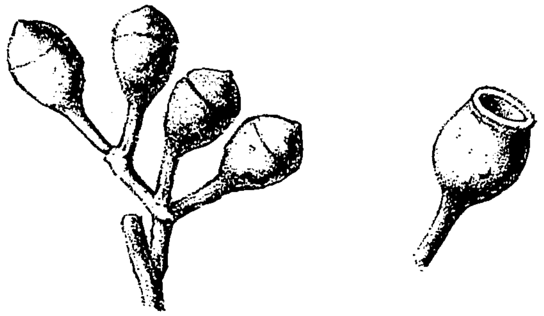
a7-12

a7-13

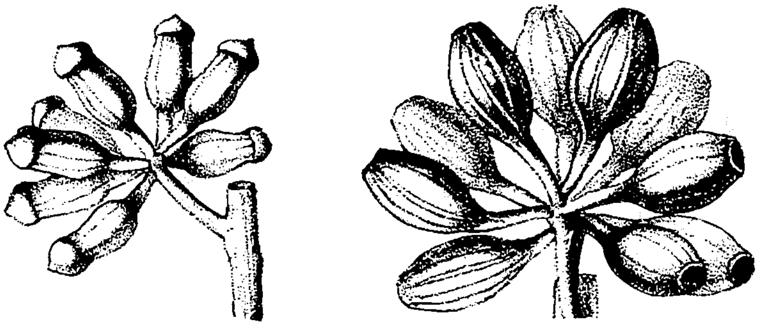
197 *E. camaldulensis*

283 *E. cinerea*

a7–14



53 *E. citriodora*

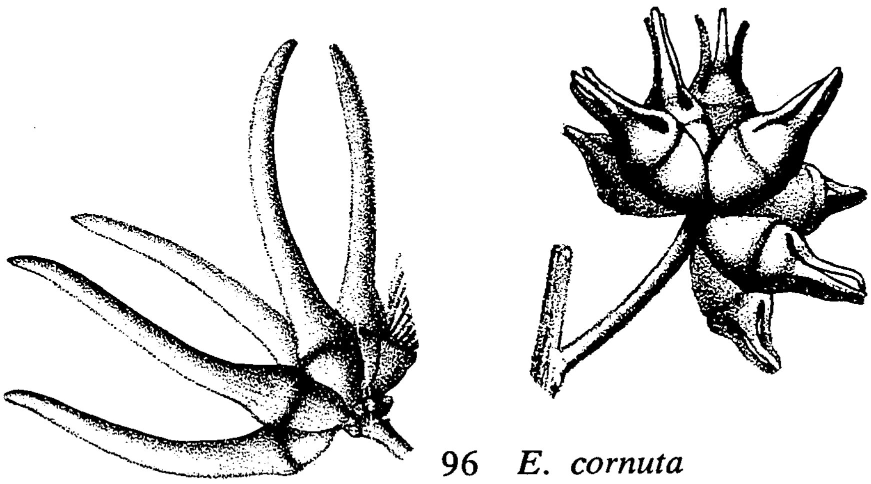


a7–15

121 *E. cladocalyx*

a7–16

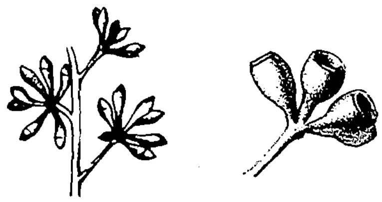
295 *E. cloeziana*



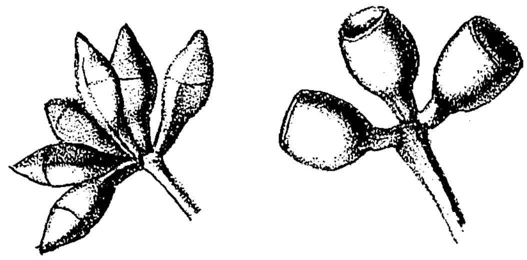
a7–17

96 *E. cornuta*

a 7–18



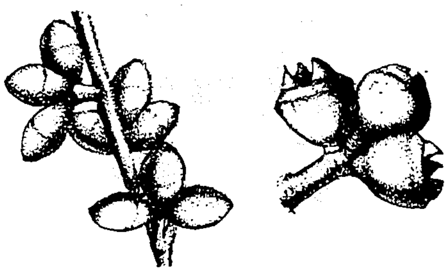
a 7–19



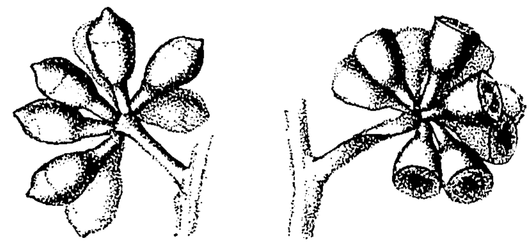
514 *E. crebra*

262 *E. cypellocarpa*

a 7–20



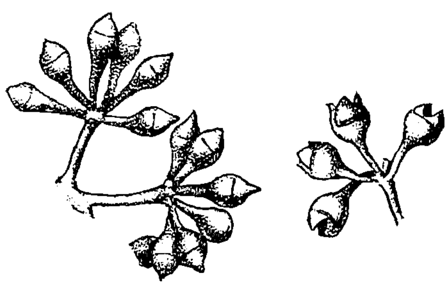
a 7–21



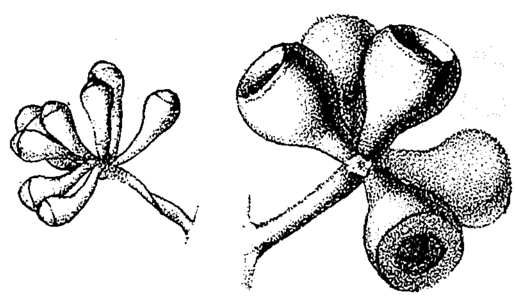
236 *E. dalrympleana ssp. dalrympleana*

62 *E. deanei*

a 7–22



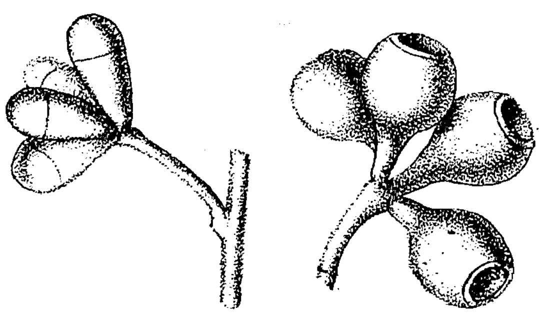
a 7–23



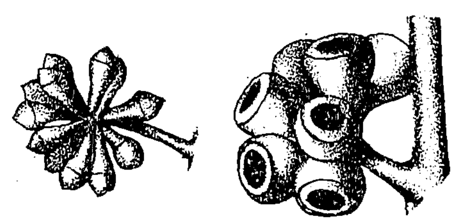
437 *E. deglupta*

370 *E. delegatensis*

a 7–24



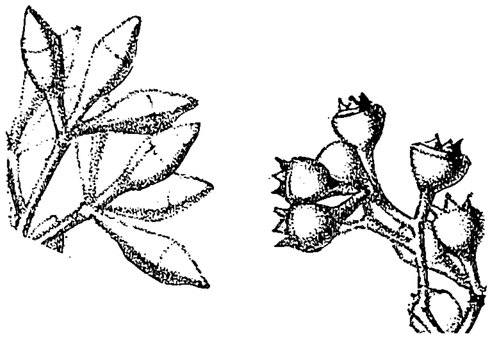
a 7–25



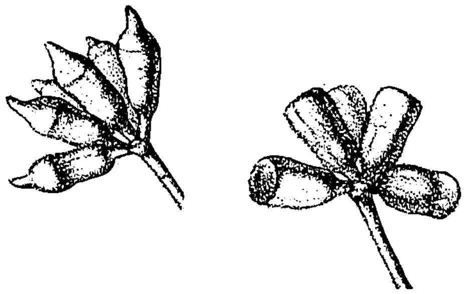
57 *E. diversicolor*

417 *E. dives*

a7-26



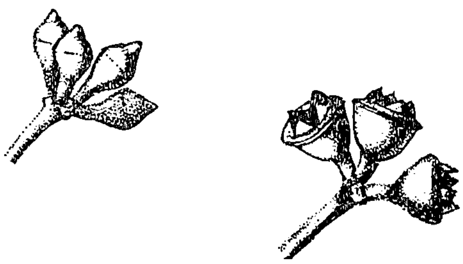
533 *E. drepanophylla*



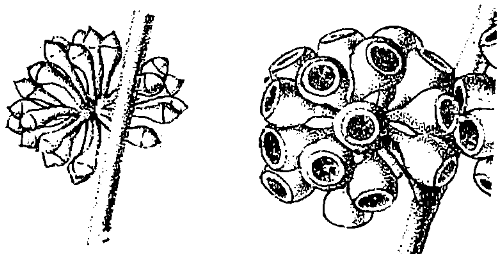
134 *E. dundasii*

a7-27

a7-28

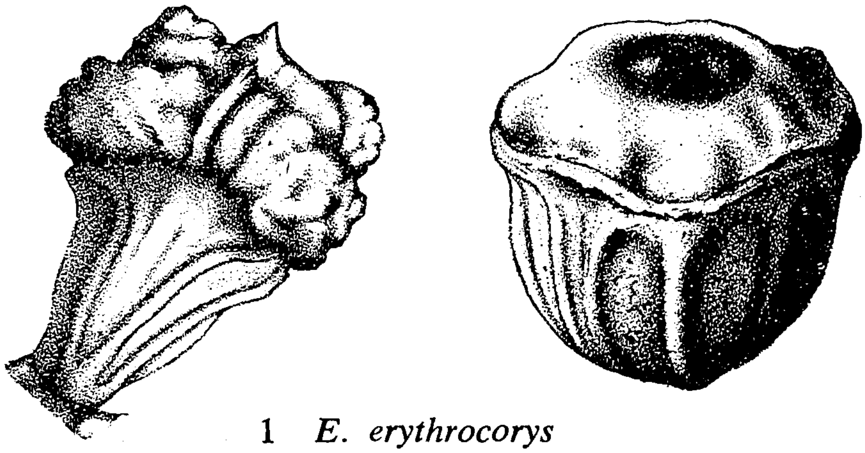


223 *E. dunnii*



406 *E. elata*

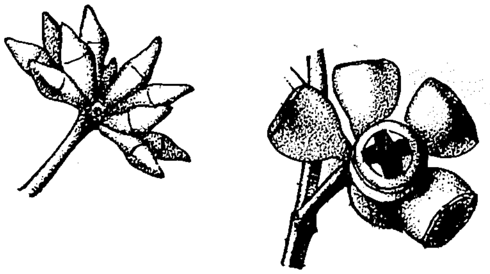
a7-29



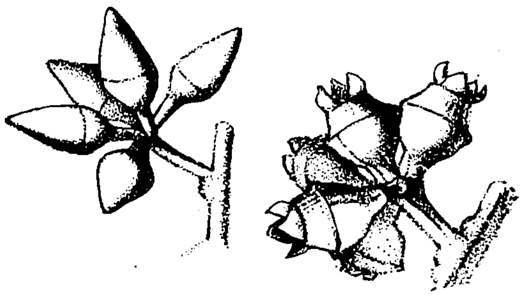
1 *E. erythrocorys*

a7-30

a7-31



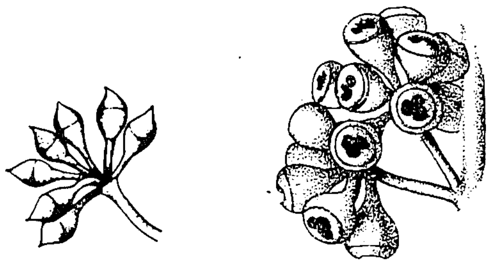
318 *E. eugenioides*



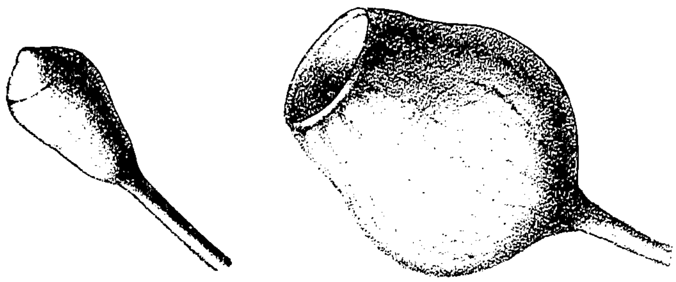
173 *E. exserta*

a7-32

a7-33



368 *E. fastigata*

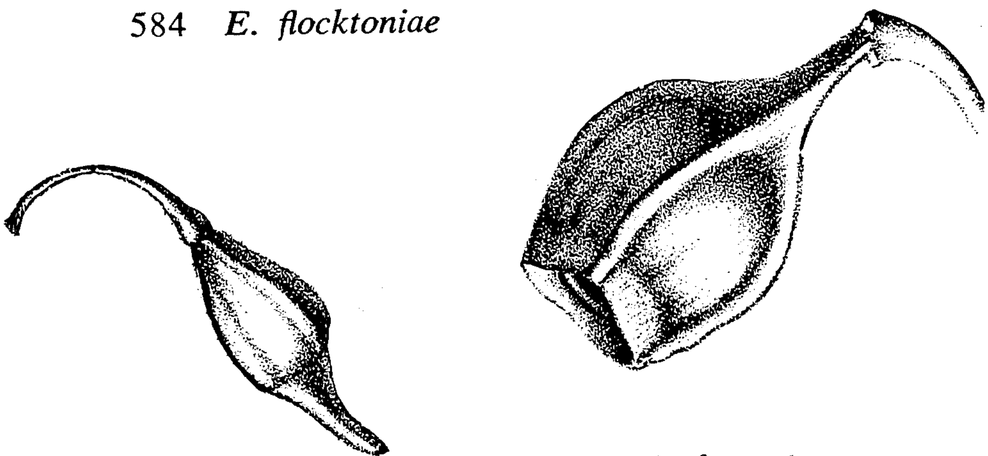


a7-34

36 *E. ficifolia*

a7-35

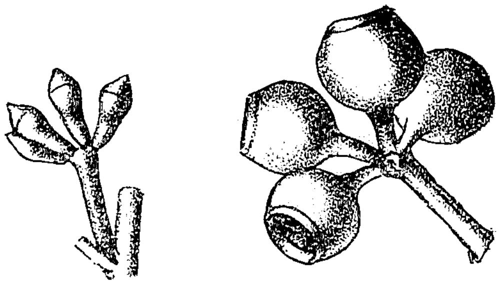
584 *E. flocktoniae*

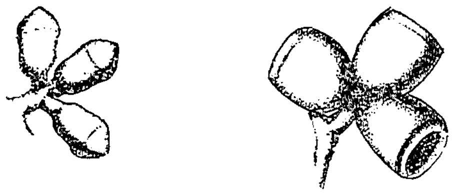


a7-36

596 *E. forrestiana*

a7-37

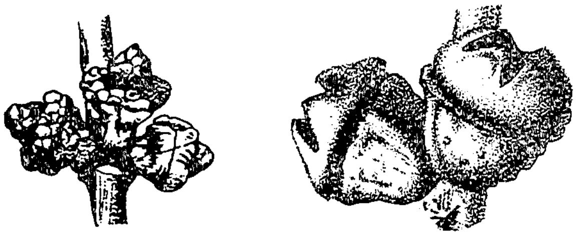




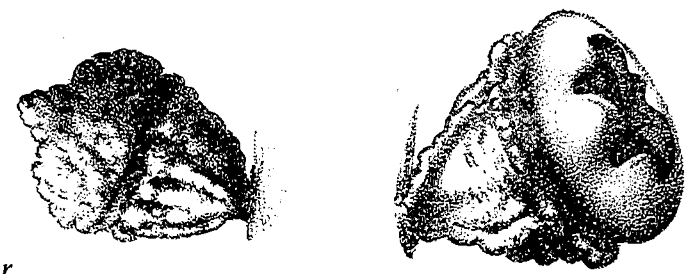
a7-38

381 *E. fraxinoides* 237 *E. glaucescens*

a7-39

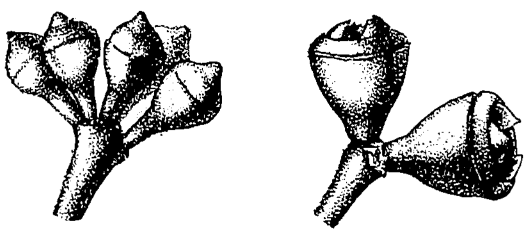


250 *E. globulus* var. *bicostata*



a7-40

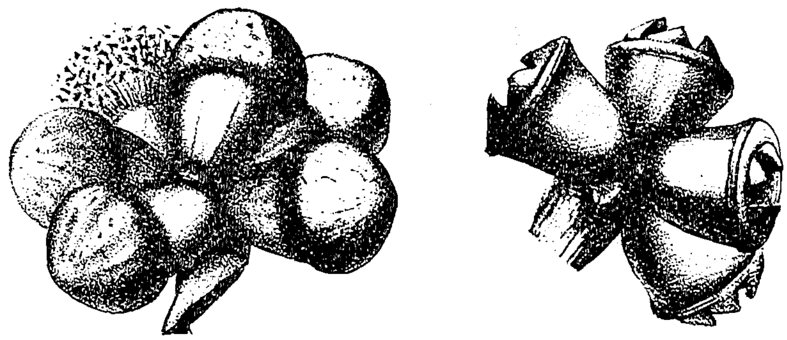
248 *E. globulus* var. *globulus*



a7-41

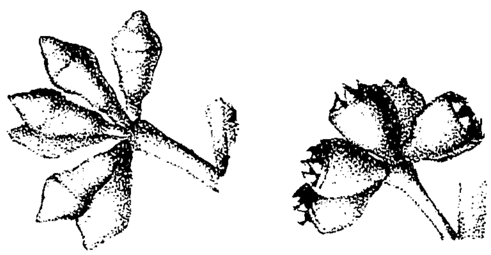
261 *E. globulus* var. *maidenii*

a7-42

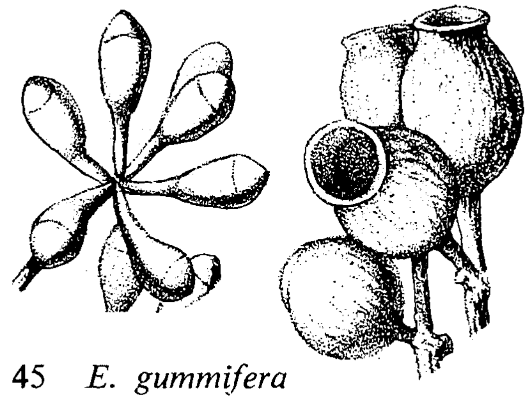


98 *E. gomphocephala*

a7-43



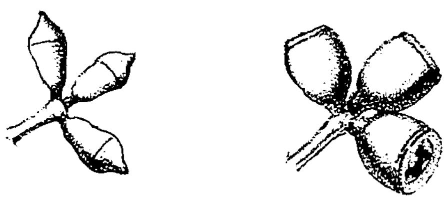
58 *E. grandis*



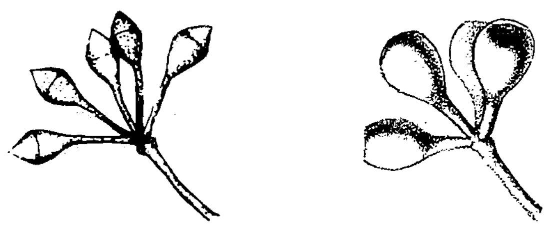
45 *E. gummifera*

a7-44

a7-45



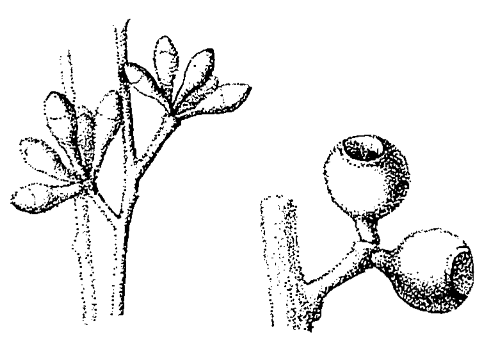
239 *E. gunnii*



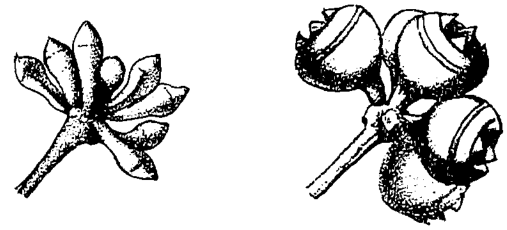
291 *E. intertexta*

a7-46

a7-47



56 *E. jacksonii*

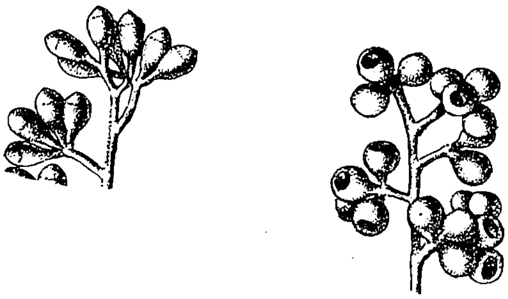


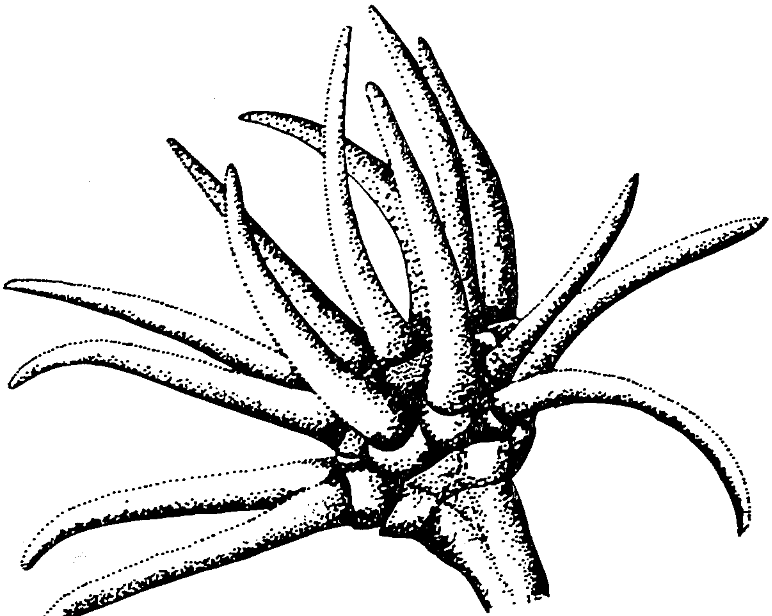
327 *E. laevopinea*

a7-48

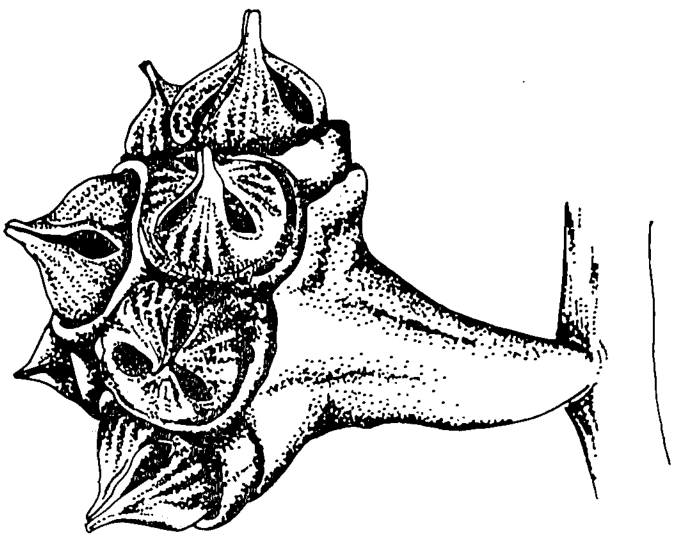
472 *E. largiflorens*

a7-49

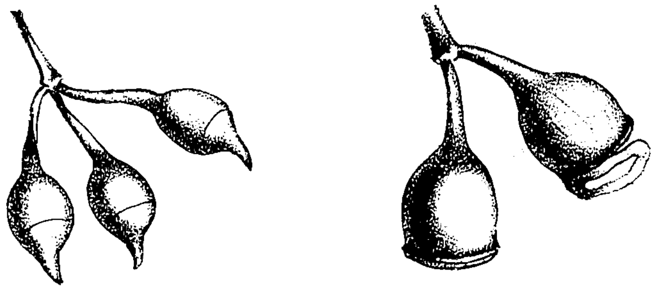




a7-50

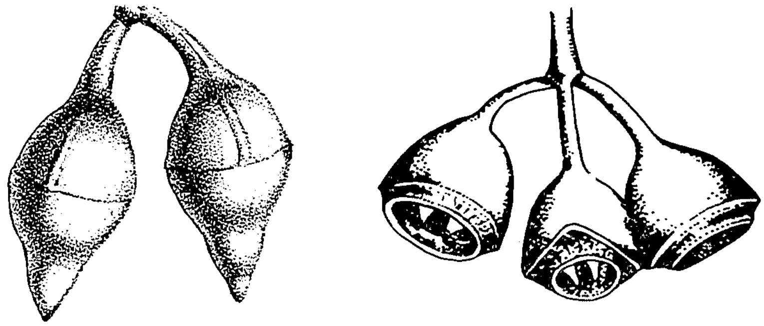


97 *E. lehmannii*



a7-51

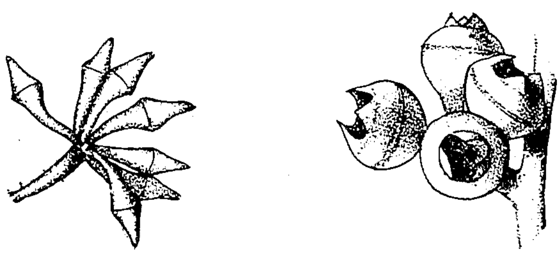
542 *E. leucoxylon var. leucoxylon*



a7-52

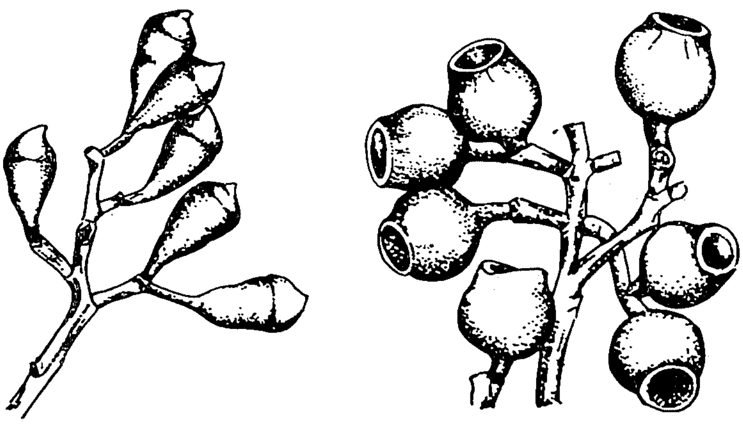
81 *E. longifolia*

a7-53 273 *E. macarthurii*



a7-54

331 *E. macrorhyncha*

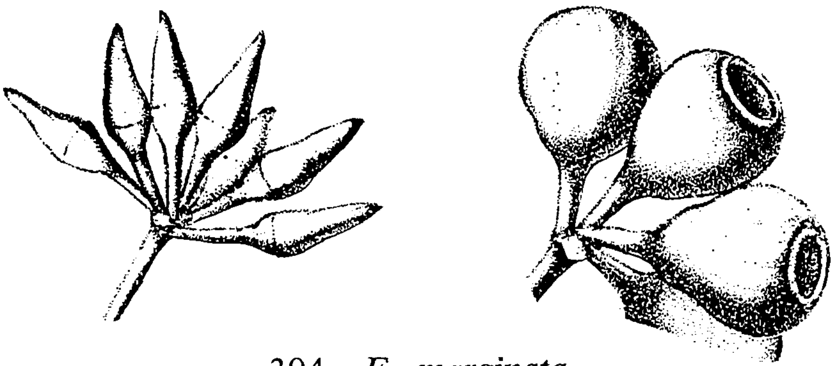


a7-55

54 *E. maculata*

a 7–56

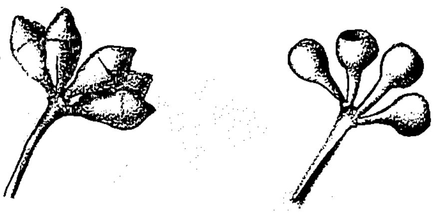
233 *E. mannifera ssp. mannifera*



a 7–57

304 *E. marginata*

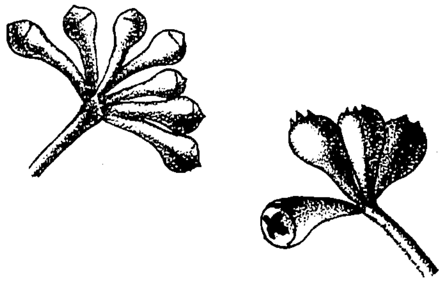
a 7–58

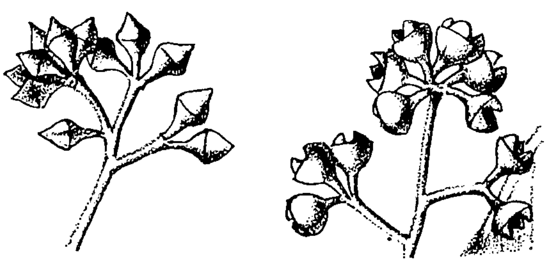


a 7–59

526 *E. melanophloia* 550 *E. melliodora*

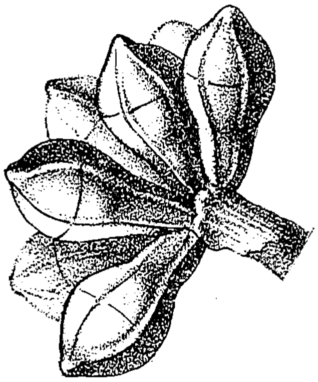
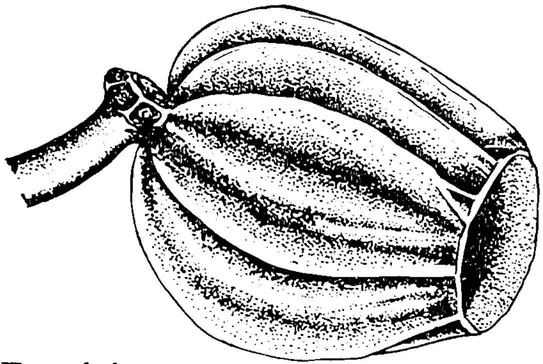
a 7–60





a 7–61

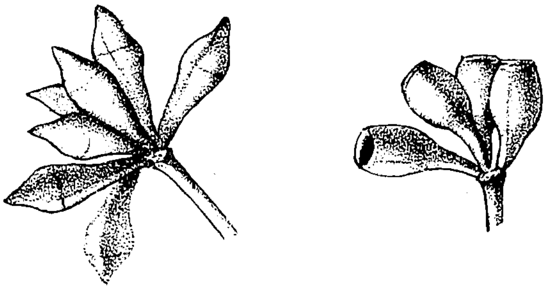
314 *E. microcorys* 507 *E. microtheca*

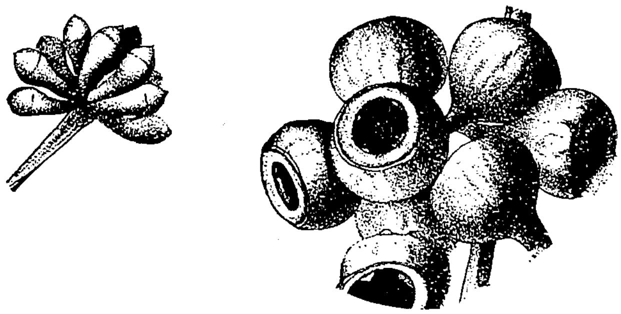
a7-62

14 *E. miniata*

a7-63



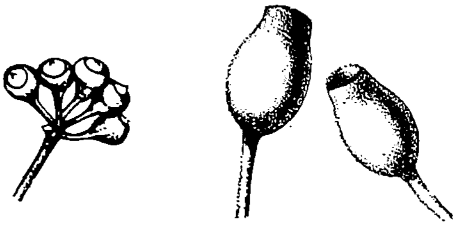
484 *E. moluccana*



a7-64

308 *E. muellerana*

a7-65

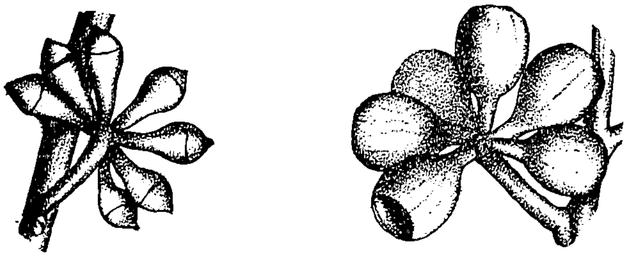


a7-66

46a *E. nesophila*

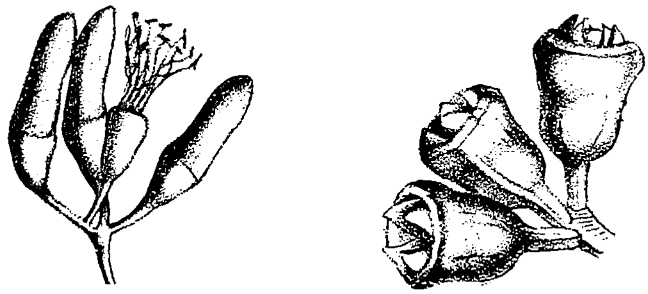
263 *E. nitens*

a7-67



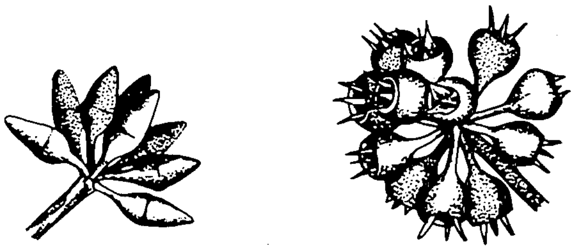
362 *E. obliqua*

110 *E. occidentalis*
var. occidentalis



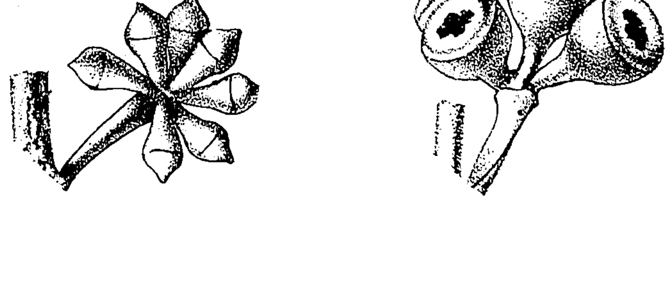
a7-68

a7-69



578 *E. oleosa var. oleosa*

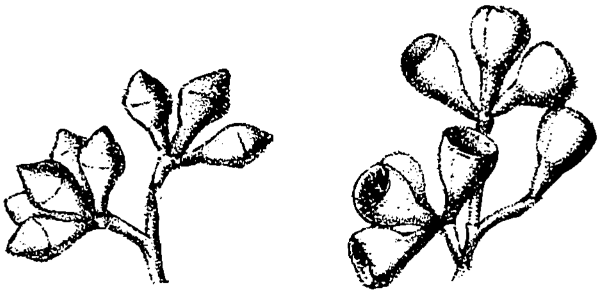
380 *E. oreades*



a7-70

a7–71

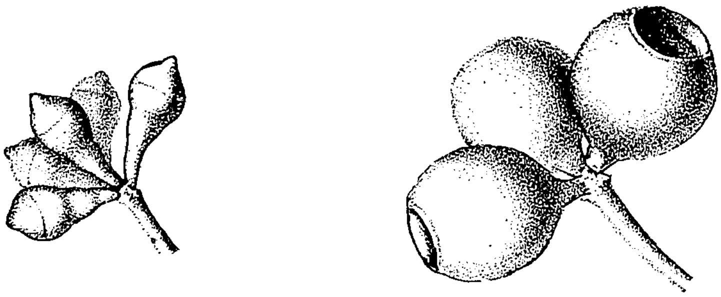
210 *E. ovata*



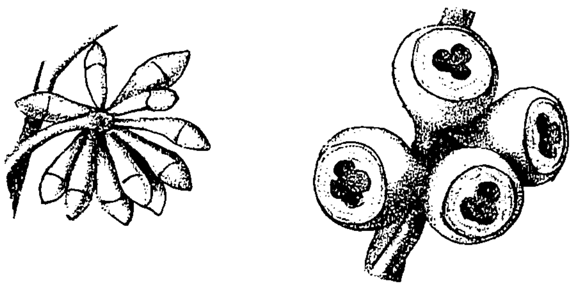
537 *E. paniculata*

a7–72

a7–73

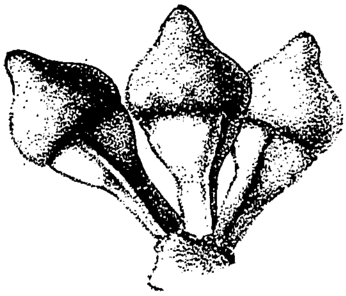


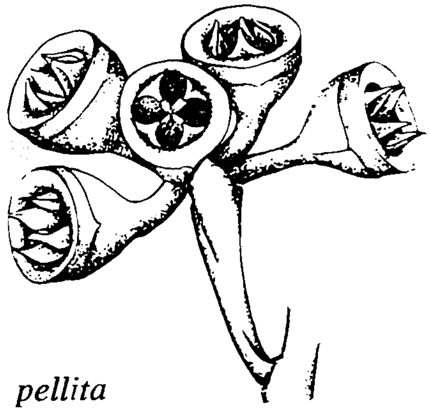
299 *E. patens*



394 *E. pauciflora*
var. pauciflora

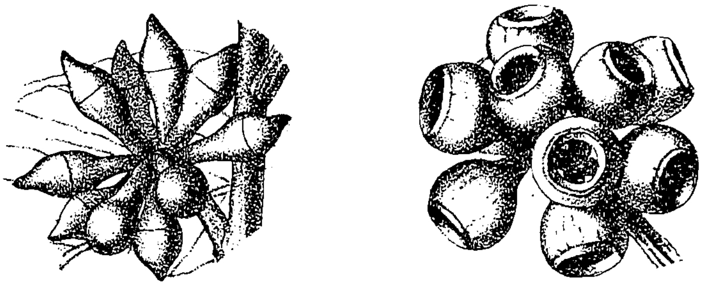
a7–74





73 *E. pellita*

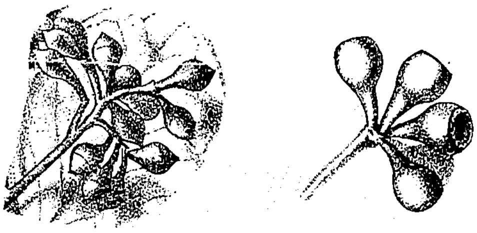
a7–75

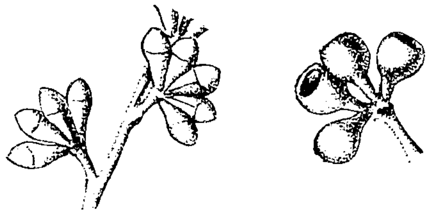


a7–76

306 *E. pilularis var. pilularis*

a7–77





a7–78

558 *E. polyanthemos*

464 *E. polybractea*

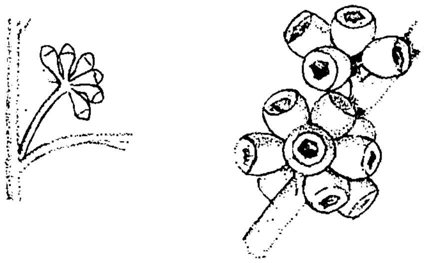
a7–79

a7–80

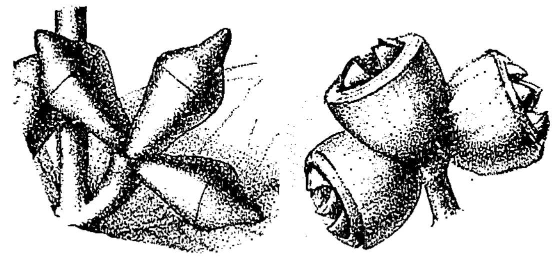
501 *E. populnea*

75 *E. propinqua*

a7-81



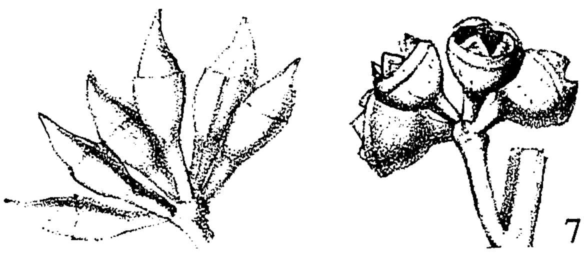
405 *E. pulchella*



a7-82

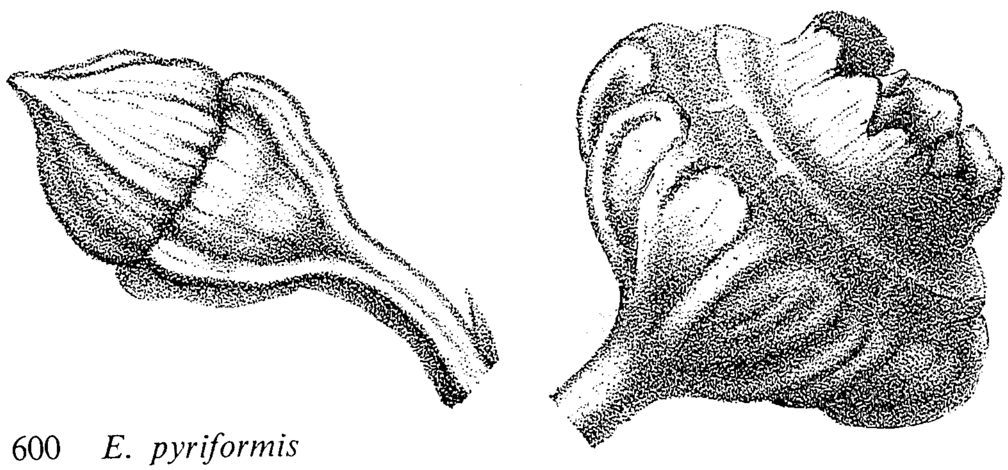
245 *E. pulverulenta*

a7-83



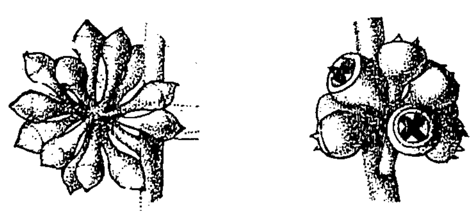
78 *E. punctata var. punctata*

a7-84

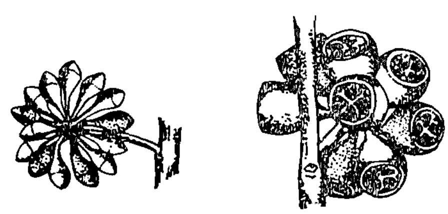


600 *E. pyriformis*

a7-85



411 *E. radiata*

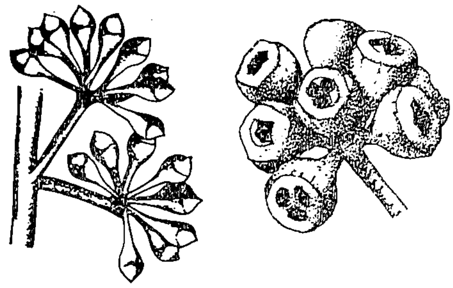


a7-86

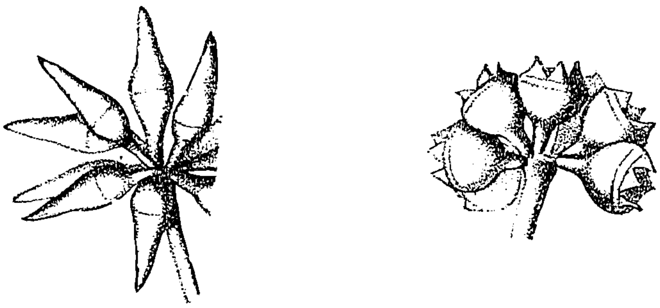
407 *E. radiata subsp. robertsonii*

a 7–87 

438 *E. raveretiana*

 a 7–88

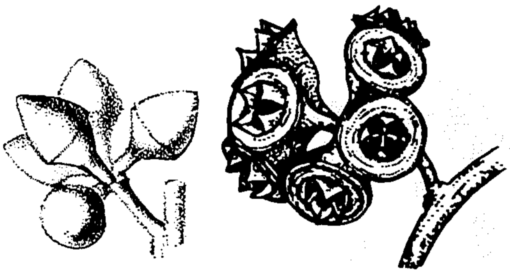
369 *E. regnans*

a 7–89 

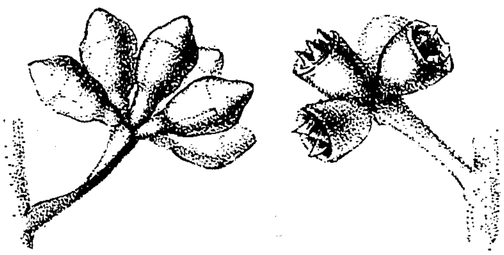
69 *E. resinifera*

 a 7–90

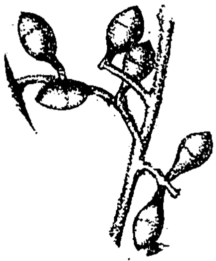
67 *E. robusta*

a 7–91 

204 *E. rudis*

 a 7–92

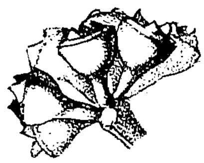
60 *E. saligna*



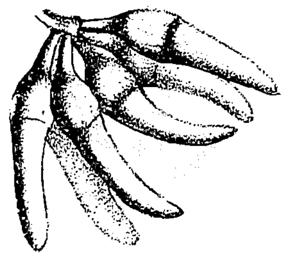
a7–93

593 *E. salmonophloia*

a7–94



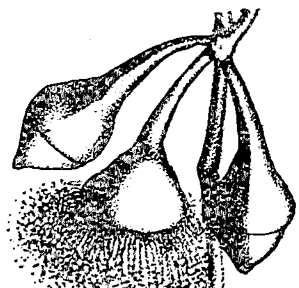
594 *E. salubris*

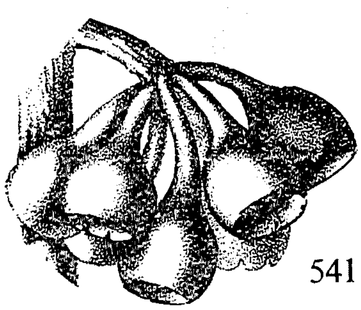


a7–95

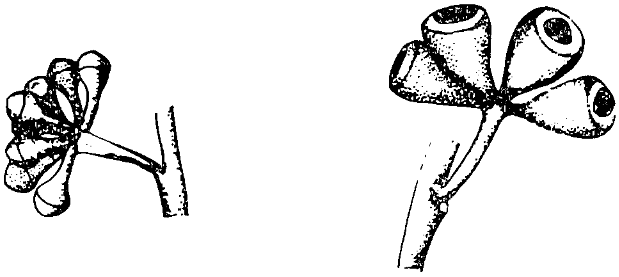
113 *E. sargentii*

a7–96





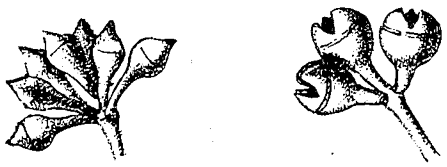
541 *E. sideroxylon ssp. sideroxylon*



a7–97

371 *E. sieberi*

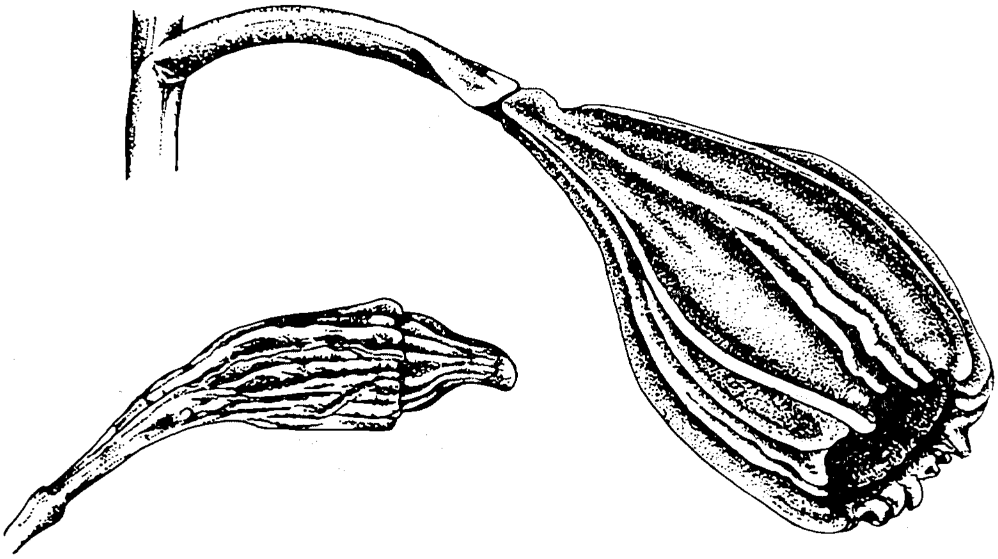
a7–98



274 *E. smithii*

a7–99

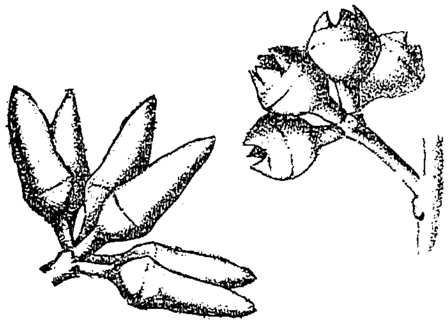
520 *E. staigerana*



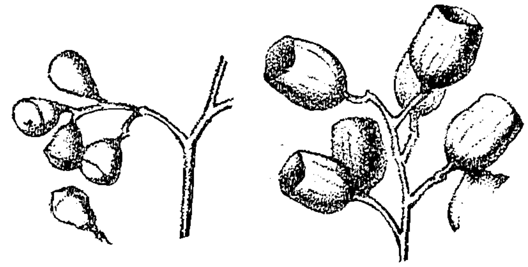
a7–100

161a *E. stoatei*

a 7–101

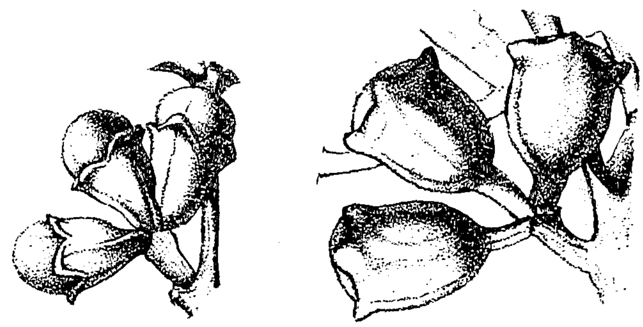


178 *E. tereticornis*



a 7–102

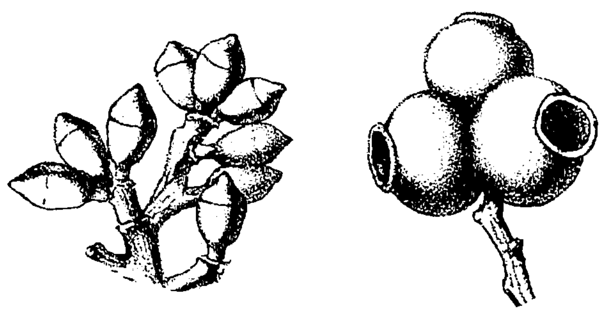
16 *E. tessellaris*



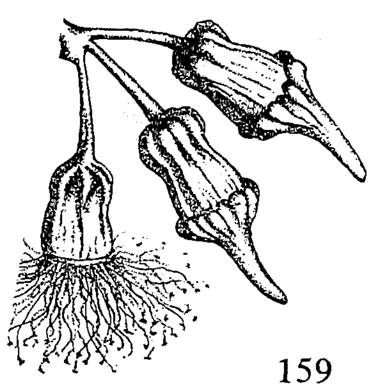
a 7–103

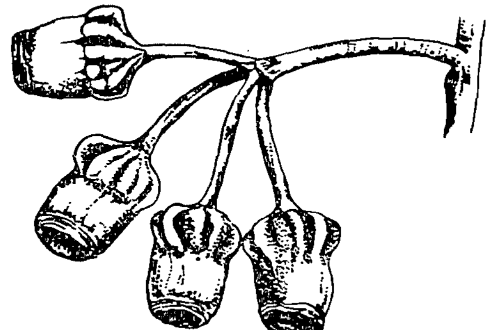
7 *E. tetrodonta*

a 7–104



49 *E. torelliana*

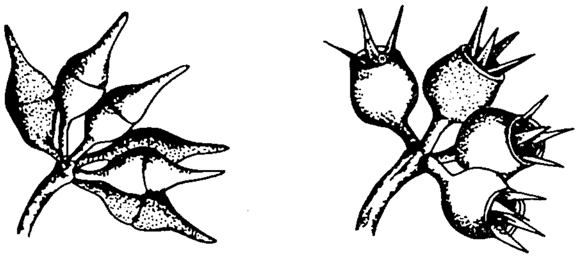




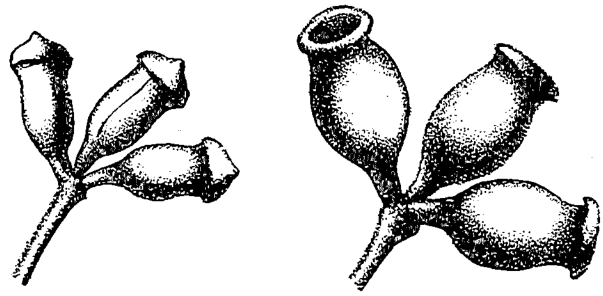
a 7–105

159 *E. torquata*

a 7–106



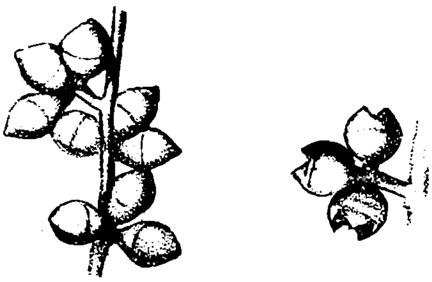
581 *E. transcontinentalis*



a 7–107

240 *E. urnigera*

a 7–108



277 *E. viminalis*

a 7–109

120 *E. wandoo*

a 7–110

482 *E. woollsiana*

Appendix 8. Comparative climodiagrams

A useful aid for making rapid comparisons of climate, between proposed new planting sites for eucalypts and the original location in Australia of the candidate species or provenances to be planted, is the method of Gaussen (1954). A global series of climodiagrams derived by this method is available in the Klimadiagramm-Weltatlas (Walter and Lieth, 1967). The method is illustrated here by a few examples, in which each climatic station in Australia is paired with a station in another eucalypt-planting country having a similar climatic regime.

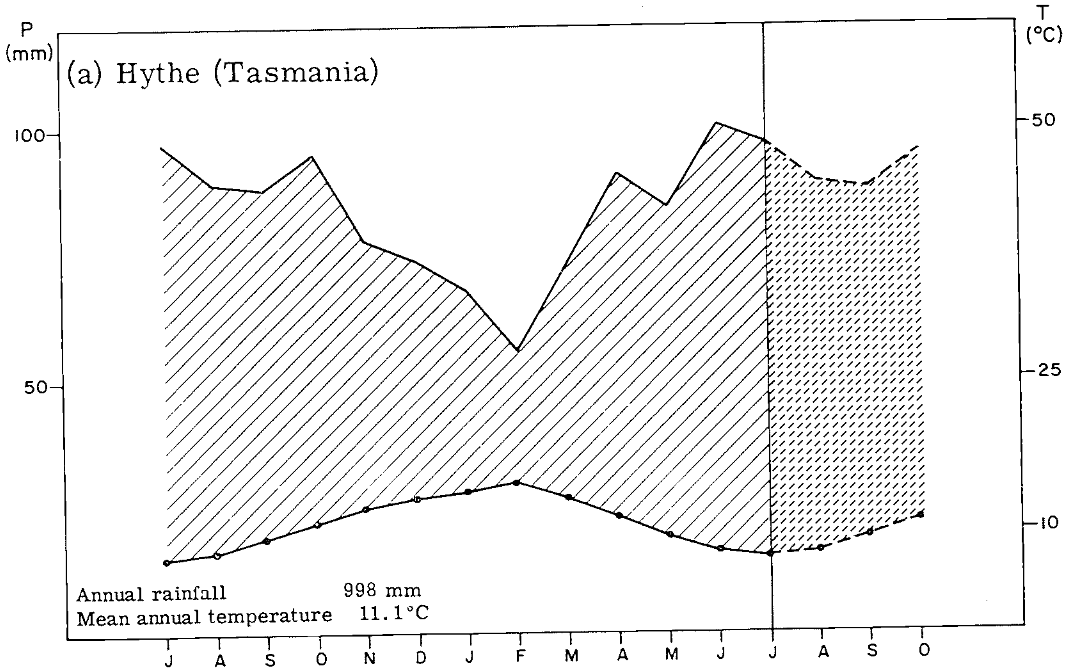
In each climodiagram months are indicated along the abscissa. In order to represent continuity in time, four months are shown twice, both at the beginning and at the end of the time sequence. In every diagram the hottest months of the year (January-February in the southern hemisphere, July-August in the northern) are shown near the middle of the time sequence. Mean monthly temperature in °C is represented by •—•—• and mean monthly precipitation in mm as /\. Temperature is plotted at twice the scale of precipitation, i.e., 1°C = 2 mm of precipitation. Monthly precipitation above 100 mm is represented at a scale of one tenth of precipitation up to 100 mm.

The period(s) of the year during which the temperature curve is above the precipitation curve (dotted area) is considered to be "dry" (soil moisture deficit likely), while the period(s) during which the precipitation curve exceeds the temperature curve (hatched area) is considered to be "humid" (soil moisture surplus likely). The climodiagram thus represents the duration and intensity of the "dry" and "humid" seasons and whether they coincide with the hot or cool seasons of the year.

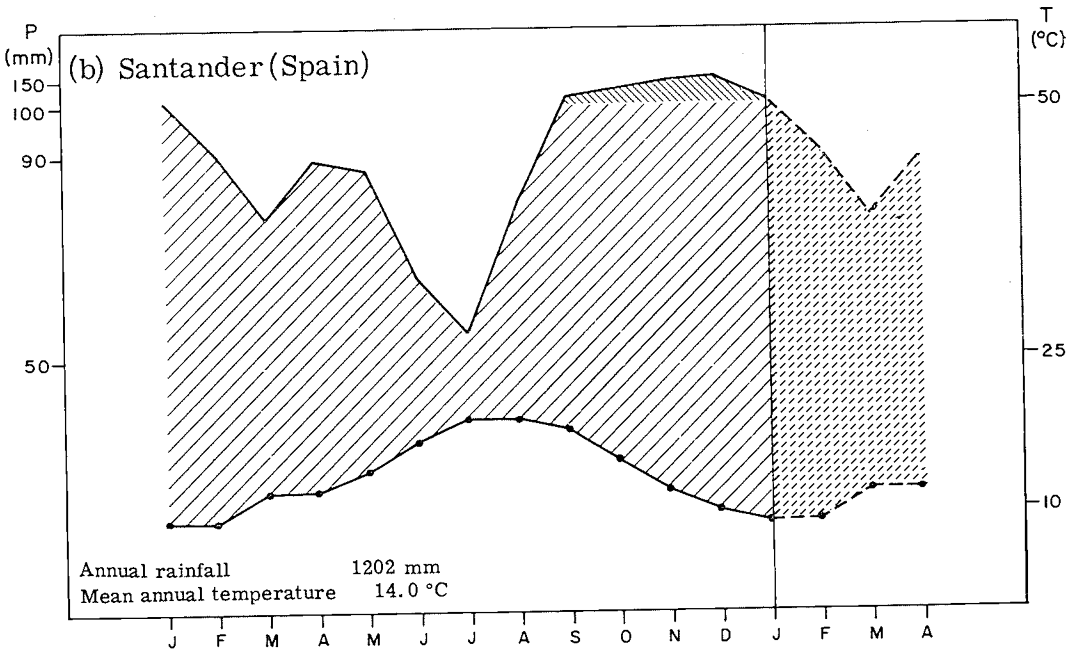
The Hythe and Santander pair of climodiagrams (Figure A8.1) represent a rainfall regime in which winter rainfall exceeds summer rainfall, but the temperature curve never exceeds the rainfall curve, even in summer. There is thus no dry season.

The Narrogin and Rabat pair of climodiagrams (Figure A8.2) represent a pronounced winter-rainfall regime with a severe dry season lasting about five months.

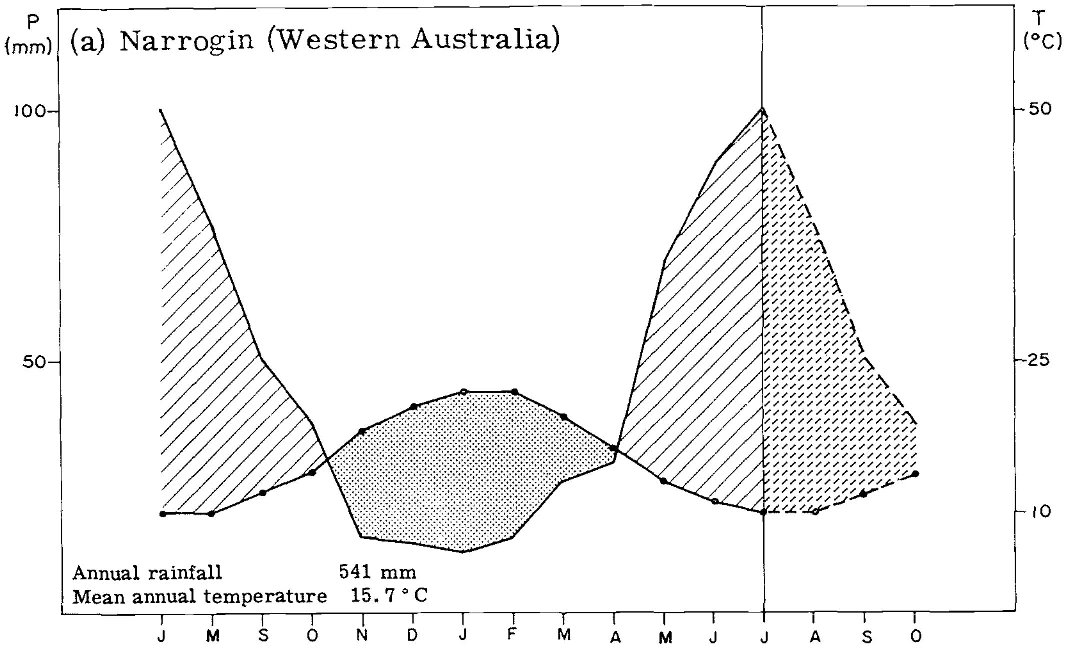
The Atherton and Piracicaba pair of climodiagrams (Figure A8.3) represent a pronounced summer-rainfall regime with a distinct dry season of two to three months during the cool season.

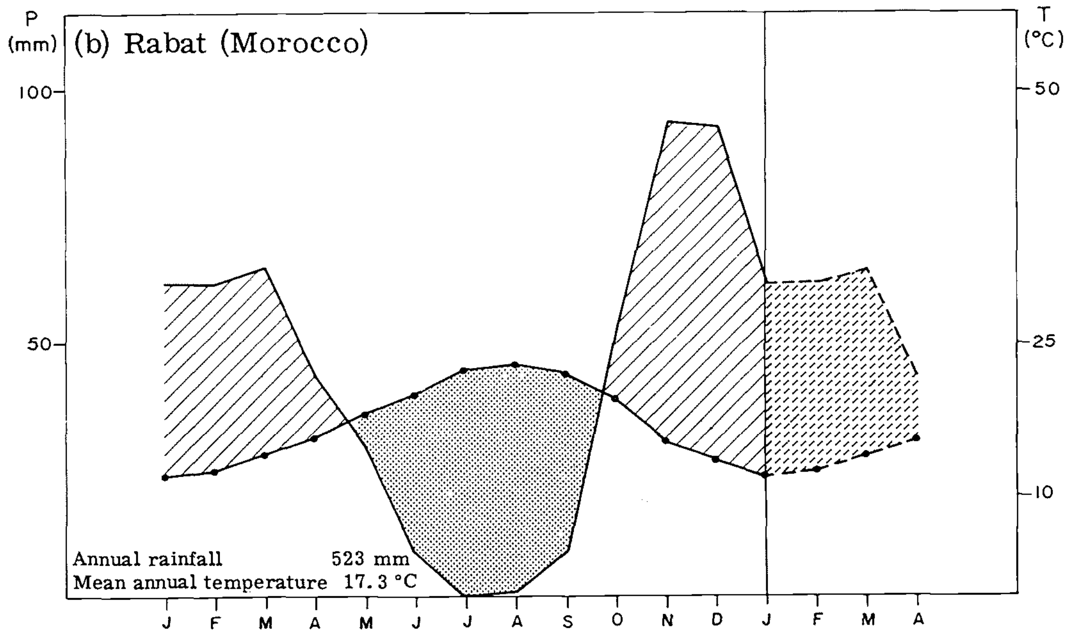


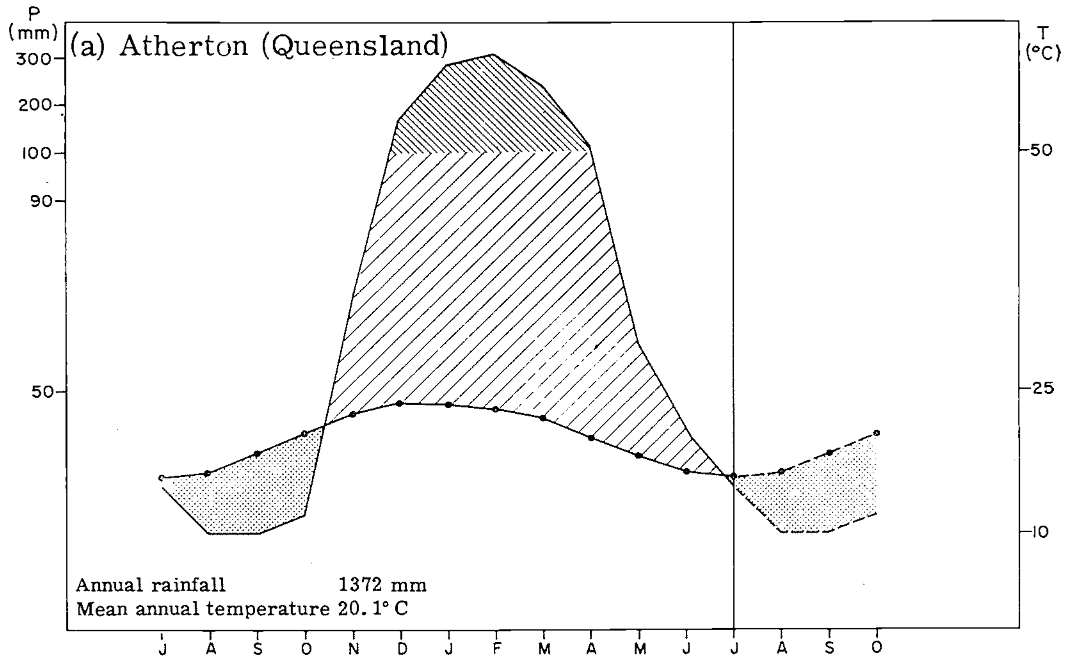
P
(mm)
(a) Hythe (Tasmania)
100
50
T
(°C)
50
25
10
Annual rainfall 998 mm
Mean annual temperature 11.1 °C
J A S O N D J F M A M J J A S O



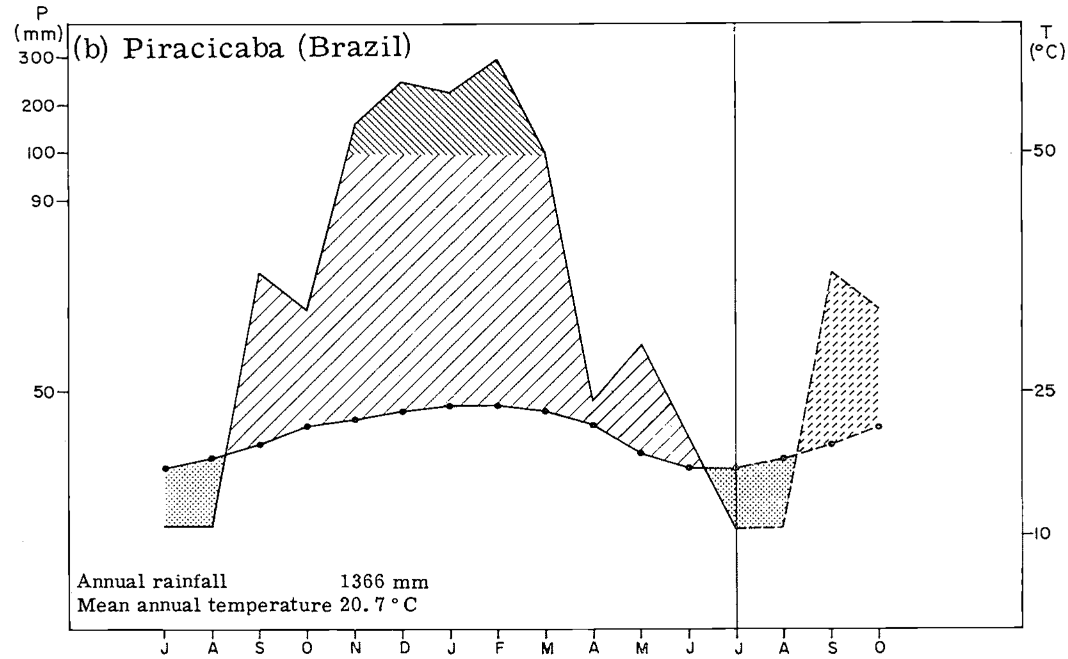
P
(mm)
(b) Santander (Spain)
150
100
90
50
T
(°C)
50
25
10
Annual rainfall 1202 mm
Mean annual temperature 14.0 °C
J F M A M J J A S O N D J F M A


P (mm)
(a) Narrogin (Western Australia)
T (°C)
100
50
50
25
10
Annual rainfall 541 mm
Mean annual temperature 15.7 °C
J M S O N D J F M A M J J A S O


P (mm)
(b) Rabat (Morocco)
T (°C)
100
50
50
25
10
Annual rainfall 523 mm
Mean annual temperature 17.3 °C
J F M A M J J A S O N D J F M A



P (mm)
300
200
100
90
50
T (°C)
50
25
10
(a) Atherton (Queensland)
Annual rainfall 1372 mm
Mean annual temperature 20.1° C
J A S O N D J F M A M J J A S O



P (mm)
300
200
100
90
50
T (°C)
50
25
10
(b) Piracicaba (Brazil)
Annual rainfall 1366 mm
Mean annual temperature 20.7 °C
J A S O N D J F M A M J J A S O

Glossary

ABSCISSION — The organized shedding of a part of a plant by means of an absciss layer.
ADNATION — Attachment of one organ to another by its whole length; sometimes used as equivalent to adhesion.
AEOLIAN DEPOSITS — Rocks or sediments which have accumulated in a non-marine environment (typically on a desert surface) and consist of essentially windblown sand or dust grains.
AMPLEXICAUL — Said of a sessile leaf with its base clasping the stem horizontally.
ANASTOMOSIS — Communication by cross-connections to form a network.
ANTHESIS — The opening of a flower bud; by extension, the duration of life of any one flower, from the opening of the bud to the setting of fruit.
ANTHRACNOSE — A fungus disease of plants caused by members of the Melanconiales and characterized by dark or black limited stem lesions.
APICULATE — Ending in a short sharp point.
ASCOMYCETE — One of the main groups of fungi, including some 15 000 species. The principal spores are ascospores.
AURICLE — Small ear-shaped lobe at the base of a leaf or other organ.

BACK-CUTTING — See BACK-SAWN.
BACK-SAWN — Of timber converted so that the growth layers meet the face of any part at an angle $< 45^{o}$, i.e., with the wider face tangential to a radius (*cf.* 'quarter-sawn').
BASIDIOMYCETE — Major class of fungi, with about 4 000 species, worldwide in distribution. The principal spores are basidiospores.
BEDDING — Technique used in areas with a high water-table to improve drainage and microsite environment. By means of a disc bedding-harrow the surface soil, litter and vegetative debris is concentrated into raised beds 15-30 cm high and about 1.2 m wide at the base.
BEATING UP — See BLANK-FILLING.
BIRRETA — Operculum shaped like the square official cap (*berretta*) worn by some ecclesiastics.
BLANKING — See BLANK-FILLING.
BLANK-FILLING — Restocking failed areas in a crop or stand by further sowings or plantings.
BRACT — Leaf which subtends an inflorescence or a flower.
BUNCHING — To skid or otherwise assemble logs together to form a load for subsequent haulage by other equipment.

CALCICOLE — Plant or tree which flourishes on soils or rocks rich in calcium carbonate.
CALCIMORPHIC — Said of a soil developed on a calcium-rich parent material, e.g., Rendzina soils developed on chalk.
CALYX — Outer whorl of the flower, consisting of sepals. It is usually green and protects the unopened bud.
CAMPANULATE — Bell-shaped.
CATENA — A sequence of soils showing variations in type due to differences in topography or drainage,

although derived from uniform or similar parent material.
Chlamydospore — A thick-walled fungal spore, capable of a resting period and often formed inside a hypha.
Clone — A group of genetically identical plants derived asexually from a single individual.
Commissure — Cleft or suture; plane of coherence of two carpels (family Umbelliferae).
Conidium — Asexually formed spore, produced by many species of fungi.
Connation — Union of parts of a plant as growth proceeds; applied especially to the union of like parts.
Cordate — Heart-shaped; said of a leaf base which has the form of the indented end of a conventional heart.
Coriaceous — Of or like leather.
Cortex — Primary ground tissue of a stem or root.
Crenulate — Having small rounded teeth on the margin.
Cultivar, primitive — See Landrace.
Cuneiform — Wedge-shaped; attached to something by its point.
Cupping — Distortion, due to seasoning, whereby the face of a sawnboard becomes concave or convex across the grain.
Cyme — Inflorescence in which the main axis ends in a flower, and in which subsequent flowers are produced at the ends of lateral axes or of successive branches of these.

Decussate — Having leaves in pairs, each pair being at right angles to those above and below.
Dehisce — To open spontaneously at maturity (fruit, anther, sporangium or other reproductive body).
Deltoid — Having the form of an equilateral triangle.
Dichasium — Cymose inflorescence in which each branch has two lateral branches of about the same strength of development.

Ecotype — Race adapted to the selective action of a particular environment.
Equilibrium moisture content (emc) — Moisture content at which a material (e.g., fuel, timber) neither gains nor loses moisture upon exposure to any constant condition of humidity and temperature.
Eutrophic — Of habitats, particularly soils and water, that are rich or adequate in nutrients.

Falcate — Sickle-shaped.
Ferralitic — Red, weathered soils occurring in the humid and wet tropics; highly permeable, heavily leached of bases and silica, consisting mainly of hydrated oxides of iron and aluminium.
Ferrisol — Tropical "red earth" with properties intermediate between ferruginous and ferralitic soils.
Ferruginous — Soil group of the tropics with marked seasonality of rainfall. It is characterized by high content of iron compounds, particularly oxides, which may result in the formation of an iron crust. Permeable but greatly vulnerable to erosion.
Fibril — Threadlike component of cell walls, visible under optical microscope.
Filament — The stalk of a stamen.
Filling-in — See Blank-filling.
Fissile — Cleavable, tending to split.

Gene — Basic unit of heredity, normally associated with a fixed position (locus) on a chromosome; transmitted in the gametes from parent to offspring; governs transmission and development of a hereditary character.
Genetic gain — Improvement in the mean genotypic value of a selected character, obtained by breeding.
Genotype — Hereditary constitution of an individual, with or without phenotypic expression of the one or more characters it underlies; interacts with the environment to produce the phenotype; also, individual(s) characterized by a certain genetic constitution.
Glaucous — Having a dull greenish grey waxy or powdery bloom.
Gummosis — A pathological condition in which cell walls are converted into gum.

HALF-SIBS — Offspring having one parent in common.
HANG-UP — A tree caught or snagged as it falls in the crown or branches of a standing tree.
HARDEN OFF — Preparation of seedlings or rooted cuttings in a nursery for transplanting or planting out by, e.g., gradually reducing watering and/or shade and/or shelter, thereby inducing changes in the leading shoot that render it more resistant to desiccation, cold, etc.
HERITABILITY — Degree to which a character is influenced by heredity as compared to environment. High heritability indicates that individual phenotypes are indicative of their genotypes.
HISTOSOL — One of the major orders into which soils may be classified; typically a soil with 30 percent organic matter to a depth of 40 cm.
HOMOCLIMES — Places having similar climates.
HYDROMORPHIC — Referring to a soil that has developed in the presence of water sufficient to create anaerobic conditions in the soil.
HYGROPHYTE — Plant more or less restricted to moist sites.
HYGROSCOPIC — Absorbing moisture from the air and showing a change of form as a result.
HYPANTHIUM — Flat or concave receptacle of a perigynous flower.
HYPHA — Simple or branched filament of the thallus (mycelium) of a fungus.

INCEPTISOL — Soil order in which materials other than carbonates or amorphous silica are removed from the pedogenic horizon.
INFLECTED — Bent or flexed.
INFLORESCENCE — Disposition of the flowers on the floral axis.
INTERLOCKED GRAIN — Form of spiral grain in which the deviation is reversed successively in the growth layers.
ISOENZYME — Multiple forms of a single enzyme. The assessment of presence or absence of isoenzymes can give an indication of genetic variability. Increasingly used in the assessment of intraspecific variation in tree species.

KAPPA NUMBER — Index of residual lignin in the pulp, measured as the amount of potassium permanganate consumed in reacting with a given amount of pulp. Kappa number decreases as delignification proceeds.
KRASNOZEM — Name given to tropical and subtropical red soils developed upon base-rich parent materials.

LAMINA — Blade or expanded part of a leaf.
LANCEOLATE — Narrow, tapering to one end, with base usually somewhat broadened; greatest breadth at about one third up from the base.
LANDRACE — Primitive cultivar which represents an early stage in cultivation subsequent to its original wild state.
LATERITE — Residual clay formed under tropical climatic conditions by the weathering of igneous rocks, usually of basic composition. Consists chiefly of hydroxides of iron and aluminium grading through increase of the latter into bauxite.
LATOSOL — Any reddish soil developed from weathering.
LEPIDOPTERA — Insect order characterized by having two pairs of large and nearly equal wings clothed in scales (e.g., moths and butterflies).
LITHOSOL — Group of shallow soils lacking well-defined horizons and composed of imperfectly weathered fragments of rock.
LOCULUS — Cavity of an ovary or anther.
LOESS — Aeolian clay, consisting of fine rock-flour (mainly quartz) originating in arid regions and transported by wind.
LUMEN — Space bounded by the walls of an organ, e.g., the central cavity of a cell.

MARL — Soil consisting of an indefinite mixture of calcareous clay or calcareous loam.
MATPACK — Timber used in mines for shoring up walls and providing solid foundations for machinery on soft ground.
MERISTEM — A group of localized

dividing, undifferentiated cells, found in regions of active growth, e.g., apical meristem.

MESOPHYTE — Plant occurring in places where the water supply is neither scanty nor excessive.

MINE PACK — Waste rock or timber supports for roof of underground workings or used to fill excavations.

MONOCHASIUM — Cymose inflorescence in which each successive branch bears one branch in its turn.

MYCELIUM — Vegetative portion of the thallus of Fungi, composed of hyphae.

MYCOPLASM — An assumed property of the protoplasm of parasitic fungi, i.e., of remaining latent in the seed of the host and reawakening to complete its cycle on the return of favourable conditions.

OBLIQUE — Slanting or of unequal sides.

OCHRACEOUS — Yellowish brown.

ONTOGENESIS — History of the development of an individual.

OOSPORE — Thick-walled spore, which normally germinates only after a period of inactivity.

OPERCULUM — Cover or lid which opens to allow the escape of spores from a sporangium or other container.

ORBICULAR — Said of a flat body with a circular outline.

ORTET — The original plant from which a clone has been derived.

OVATE — Egg-shaped; broader end basal.

OVEN-DRY — To dry wood to constant weight in a ventilated oven at a temperature above the boiling point of water, generally 103 ± 2°C.

PANICLE — Branched raceme, each branch bearing a raceme of flowers; or, more generally, any branched inflorescence which is in any way complex.

PANMIXIS — Unrestricted, random mating.

PEAVEY — Logging tool. A stout wooden lever fitted into a metal socket and terminating in a steel spike, with a hinged steel hook at its upper end.

PEDICEL — Stalk of an individual flower of an inflorescence; or a small stalk.

PEDUNCLE — Stalk of a flower or inflorescence.

PELTATE — Of a leaf, more or less flattened and having the stalk attached to the middle of the lower surface.

PERIGYNOUS — Describing a flower in which the receptacle is developed into a flange or concave structure, on which the sepals, petals and stamens are borne. The receptacle remains distinct from the carpels.

PERIDERM — The layers (phelloderm, phellogen and phellem) that form the impermeable covering of older stems, roots and branches.

PETIOLE — Stalk of a leaf.

PHELLODERM — Cylinder of unthickened cells formed from a phellogen on the inner side.

PHELLOGEN — Cork cambium; layer of meristematic cells lying in the cortex of a stem or root forming phellem (cork) on its outer surface, and phelloderm on the inside.

PHENOLOGY — Study of periodical phenomena in plants, e.g., time of flowering in relation to climate.

PHENOTYPE — Observable characteristics of an organism produced by the interaction of genes and environment.

PILEUS — Cap of an agaric (mushrooms, toadstools), bearing the basidia on its lower surface.

PLINTHITE — Hard, illuviated horizon, formed at depth in a lateritic latosol.

PODZOL — Soil group characterized by mats of organic matter in the surface layer and thin horizons of organic minerals overlying grey, leached horizons and dark-brown illuvial horizons; found in temperate coniferous or mixed forests.

POLYHEDRON — Solid rectilineal figure.

PROPAGULE — Plant part, such as a bud, tuber, root or shoot, used to propagate an individual vegetatively.

PROTANDRY — Ripening of anthers before the stigma of the same flower is receptive.

PULVERULENT — Consisting of dust or fine powder.
PYCNIDIUM — Fertile layer of an Ascomycete when it lies in a cup- or flask-shaped cavity that is open from the beginning.
PYRIFORM — Pear-shaped.

QUARTER-SAWN — Boards cut radially.

RACEME — Definite inflorescence, with the main axis bearing stalked flowers which are borne in acropetal succession, i.e., produced in succession from the base upward, so that the oldest members are at the base, and the youngest at the top.
RAMET — (= propagule) — An individual member of a clone, descended from the ortet.
REFILLING — See 'blank-filling'.
REFRACTORY — Said of timber difficult to work or treat.
REGOSOL — One of an azonal group of soils that form deep unconsolidated deposits and have no definite genetic horizons.
RENDZINA — A humus-carbonate soil with the form generally determined by the parent material which is always calcareous. There is no B-horizon, the humus-containing A-horizon rests directly on the calcareous parent rock.
RENIFORM — Kidney-shaped, either solid or flat.
RHIZOMORPH — A compact strand of fungal hyphae. It elongates by apical growth transporting food material from one part of the thallus to another. It also helps in the spread of the fungus over or through the substratum.
RHYTIDOME — A tissue cut-off outside a periderm. The cells die leaving a crust made up of alternate layers of cork and dead phloem or cortex.
ROGUE — Variant from the standard type of variety. Verb: to remove such (inferior) variants and plants infected by disease etc. from a crop; to cull.
ROSTRATE — Ending in a long and usually hard point.
SCHIST — Name given to a group of medium or coarse-grained metamorphic rocks which have a tendency to split on account of the presence of folia of flaky and elongated materials such as mica, talc and chlorite. Formed from original sedimentary or igneous rocks by action of combined heat and pressure.
SCLERENCHYMA — A tissue composed of cells with thick lignified walls and with little or no living contents, e.g., fibres.
SCLEROPHYLL — A hard, stiff leaf which is heavily cutinized.
SCLEROPHYLLOUS VEGETATION — Woody plants with hard, tough, and generally small leaves. It is characteristic of dry places.
SCLEROTIUM — A compact mass of fungal hyphae often with a thickened rind. It varies in size from a pinhead to a man's head. They are organs of perennation, and may give rise to fruit bodies.
SESSILE — Lacking a stalk.
SHAKE — A cleavage, or split, in wood; a separation between adjacent layers of fibres.
SLABBED — Describing a log that has been squared; and wood that is cut tangentially to the growth rings.
SLASHING — Cutting back the less tough, competing vegetation in plantations; a form of cleaning.
SPLIT — Separation of the fibres of a piece of wood from face to face.
SPORANGIUM — Structure containing asexual spores.
SPOROPHORE — Of fungi, a general term for any structure producing and bearing spores.
STERE — A term, adopted from French usage, for a stack of cordwood $1 \times 1 \times 1$ m, i.e., 1 cubic metre stacked volume.
STIPE — Stalk of fruit-bodies of certain higher fungi.
STIPITATE — Having a stalk.
STRAIN (GENETIC) — Natural or artificial mating group, uniform in some particular; also, a variety of species with distinct morphological and/or physiological characters.
SUBCULTURE — Culture of bacteria or fungi prepared from a pre-existing culture.

SUBERIN — Complex mixture of fatty substances present in the cell walls of corky tissue making them waterproof and decay-resistant.
SUBEROSE — Having a corky texture.
SUBULATE — Awl-shaped, i.e., linear, delicate and tapering to a sharp point.
SURFACTANT (SURFACE-ACTIVE AGENT) — A soluble compound that reduces the surface tension of liquids, or reduces interfacial tension between two liquids or a liquid and a solid.
SYMBIONT — One of a symbiotic pair.

TAXON — Taxonomic group or entity.
TAXONOMY — Science of classifying living organisms.
TERRA ROSSA — A red soil, associated with limestone, and occurring in countries bordering the Mediterranean Sea.
TESSELLATED — Said of a surface marked in squarish areas like a pavement.
THALLUS — Plant body which is not differentiated into stem, leaf or root. Characteristic of the most primitive division of the plant kingdom the Thallophyta containing algae, fungi and lichens.
TOMENTOSE — Covered with a felt or cottony hairs; downy.
TOPOPHYSIS — Persistent growth and differentiation, without genetic change, of a plant cutting, depending on the tissue of source.
TURBINATE — Shaped like a top and attached at the point.

UMBEL — A raceme in which the axis has not elongated, so that the flower stalks arise at the same point. Thus the flowers are in a head with the oldest at the outside.
URCEOLATE — Urn-shaped.

VARIANCE — The average of the squares of the deviations of a number of observations of a quantity from their mean value, the quantity being termed a variate; the square of the Standard Deviation.
VERMICULITE — A group of hydrous silicates occurring as decomposition products of biotite mica. When slowly heated, they exfoliate and open into long worm-like threads, forming a very lightweight water-absorbent aggregate. They are used in seed planting and in building, as an insulating material.
VERTISOL — Soil order characterized by at least 30 percent clay; found in regions having pronounced dry seasons, causing deep, wide surface cracks.

SOURCES: *A dictionary of botany*, Constable, London, 1966; *Dictionary of geological terms*, Anchor Books, NY 1976; *Dictionary of science and technology*, W.R. Chambers, Edinburgh, 1974; *Dictionary of scientific and technical terms*, McGraw-Hill, NY, 1974; *Glossary of botanic terms*, Gerald Duckworth, London, 1953; *Glossary for forest tree improvement workers*, US Dept of Agriculture, Forest Service, 1972; *A glossary of wood*, Nema Press Ltd, London, 1948; *Environmental word list*, Swedish Univ. of Agricultural Sciences, 1979; *Methodology of conservation of forest genetic resources*, FAO, Rome, 1975; *World soils*, Cambridge Univ. Press, Cambridge, 1978; *Dictionary of biological terms*, Oliver & Boyd, Edinburgh, 1963; *Dictionary of the natural environment*, John Wiley & Sons, NY, 1976.

Indexes

Latin names

Note: in the following INDEXES, "App." = Appendix; "Cp" = Colour plate.

Subjects

Bibliography

ACOSTA SOLIS, M. *El eucalipto en el Ecuador.* Quito, Departamento Forestal.
1949

AGRICULTURAL EXTENSION (TRIPOLI). *Sand dunes.* Tripoli, Ministry of Agriculture
1973 and Agrarian Reform. Stabilization and Afforestation Bulletin No. 33.

AHMED EL HOURI, AHMED. *The silviculture and management of* Eucalyptus microtheca
1977 *in irrigated plantations in the Gezira of the Sudan.* Soba, Forest Research Institute. Bulletin No. 3.

ALEXANDER, J.A. Management of white stringybark forests (*Eucalyptus eugenioides*)
1954 for pulpwood production. *Australian Forestry,* 18(2): 74-85.

ALLAN, T.G. & ENDEAN, F. *Handbook of plantation techniques.* Zambia, Forest
1966 Department.

AMOS, G.L. & STEWART, C.M. Note on the turgidity of differentiating wood elements
1948 in *E. regnans* (F.v.M.). *Australian Journal of Science,* 10, April 1948.

AMOS, G.L., BISSET, I.J.W. & DADSWELL, H.E. Wood structure in relation to growth
1950 in *Eucalyptus delegatensis* Hook F. *Australian Journal of Scientific Research, Series* B, 3(4).

AMOUGOU, J.-F. *Peuplements forestiers artificiels au Cameroun.* Yaoundé, Direction des eaux et forêts et des chasses.

AUBRÉVILLE, A. Il n'y aura pas de guerre de l'*Eucalyptus* à Madagascar. *Bois et*
1953 *forêts des tropiques,* 30, juillet-août 1953.

AWE, J.O. & SHEPHERD, K.R. Provenance variation in frost resistance in *Eucalyptus*
1975 *camaldulensis* Dehn. *Australian Forestry,* 38(1).

ASHTON, D.H. Studies in flowering behaviour in *Eucalyptus regnans* F. Muell.
1975 *Australian Journal of Botany,* 23: 399-411.

BAKER, R.T. & SMITH, H.G. *A research on the eucalypts especially in regard to their*
1920 *essential oils.* Sydney, Government Printer.

BAKER, K.E. *The U.C. system for producing healthy container-grown plants.* Berkeley,
1957 University of California, College of Agriculture. Manual 23.

BAKSHI, B.K. Mycorrhiza in eucalypt in India. *Indian Forester,* 92: 19-20.
1966

BAKSHI, B.K. Quantification of forest disease losses. Report from Asia. *Proceedings*
1967 *of the 14th Congress of the International Union of Forest Research Organizations, Munich, 1967,* 5: 361-372.

BAKSHI, B.K., RAM REDDY, M.A., SINGH, S. & PANDEY, P.C. Disease situation in
1970 Indian forests. I. Stem disease of some exotics due to *Corticium salmonicolor* and *Monochaetia unicornis.* *Indian Forester,* 96: 826-829.

BAKSHI, B.K., RAM REDDY, M.A., PURI, Y.N. & SINGH, S. *Forest Disease Survey*
1972 *(Final Technical Report) (1967-1972).* Dehra Dun, Forest Pathology Branch, Forest Research Institute. 117 p.

BALAIDI, A.S. Eucalyptus *in People's Democratic Republic of Yemen.* (Note)
1977

BALL, J.B. Plastic containers and coiling roots. *Unasylva,* 28(111): 27.
1976

BALL, J.B. Personal communication.
1977

BANKS, P.F. Observations of the June, 1968 frosts and their effect on the plantations
1969 and trial plots of exotic trees in Rhodesia. *Rhodesia Science News,* 3(4): 108-113.

BARBER, H.N. Adaptive gene substitutions in Tasmanian eucalypts. Part I. Genes
1955 controlling the development of glaucousness. *Evolution,* 9: 1-14.

BARBER, H.N. Selection in natural populations. *Heredity,* 20: 551-572.
1965

BARBER, H.N. & JACKSON, W.D. Natural selection in action in *Eucalyptus. Nature,*
1957 *Lond.,* 179: 1267-1269.

BARNARD, R.C. *Eucalyptus robusta* Sm. planting trials. *Malaysian Forester,* 14(1).
1951

BARNARD, R.C. An introduction to some garden eucalypts. *Journal of the Royal*
1966 *Horticultural Society,* 91, Parts 5-7.

BARRETT, A.O. & GREEN, H. The seasonal sap flow of *Eucalyptus botryoides.*
1931 *Proceedings of the Royal Society of Victoria,* 43: 241-250.

BARRETT, R.L. *Forest nursery practice for the wattle regions in the Republic of South*
1978 *Africa.* Pietermaritzburg, Wattle Research Institute.

BARRETT, R.L. & MULLIN, L.J. A review of introductions of forest trees in Rhodesia.
1968 *Rhodesian Bulletin of Forestry Research,* No. 1: 227.

BARRETT, R.L. & CARTER, D.T. *Eucalyptus camaldulensis* provenance trials in Rhodesia.
1970 Part I. Early results. *Rhodesian Bulletin of Forestry Research,* No. 2 (Part 1): 50.

BARRETT, R.L. & WOODVINE, F. Possibilities for irrigated forestry in the Rhodesian
1971 lowveld. *Rhodesian Bulletin of Forestry Research,* No. 1: 50.

BARRETT, R.L., CARTER, D.T. & SEWARD, B.R.T. Eucalyptus grandis *in Rhodesia.*
1975 Salisbury, Rhodesia Forestry Commission. Rhodesian Bulletin of Forestry Research, No. 6.

BARRINGTON, C.A. *Forestry in the Weald.* London, Forestry Commission. Booklet
1968 No. 22.

BATISTA, A.C. *Cylindrocladium scoparium* Morgan var. *brasiliensis* Batista and Ciferri.
1951 Um nuovo fungo do eucalypto. *Boletim da Secretaria de Agricultura, Industria e Comercio, Pernambuco,* 18: 188-191.

BAZÁN DE SEGURA, C. *Enfermedades del eucalipto en el Perú.* Lima, Instituto de
1967 Investigaciones Forestales. Boletín No. 10. 10 p.

BEARD, J.S. A search for cold-resistant species of eucalypt in Australia suitable for
1958 planting in the eastern Transvaal. *Journal of the South African Forestry Association,* No. 32.

BEDNALL, B.H. An application of crown ratio to jarrah stocking. *Australian Forestry,*
1938 3(1): 41-43.

BÉGIN, L. Les eucalyptus au sud du Sahara. *Bois et forêts des tropiques*, No. 91,
1963 septembre-octobre 1963.

BENJAMIN, L.R. *Newsprint: preliminary experiments on the grinding of immature*
1927 *eucalypts for mechanical pulp*. Melbourne, Commonwealth Scientific and Industrial Research Organization. Bulletin 31.

BENJAMIN, L.R. & SOMERVILLE, J. L. *Paper pulp and cellulose from the eucalypts by*
1928 *the sulphite process*. Melbourne, Commonwealth Scientific and Industrial Research Organization. Bulletin 37.

BENTHAM, G. *Flora australiensis*. London, Lovell, Reeve & Co.
1864

BENTHAM, G. *Flora australiensis*. Vol. 1. London, Reeve.
1867

BESKOK, T.E. *Report to the Government of the Yemen Arab Republic on afforestation*
1974 *and quick-growing tree species*. Rome, FAO.

BEUHNE, F.R. *The honey flora of Victoria*. 2nd ed. rev. Melbourne, Government
1925 Printer.

BLACK, J.M. *Flora of South Australia*. 2nd ed. Part 3: 623. Adelaide.
1952

BLAKE, S.T. Studies on northern Australian species of eucalypts. *Australian Journal*
1953 *of Botany*, 1(2): 185-352.

BLAKELY, W.F. *A key to the eucalypts*. Sydney, The Workers Trustees. (Reprint,
1934 Commonwealth Forestry and Timber Bureau, Canberra, 1955)

BOAS, J.H. *The commercial timbers of Australia, their properties and uses*. Melbourne,
1947 Government Printer.

BODEN, P.W., HIGGS, A.L. & SETCHELL, P.J. Raising large eucalypt seedlings in
1969 containers. *Australian Forest Research*, 4(1): 21-28.

BOERBOOM, J.H.A. & MAAS, P.W.TH. Canker of *Eucalyptus grandis* and *E. saligna* in
1970 Surinam caused by *Endothia havanensis*. *Dasonomia Interamericana*, 20(1), March 1970.

BOLAND, D.J. Variation patterns and breeding systems in eucalypts. In *Selected*
1977 *reference papers, International Training Course in Forest Tree Breeding*, p. 163-173. Canberra, Australian Development Assistance Agency.

BOLAND, D.J. & MORAN, G.F.J. Provenance collections of *Eucalyptus delegatensis*
1979 R.T.Bak. seed in 1977-78. In *Forest Genetic Resources Information*, No. 9. Rome, FAO.

BOLAND, D.J., BROOKER, M.I.H. & TURNBULL, J.W. Eucalyptus *seed manual*. Canberra, CSIRO, Division of Forest Research. (In press)

BOLZA, E. & KEATING, W.G. *African timbers. The properties, uses and characteristics*
1972 *of 700 species*. Melbourne, CSIRO, Division of Building Research.

BOOMSMA, C.D. The red gum (*E. camaldulensis* Dehn.) association of Australia.
1950 *Australian Forestry*, 14(2), 99-110.

BOROTA, J. *The* Eucalyptus *at Lushoto arboretum*. Tanzania Silviculture Research
1969 Note No. 12.

BOYD, J.D. Tree growth stresses. Part I. Growth stress evaluation. *Australian*
1950a *Journal of Scientific Research, Series B*, 3(3): 270-293.

BOYD, J.D. Tree growth stresses. Part II. The development of shakes and other
1950b visual failures in timber. *Australian Journal of Applied Science*, 1(3): 296-312.

BOYD, J.D. Tree growth stresses. Part III. The origin of growth stresses. *Australian*
1950c *Journal of Scientific Research, Series B*, 3(3), 294-309.

BOYD, J.D. Tree growth stresses. Part V. Evidence of origin in differentiation and
1972 lignification. *Wood Science and Technology*, 6(4): 251-262.

BOYD, J.D. Compression wood force generation and functional mechanics. *New*
1973a *Zealand Journal of Forestry Science*, 3(3): 240-258.

BOYD, J.D. Helical fissures in compression wood cells: causative factors and mechanics
1973b of development. *Wood Science and Technology*, 7(2): 92-111.

BOYD, J.D. & SCHUSTER, K.B. Tree growth stresses. Part IV. Visco-elastic strain
1972 recovery. *Wood Science and Technology*, 6(2): 95-120.

BREITENBACH, F. VON. *Exotic forest trees in Ethiopia.* Addis Ababa, Ethiopian Forestry
1961 Association. Ethiopian Forestry Review, No. 2.

BRETT, R.G. A survey of eucalypt species in Tasmania. *Proceedings of the Royal*
1937 *Society of Tasmania*, 1937: 75-109.

BROCKWAY, G.E. Forest of the arid goldfields region of Western Australia. *Empire*
1941 *Forestry Journal*, 20(1).

BROOKER, M.I.H. Phyllotaxis in *Eucalyptus socialis* F. Muell. and *E. oleosa* F. Muell.
1968 *Australian Journal of Botany*, 16: 455-468.

BROUARD, N.R. *Damage by tropical cyclones to forest plantations, with special reference*
1967 *to Mauritius.* Mauritius, Government Printer.

BROWN, A.G. Planning a tree improvement programme. In *Selected Reference*
1977 *Papers. International Training Course in Forest Tree Breeding*, p. 133-146.
Canberra, Australian Development Assistance Agency.

BROWN, A.G. & HALL, N. *Growing trees on Australian farms.* Canberra, Government
1968 Printer.

BROWN, A.G., ELDRIDGE, K.G. & GREEN, J.W. *Genetic variation of* Eucalyptus
1972 obliqua *in field trials.* Document, Appita 26th General Conference, Hobart,
Tasmania, March 1972.

BROWN, A.G., ELDRIDGE, K.G., GREEN, J.W. & MATHESON, A.C. Genetic variation of
1976 *Eucalyptus obliqua* in field trials. *New Phytologist*, 77: 191-201.

BROWN, A.H.D., MATHESON, A.C. & ELDRIDGE, K.G. Estimation of the mating system
1975 of *Eucalyptus obliqua* l'Hérit. by using allozyme polymorphism. *Australian*
Journal of Botany, 23: 931-934.

BROWNE, F.G. *Pests and diseases of forest plantation trees.* Oxford, Clarendon
1968 Press.

BRUNCK, F. Personal communication.
1978

BUNN, E.H. & VAN DROSSER, J.C. *Eucalypt nursery practice.* (Mimeographed)
1965

BUNN, E.H. & VAN DROSSER, J.C. *Eucalypt nursery practice.* (Mimeographed)
1969

BURBRIDGE, N.T. Key to the Australian species of *Eucalyptus. Transactions of the*
1947 *Royal Society of South Australia*, 71(2).

BURDON, R.D., SHELBOURNE, C.J.A. & WILCOX, M.D. Advanced selection strategies. *In*
1978 Third World Consultation on Forest Tree Breeding, Canberra. *Documents:*
Canberra, Government Printers. (FO-FTB-77-6/2)

BURGESS, I.P. Breeding programme for *Eucalyptus grandis.* In *Tropical provenance*
1973a *and progeny research and international cooperation*, ed. by J. Burley and
D.G. Nikles. Oxford, Commonwealth Forestry Institute.

BURGESS, I.P. Provenance trial of *Eucalyptus pilularis* in northern New South
1973b Wales at seven years. In *Tropical provenance and progeny research and international cooperation*, ed. by J. Burley and D.G. Nikles. Oxford. Commonwealth Forestry Institute.

BURGESS, I.P. Vegetative propagation of *Eucalyptus grandis*. *New Zealand Journal*
1974 *of Forestry Science*, 4(2): 181-184.

BURLEY, J. & NIKLES, D.G., eds. *Tropical provenance and progeny research and*
1973 *international cooperation. Proceedings of a Joint Meeting on Tropical Provenance and Progeny Research and International Cooperation, Nairobi, Kenya, 22-26 October 1973.* Oxford, Commonwealth Forestry Institute.

BURLEY, J. & WOOD, P.J. *A manual on species and provenance research with particular*
1976 *reference to the tropics.* Oxford, Commonwealth Forestry Institute. Tropical Forestry Papers No. 10.

BURROWS, P.M. *The whole crop concept for coppicing species such as some* Eucalyptus.
1969 Document, Second World Consultation on Forest Tree Breeding, Washington, D.C., 1969. (FO-FTB-69-7/2)

CAMBAGE, R.H. The development and distribution of the genus *Eucalyptus*. *Pro-*
1913 *ceedings of the Royal Society of New South Wales*, 1913: 18-58.

CAMERON, J. *Personal communication.* Quoted in Doran, J.C., 1977.
1977

CAMPINHOS, E. & IKEMORI, Y.K. Tree improvement program of *Eucalyptus* spp.
1978 — preliminary results. *In* Third World Consultation on Forest Tree Breeding, Canberra. *Documents.* Canberra, Government Printer. (FO-FTB-77-3/22)

CANTIANI, M. I cedui di eucalitto (*E. camaldulensis* ed *E. globulus*) nella Sicilia
1976 centrale. *Italia Forestale e Montana*, 31(2).

CARRIBBEAN FORESTER. *Eucalyptus* experience summarized. January-April 1953, p. 17-20.
1953

CARITA FRADE, E. Plantaçaos de Eucalyptos da Companhia do Caminho de Ferro de
1963 Benguela. *Jornadas Silvo-Agronómicas*, 2: 87.

CARLSON, K.A. *Growing of mine props on the High Veld.* Pretoria, South African
1920 Forests Department. Bulletin No. 1.

CARNE, P.B., GREAVES, R.T.G. & MCINNES, R.S. Insect damage to plantation-grown
1974 eucalypts in north coastal New South Wales with particular reference to Christmas beetles (*Coleoptera scarabaeidaea*). *Journal of the Australian Entomological Society*, 13: 189-206.

CARR, D.J. & CARR, STELLA G.M. Floral morphology and taxonomy of *Eucalyptus*.
1959 *Nature, Lond.*, 184: 1549-1552.

CARR, D.J. & CARR, STELLA G.M. Natural groups within the genus *Eucalyptus*. In
1962 *The evolution of living organisms.* Melbourne, Royal Society of Victoria.

CARR, STELLA G.M. & CARR, D.J. Convergence and progression in *Eucalyptus* and
1962 *Symphyomyrtus*. *Nature, Lond.*, 196: 969-972.

CARR, STELLA G.M. & CARR, D.J. The taxonomic position of certain eucalypts.
1963 *Proceedings of the Royal Society of Australia*, 77: 207-216.

CARR, STELLA G.M. & CARR, D.J. Operculum development and the taxonomy of
1968 eucalypts. *Nature, Lond.*, 219: 513-515.

CARR, STELLA G.M. & CARR, D.J. Oil glands and ducts in *Eucalyptus* L'Hérit. I.
1969 The phloem and the pith. *Australian Journal of Botany*, 17: 471-513.

CARRON, L.T. Measurement of stacked firewood. *Australian Forestry*, 17(2): 43-48.
1953

CARTER, C.E. Lignotubers. *Australian Forestry Journal*, 12(4): 119-122.
1929

CARTER, C.E. *The distribution of the more important timber trees of the genus*
1945 Eucalyptus. *Atlas No. 1.* Canberra, Forestry and Timber Bureau.

CARTER, W.G. Growing and harvesting eucalypts on short rotations for pulping.
1974 *Australian Forestry*, 36(3).

CARTWRIGHT, K. ST G. & FINDLAY, W.P.K. *Decay of timber and its prevention.*
1958 London, HMSO.

CATERPILLAR TRACTOR COMPANY. *Land clearing.* Peoria, Ill.
1970

CATERPILLAR TRACTOR COMPANY. *The clearing of land for development.* Peoria, Ill.
1974

CAVALCASELLE, B. Il tarlo dell'eucalitto (*Phoracantha semipunctata* Fabr.): biologia
1971 e mezzi di lotta. *Cellulosa e Carta*, No. 4.

CHAMPION, H.G. & PANT, B.D. The use of stumps in artificial regeneration. *Indian*
1932 *Forest Records*, 16 (vi).

CHAMPION, H. & BRASNETT, N.V. *Choice of tree species for planting. See* FAO,
1958 1958.

CHANDLER, W.G. Thinning responses in mallet (*Eucalyptus astringens*). *Australian*
1936 *Forestry*, 1(2): 43-48.

CHAPERON, H. Amélioration génétique des *Eucalyptus* hybrides au Congo-Brazzaville.
1978a *In* Third World Consultation on Forest Tree Breeding, Canberra. *Documents.* (FO-FTD-77-4/27)

CHAPERON, H. Particularités de l'amélioration génétique des *Eucalyptus* au Congo-
1978b Brazzaville. *In* Third World Consultation on Forest Tree Breeding, Canberra. *Documents.* Canberra, Government Printer. (FO-FTB-77-3/8)

CHAPERON, H. & QUILLET, G. Résultats des travaux sur le bouturage des *Eucalyptus*
1978 au Congo-Brazzaville. *In* Third World Consultation on Forest Tree Breeding, Canberra. *Documents.* (FO-FTB-77-4/9)

CHAPMAN, G.W. & ALLAN, T.G. *Establishment techniques for forest plantations.*
1979 Rome, FAO. FAO Forestry Paper No. 8.

CHARARAS, C. Biologie et écologie de *Phoracantha semipunctata* F., ravageur des
1969 *Eucalyptus* en Tunisie, et méthodes de protection des peuplements. *Annales de l'Institut national de Recherches forestières de Tunisie*, 2, Fasc. 3.

CHARARAS, C. *Rélations entre la pression osmotique des* Eucalyptus *et leur adaptation*
1971 *en Tunisie.* Rome, FAO. FO: SF/TUN 11 Rap. tec. 6.

CHATTAWAY, M.M. The sapwood-heartwood transition. *Australian Forestry*, 16(1):
1952 25-34.

CHATTAWAY, M.M. The anatomy of bark. Part I. The genus *Eucalyptus. Australian*
1953 *Journal of Botany*, 1(3): 402-433.

CHATTAWAY, M.M. The anatomy of bark. Part II. Oil glands in *Eucalyptus* species.
1955a *Australian Journal of Botany*, 3: 21-27.

CHATTAWAY, M.M. The anatomy of bark. Part III. Enlarged fibres in the bloodwoods
1955b (*Eucalyptus* spp.). *Australian Journal of Botany*, 3: 28-38.

CHATTAWAY, M.M. The anatomy of bark. Part IV. Radially elongated cells in the
1955c phelloderm of species of *Eucalyptus. Australian Journal of Botany*, 3: 39-47.

CHATURVEDI, A.N. General standard volume tables for *Eucalyptus* hybrid. *Indian*
1973a *Forest Records*, 12(14).

CHATURVEDI, A.N. Rotation in *Eucalyptus* hybrid plantations. *Indian Forester,*
1973b April 1973.

CHATURVEDI, A.N. *Eucalyptus* in India. *Indian Forester,* January 1976.
1976

CHATURVEDI, A.N. & PANDE, G.C. General volume tables for *Eucalyptus grandis.*
1973 *Indian Forest Records (New Series), Silviculture,* 12(17).

CHILVERS, G.A. Some distinctive types of eucalypt mycorrhiza. *Australian Journal*
1968 *of Botany,* 16: 49-70.

CHILVERS, G.A. & PRYOR, L.D. The structure of eucalypt mycorrhiza. *Australian*
1965 *Journal of Botany,* 13: 245-259.

CHIPPENDALE, G.M., ed. *Eucalyptus buds and fruits.* Canberra, Forestry and Timber
1968 Bureau. 96 p.

CHIPPENDALE, G.M. *Eucalypts of the Western Australian gold-fields (and the adjacent*
1973 *wheatbelt).* Canberra, Australian Government Publishing Service. 218 p.

CHIPPENDALE, G.M. *Eucalyptus* nomenclature. *Australian Forestry Research,* 7:
1976 69-107.

CHRISTENSEN, H.G. *Eucalyptus grandis* improvement programme, Zambia. In *Tropical*
1973 *provenance and progeny research and international cooperation,* ed. by J. Burley and D.G. Nikles. Oxford, Commonwealth Forestry Institute.

CIANCIO, O. Tavola cormometrica dell'*Eucalyptus camaldulensis* e dell'*Eucalyptus*
1966 *globulus* di Piazza Armerina. *Italia Forestale e Montana,* 21(4).

CIANCIO, O. Tavola cormometrica dell'*Eucalyptus camaldulensis* a Policoro. *Annali*
1970 *dell'Istituto Sperimentale Selvicoltura, Arezzo,* 1: 271-291.

CIANCIO, O. & HERMANIN, L. Tavole cormometriche a doppia entrata per *l'E.*
1974 *occidentalis* e *E.* × *trabutii* della Calabria. *Annali dell'Istituto Sperimentale Selvicoltura, Arezzo,* 5: 23-36.

CIANCIO, O. & HERMANIN, L. Gli eucalitteti della Calabria, tavole alsometriche
1976 dell'*Eucalyptus occidentalis* e dell'*E.* × *trabutii. Annali dell'Istituto Sperimentale Selvicoltura, Arezzo,* 7: 67-107.

CLARK, E.W. *Report of the consultant in forest entomology, Brazil.* Project
1973 DP/BRA/71/545. Working Document No. 7.

CLARKE, B. Establishment of eucalypt plantations. *Australian Forest Industries*
1975 *Journal,* 41(9): 45-51.

CLARKE, S.A. Seasoning eucalypts. *Timberman,* 30(3).
1929

CLIFFORD, H.T. A note on the germination of *Eucalyptus* seed. *Australian Forestry,*
1953 17(1): 17-20.

COHEN, W.E. Pulp and paper from Australian eucalypts. *Unasylva,* 2(6): 309-315.
1948

COKLEY, K.V. & SMITH, N.A.H. *Synopsis of experimental results in the formulation*
1965 *of the vacuum pressure diffusion process and the economic advantages accruing therefrom.* Queensland Forest Service Project QP 9-2-1. Report No. 6.

COLA ZANUNCIO, J. & GOMES DE LIMA, J.O. Ocorrencias de *Sarsina violascens*
1975 (Herrich-Schaeffer 1856) (Lepidoptera: Lymantriidae) em eucaliptos de Minas Gerais. *Brasil Florestal,* 6(23).

COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION. *Meteorological*
1933 *data for certain Australian localities.* Melbourne, Government Printer. Pamphlet No. 42.

COOLING, E.N. & JONES, B.E. The importance of boron and NPK fertilizers to
1970 *Eucalyptus* in the southern province, Zambia. *East African Agricultural and Forestry Journal*, 36(2).

COSTA, A. DA. Use of *Eucalyptus* (*E. globulus*) as raw material in the chemical pulp
1936 industry. *Paper Trade Journal*, 102(7).

CRESSWELL, R. & NITSCH, C. Organ culture of *Eucalyptus grandis* L. *Planta*, 125:
1975 87-90.

CROCKER, R.L. & WOOD, J.G. Some historical influences on the development of the
1947 South Australian vegetation communities and their bearing on concepts and classification in ecology. *Transactions of the Royal Society*, 71(1).

CROMER, R.N. Personal communication.
1978

CROMER, R.N., RAUPACH, M., CLARKE, A.R.P. & CAMERON, J.N. Eucalypt plantations
1975 in Australia. The potential for intensive production and utilization. *Appita*, 29(3).

DADSWELL, H.E. *Anatomy of the eucalypts*. Melbourne, Commonwealth Scientific
1952 and Industrial Research Organization.

DADSWELL, H.E. & BURNELL, M. *Methods for the identification of the coloured woods*
1932 *of the genus* Eucalyptus. Melbourne, Commonwealth Scientific and Industrial Research Organization. Bulletin No. 67.

DADSWELL, H.E. & ECKERSLEY, A.M. Card sorting method applied to the identification
1941 of the commercial timbers of the genus *Eucalyptus*. *Journal of the Commonwealth Scientific and Industrial Research Organization*, 14.

DADSWELL, H.E. & LANGLANDS, J. Brittle heart in Australian timbers: a preliminary
1934 study. *Journal of the Commonwealth Scientific and Industrial Research Organization*, 7(11).

DADSWELL, H.E., BURNELL, M. & ECKERSLEY, A.M. *Methods for the identification*
1933 *of the light coloured woods of the genus* Eucalyptus. Melbourne, Commonwealth Scientific and Industrial Research Organization. Bulletin No. 78.

D'ARAUJO E SILVA, A.G., GONCALVES, R.C., GALVAO, D.M., GONCALVES, A.J.L., GOMES, J., SILVA, M. do N. & DE SIMONI, L. *Quarto catálogo des insetos que vivem nas plantas do Brasil*. Rio de Janeiro, GB.

DAVIDSON, J. *Forest tree improvement in Papua New Guinea. II. Kamarere.*
1968 Document, Ninth Commonwealth Forestry Conference.

DAVIDSON, J. Grafting *Eucalyptus deglupta*. *New Zealand Journal of Forestry*
1974a *Science*, 4(2): 204-211.

DAVIDSON, J. Reproduction of *Eucalyptus deglupta* by cuttings. *New Zealand Journal*
1974b *of Forestry Science*, 4(2): 191-203.

DAVIDSON, J., ed. *Action Group on Tropical Eucalypts*. *Newsletters*, 1-7. Lae,
1975-76 Papua New Guinea, University of Technology.

DAVIDSON, J. Advances from international co-operation on tropical *Eucalyptus*. *In*
1978a Third World Consultation on Forest Tree Breeding, Canberra. *Documents*. (FO-FTB-77-2/26)

DAVIDSON, J. Breeding *Eucalyptus deglupta*. A case study. *In* Third World
1978b Consultation on Forest Tree Breeding, Canberra. *Documents*. (FO-FTB-77-6/6)

DAVIDSON, J. Exploration, collection, evaluation, conservation and utilisation of the
1978c gene resources of tropical *Eucalyptus deglupta* Bl. *In* Third World Consultation on Forest Tree Breeding, Canberra. *Documents*. (FO-FTB 77-1/7)

DAVIDSON, J. Problems of vegetative propagation of *Eucalyptus*. *In* Third World
1978d Consultation on Forest Tree Breeding, Canberra. *Documents.* (FO-FTB-77-4/10)

DEANE, H. & MAIDEN, J.H. *Observations on the* Eucalyptus *of New South Wales.*
1898 (Proceedings of the Linnean Society of New South Wales)

DE BOER, R. Personal communication. Quoted in Doran, J.C., 1977.
1977

DEGOS, G. Les plantations d'*Eucalyptus* en Corse. *Revue forestière française*, 14.
1962

DE LA LAMA GUTIERREZ, G. *Atlas del eucalipto.* 4 vols. Sevilla, INIA y ICONA.
1976-77

DE PINA MANIQUE & ALBUQUERQUE, J. *Carta ecológica do Portugal.* Lisboa, Direccão
1954 Geral des Serviços Agrícolas.

DESCH, H.E. *Timber, its structure and properties.* 5th ed. New York, St. Martin's
1973 Press.

DILLNER, B., LJUNGER, A., HERUD, O.A. & THUNE-LARSEN, E. The breeding of
1971 *Eucalyptus globulus* on the basis of wood density, chemical composition and growth rate. *Timber Bulletin for Europe*, 23, Suppl. 5.

DOMINGO, I.L. Personal communication.
1977

DORAN, J.C. Propagation and nursery techniques in eucalypts. In *Selected Reference*
1977 *Papers, International Training Course in Forest Tree Breeding*, p. 207-215. Canberra, Australian Development Assistance Agency.

DUFFIELD, J.W. *California experience with* Eucalyptus. California Forest and Range
1952 Experiment Station.

DURZAN, D.J. & CAMPBELL, R.A. Prospects for the introduction of traits in forest
1974 trees by cell and tissue culture. *New Zealand Journal of Forestry Science*, 4(2): 261-266.

ECUADOR. *Informe del Ecuador. In* Instituto Interamericano de Ciencias Agrícolas.
1973 Primera reunión del Grupo de Trabajo sobre Introducción de Especies Forestales. Serie: Informes de Conferencias, Cursos y Reuniones No. 25. Quito, Ministerio de Agricultura y Ganadería.

ELDRIDGE, K.G. Breeding system of *Eucalyptus regnans. Proceedings of IUFRO*
1970 *Section 22 Working Group meeting on Sexual Reproduction of Forest Trees, Varparanta, Finland.* Vol. 1.

ELDRIDGE, K.G. *Genetic variation in growth of* Eucalyptus regnans. Canberra,
1972 Forestry and Timber Bureau. Bulletin 46.

ELDRIDGE, K.G. *An annotated bibliography of genetic variation in* Eucalyptus
1975a camaldulensis. Oxford, Commonwealth Forestry Institute. Tropical Forestry Papers No. 8.

ELDRIDGE, K.G. *Eucalyptus* species. In *Seed orchards*, ed. by R. Faulkner, p. 134-139.
1975b London, Forestry Commission. Bulletin No. 54.

ELDRIDGE, K.G. Breeding systems, variation and genetic improvement of tropical
1976 eucalypts. In *Tropical trees: variation, breeding and conservation*, ed. by J. Burley and B.T. Styles. London, Academic Press. Linnean Society Symposium Series No. 2.

ELDRIDGE, K.G. Genetic improvement of eucalypts. *In* Third World Consultation
1978 on Forest Tree Breeding, Canberra. *Documents.* (FO-FTB-77-3/5)

EMBERGER. Une classification biogéographique des climats. *Recueil des travaux des*
1955 *Laboratoires de botanique, géologie et zoologie de la Faculté des sciences de l'Université de Montpellier, série botanique*, fasc. 7: 3-43.

Escuela Nacional de Agricultura, Chapingo. *Arboretum de Chapingo*. Chapingo,
1970 Escuela Nacional de Chapingo.

Eucalyptus and paper pulp. *Nature, Lond.*, No. 123.
1929

Ewart, A.J. Disarticulation of the branches in *Eucalyptus*. *Annals of Botany*, 49:
1935 507-512.

L'expérimentation de la culture de l'*Eucalyptus* en France. *Revue internationale du*
1953 *bois*, No. 177. (Also in *Le Chêne-liège*, No. 1461)

FAO. *Raw materials for more paper*. Rome. Forestry and Forest Products Study
1953 No. 6.

FAO. *Eucalypts for planting*, by A. Métro. Rome. FAO Forestry and Forest
1955 Products Studies No. 11.

FAO. *The choice of tree species for planting*, by H. Champion and N.V. Brasnett.
1958 Rome. FAO Forestry Development Papers No. 13.

FAO. FAO/IUFRO World Consultation on Forest Tree Breeding, Stockholm, 1963.
1964 *Unasylva*, 18 (73/74).

FAO. *Soil map of Europe*. Rome.
1966

FAO. FAO World Symposium on Man-made Forests and their Industrial Importance.
1967a *Unasylva*, 21 (86/87).

FAO. *Plantation forestry in Latin America: development and prospects*. Rome,
1967b Secretariat Note FO:LAFC-67/5, Tenth Session, Latin American Forestry Commission. 32 p.

FAO. *Forestry Research and Education Centre, the Sudan. Final report*. Rome.
1969 FAO/SF: 70/SUD 3.

FAO. Second World Consultation on Forest Tree Breeding, Washington, 1969.
1970 *Unasylva*, 24 (97/98).

FAO. *Crop water requirements*. Rome. Irrigation and Drainage Paper No. 24.
1974a

FAO. *An introduction to planning forestry development*. Rome. FAO/SWE/TF
1974b 118.

FAO. *Report on the FAO/DANIDA Training Course on Forest Tree Improvement,*
1974c *Limuru, Kenya, 24 September to 20 October 1973*. Rome. FAO/DEN/TF 12.

FAO. *Tree planting practices in African savannas*, by M.V. Laurie. Rome. FAO
1974d Forestry Development Paper No. 19.

FAO. Third World Consultation on Forest Tree Breeding. *Unasylva*, 30 (119-120).
1978a

FAO. *Report of the Study Tour on Forestry Support of Agriculture in China,*
1978b *August-September 1977*.

Faulkner, R., ed. *Seed orchards*. London, Forestry Commission. Bulletin 54.
1975

Fawcett, G.L. Departamento de Botánica y Fitopatología. Ex Memoria del año
1940 1940. *Revista Industrial y Agrícola de Tucumán*, 32: 41-45.

Feagan, W.F. & Redmond, J. *The planning of hydrology experiments for forested*
1955 *catchments in Australia*. Document presented to Section K, ANZAAS, Melbourne, 1955.

Fearnside, A. *Progress report on planting eucalypts and other species*. Australian
1975 Aid, Nepal Forestry Project. Technical Note 3/75.

FERGUSON, I.S. *The economics of plantation forestry in the savanna region.* Rome,
1973 FAO. Project Working Document, FO: DP/NIR/64/516.

FERREIRA, F.A. & ALFENAS, A.C. A enfermidade rosada do eucalipto causada por
1977 *Corticium salmonicolor* Berk. and Br. no Brasil. *Fitopatologia Brasileira,* 2: 109-115.

FERREIRA, F.A., REIS, M.S., ALFENAS, A.C. & HODGES, C.S. Avaliaçao da resistencia
1977 de *Eucalyptus* spp. ao cancro causado por *Diaporthe cubensis* Bruner. *Fitopatologia Brasileira,* 2: 225-241.

FIELDING, J.M. Eucalypt cuttings. *Wild Life,* 10(4).
1948

FIGUEIREDO, M.B. & CRUZ, B.P.M. Occurrence of *Cylindrocladium ilicicola* on
1963 *Eucalyptus* spp. in the State of São Paulo. *Arquivos do Instituto Biológico, São Paulo,* 30: 29-32.

FIGUEIREDO, M.B. & NAMEKATA, T. Constataçao de *Calonectria quinqueseptata* r. sp.
1967 forma perfecta de *Cylindrocladium quinqueseptatum* Boedijn and Reitsma sobre *Annona squamosa* L. and *Eucalyptus* spp. *Arquivos do Instituto Biológico, São Paulo,* 34: 91-96.

FISHWICK, R.W. *Report on the frost-resistance of some* Eucalyptus *provenances*
1976 *planted in southern Brazil.* (Mimeographed)

FLETCHER, J.J. & MUSSON, C.T. On certain shoot-bearing tumours of eucalypts and
1918 angophoras, and their modifying influence on the growth habit of the plants. *Proceedings of the Linnean Society of New South Wales,* 43: 191-233.

FODDAI, A. & MARRAS, F. A new virus disease of *Eucalyptus rostrata* Schleck. *Annali*
1963 *della Facoltà di Scienze Agrarie dell'Università di Sassari,* 11.

FOGGIE, A. *Report to the Government of Sudan on forestry and forest policy. The*
1967 *Gezira area.* Rome, FAO. FAO/UNDP (TA) Report 2411.

FORD-ROBERTSON, F.C., ed. *Terminology of forest science, technology practice and*
1971 *products.* Washington, D.C., Society of American Foresters.

FORWOOD. *Report of the Forestry and Wood-based Industries Development Confer-*
1975 *ence 1974.* Canberra, Australian Government Publishing Service.

FOSSARD, R.A. DE & BOURNE, R.A. Clonal propagation of *Eucalyptus* by nodal culture.
1978 *In* Third World Consultation on Forest Tree Breeding, Canberra. *Documents.* (FO-FTB-77.4/24)

FOSSARD, R.A. DE, NITSCH, C., CRESSWELL, R.J. & LEE, E.C.M. Tissue and organ
1974 culture of *Eucalyptus. New Zealand Journal of Forestry Science,* 4(2): 267-278.

FRANCLET, A. *Techniques de bouturage des* Eucalyptus camaldulensis. Tunis, Institut
1970 national de recherches forestières. Note technique No. 12.

FRANCLET, A. *Manipulation des pieds-mères et amélioration de la qualité des*
1977 *boutures.* Nangis, Association Forêt-Cellulose. Etudes et recherches No. 8-12/77.

FRANKLIN, E.C. & MESKIMEN, G.F. Genetic improvement of *Eucalyptus robusta* Sm.
1973 in southern Florida. In *Tropical provenance and progeny research and international cooperation,* ed. by J. Burley and D.G. Nikles. Oxford.

FREE, R.A. Germination and emergence of eucalypt seed when sown at depth.
1951 *Australian Forestry,* 15(2): 115-119.

GARDNER, C.A. Taxonomy and the species concept, with special reference to
1945 *Eucalyptus. Australian Forestry,* 9.

GARDNER, C.A. Trees of Western Australia, Nos. 35-38. *Journal of Agriculture,*
1959 *Western Australia,* Ser. 3, 8: 456-464.

Garnett, T.F.F. *The establishment and management of farm plantations for wood*
1973 *production.* Pretoria, Department of Forestry. Pamphlet No. 119.

Gauba, E. & Pryor, L.D. Seed coat anatomy and taxonomy in *Eucalyptus.*
1958 1. *Proceedings of the Linnean Society of New South Wales,* 83: 20-31.

Gauba, E. & Pryor, L.D. Seed coat anatomy and taxonomy in *Eucalyptus.*
1959 2. *Proceedings of the Linnean Society of New South Wales,* 84: 278-291.

Gauba, E. & Pryor, L.D. Seed coat anatomy and taxonomy in *Eucalyptus.*
1961 3. *Proceedings of the Linnean Society of New South Wales,* 86: 96-111.

Gaussen, H. Théories et classification des climats et microclimats. *Proceedings*
1954 *of the eighth International Botanical Congress, Paris,* p. 125-130.

Gentilli, J. *Climates of Australia and New Zealand. World survey of climatology.*
1971 Vol. 13. Amsterdam, Elsevier.

Gewald, N. *Eucalypts in Costa Rica.* (Mimeographed)
1977

Ghilardi, E. & Mainieri, C. Tratamento de moirões rolicos de *Eucalyptus saligna*
1961 pelo processo de banho quentefrio. *Report of the Second World Eucalyptus Conference, São Paulo,* Vol. 2: 1200-1217.

Gibson, I.A.S. Influence of disease factors on forest production in Africa. *Proceedings*
1967 *of 14th Congress of the International Union of Forest Research Organizations, Munich,* 1967, 5: 327-360.

Gibson, I.A.S. *Diseases of forest trees widely planted as exotics in the tropics and*
1975 *southern hemisphere.* Oxford, Commonwealth Forestry Institute.

Giordano, E. Gli eucalitti nel nord e nel sud della Spagna. *Cellulosa e Carta,*
1966 Novembre, p. 37-44.

Giordano, G. Forêts et bois de l'Ethiopie: forêts pluviales. (*E. globulus* in Addis
1948 Ababa). *Bois et forêts des tropiques,* 6.

Giordano, G. Le principali caratteristiche del legno di eucalipto dei rimboschimenti
1950 italiani. *Monti e Boschi,* No. 9.

Gittinger, J. *Economic analysis of agricultural projects.* Baltimore, Md, Johns
1972 Hopkins University Press for the International Bank for Reconstruction and Development.

Goes, E. *Os eucaliptos em Portugal.* Vol. 2. *Ecologia, cultura e produções.*
1962 Lisboa, Secretaria de Estado da Agricultura.

Goes, E. *Os eucaliptos.* (*Ecologia, cultura, produções e rentabilidade*). Lisboa.
1977

Golfari, L. & Pinaeiro Neto, F.A. Escolha de especies de Eucalipto potencialmente
1970 aptas para diferentes regiões do Brasil. *Brasil Forestal,* 1(3).

Golfari, L., Caser, R.L. & Moura, V.P.G. *Zoneamento ecológico esquemático para*
1978 *reflorestamento no Brasil.* Rome. PNUD/FAO/IBDF/BRA-45 Ser. Tec. No. 11.

Gottnied, D. & Thogo, S. *The growth of eucalypts at Muguga arboretum 1963-1972.*
1975 Nairobi, East African Agriculture and Forestry Research Organization. Forestry Technical Note No. 33.

Gray, K.M. *Eucalyptus* in California. *Australian Forestry,* 23(2): 121-131.
1959

Greenham, C.G. *et al.* A progress note on mistletoe control investigations. *Australian*
1951 *Forestry,* 15(1): 62-64.

GREENHAM, C.G. & HAWKSWORTH, F.G. *Known and potential hazards to forest*
1964 *production by the mistletoes and dwarf mistletoes.* Document, FAO/IUFRO Symposium on Internationally Dangerous Forest Diseases and Insects, Oxford, 1964.

GREENHILL, W.L. *Collapse and its removal: some recent investigations with* E. regnans.
1938 Melbourne, Commonwealth Scientific and Industrial Research Organization. Pamphlet No. 75.

GREENWOOD, D.E. Nursery design and irrigation. In *Savanna afforestation in Africa.*
1977 Rome, FAO.

GRIFFITHS, J.F., ed. *Climates of Africa. World survey of climatology.* Vol. 10.
1972 Amsterdam, Elsevier.

GRIMWADE, W.R. *Anthography of the eucalypts.* 2nd ed. Sydney, Angus and
1930 Robertson.

GROSE, R. J. *A discussion of some problems associated with natural regeneration of*
1955 Eucalyptus gigantea *in Victoria.* Document presented to Section K, ANZAAS, Melbourne, 1955.

GROSE, R.J. & ZIMMER, W.J. *A description of seeds of 70 Victorian eucalypts.*
1958 Melbourne, Forests Commission. Bulletin 8.

GUHA, S.R.D., SHARMA, Y.K., RAJESH PANT, SINGH, S.P., JAIN, D.K. & KARILA, B.G.
1973 Pulping qualities of *Eucalyptus* hybrid grown in U.P. Cellulose and Paper Branch, Forest Research Institute, Dehra Dun. *Indian Forester*, June 1973.

GUZMAN, E. DE. Personal communication.
1977a

GUZMAN, E. DE. Potentially dangerous diseases of forest trees in the Philippines.
1977b *Proceedings of the Symposium on Forest Pests and Diseases in South East Asia*, p. 189-194. Biotrop Special Publication No. 2.

HADI, S. Forest disease problems in Indonesia. *Proceedings of the Symposium on*
1977 *Forest Pests and Diseases in South East Asia*, p. 201-205. Biotrop Special Publication No. 2.

HAFEEZ, M. & SHEIKH, M.I. *Eucalyptus camaldulensis* Dehn. provenance trials in
1972 West Pakistan. *Pakistan Journal of Forestry*, 22(4).

HALL, C. The evolution of the eucalypts in relation to the cotyledons and seedlings.
1914 *Proceedings of the Linnean Society of New South Wales*, 29: 473-532.

HALL, N. *et al. The use of trees and shrubs in the dry country of Australia.*
1972 Canberra, Australian Government Publishing Service.

HALL, N. & JOHNSTON, R.D. The field identification of eucalypts. *Unasylva*, 7(2):
1953 64-69.

HALL, N. & JOHNSTON, R.D. *Card sorting key for the identification of* Eucalyptus.
1965 2nd ed. Canberra, Forestry and Timber Bureau.

HALL, N., JOHNSTON, R.D. & CHIPPENDALE, G.M. *Forest trees of Australia.* 3rd ed.
1975 Canberra, Government Publishing Service.

HALLIWELL, B. *Eucalyptus. Arboricultural Association Journal*, 2(6).
1974

HALPERIN, J. Injury to eucalypts caused by *Achradidius creticus* Kies. and *Opatroides*
1963 *punctulatus* Bruelle. In *Contributions on eucalypts in Israel.* II. Rehovoth, Forestry Division, National and University Institute of Agriculture.

Handbook on eucalypt growing: notes on the management of eucalypt plantations
1972 *grown for timber in the wattle-growing regions of South Africa.* Pietermaritzburg, Wattle Research Institute.

HANS, A.S. Artificial *Eucalyptus grandis* × *tereticornis* hybrids: survival, growth and
1974 wood density studies. *East African Agricultural and Forestry Journal*, January 1974.

HARDIE, A.D.K. & WOOD, A.A. *Eucalyptus grandis* timber from plantations in Zambia.
1973 *Commonwealth Forestry Review*, 52(2): 152, 153-159.

HARRIS, A.C. Debris disposal in large scale silvicultural operations in the Jarrah
1936 forest. *Australian Forestry*, 1(2): 36-38.

HARRIS, A.C. *Natural regeneration of Jarrah forests.* Document presented to Section
1955 K, ANZAAS, Melbourne, 1955.

HARTLEY, A. The establishment of *Eucalyptus tereticornis* on tailings from the
1977 Bougainville copper mine, Papua New Guinea. *Commonwealth Forestry Review*, 56(3): 239-245.

HAWKSWORTH, F.G. *Mistletoes on introduced trees of the world.* Washington, D.C.,
1974 U.S. Department of Agriculture. Forest Service. Agriculture Handbook No. 469.

HEINSDIJK, D., ONEYY SOARES, R., ANDEL, S. & BITTENCOURT ASCOLY, R. *Flantaçôes de*
1965 *eucaliptos no Brasil.* Rio de Janeiro.

HEISER, C.B. Introgression re-examined. *Botanical Review*, 39(4): 347-366.
1973

HELMS, A.D. A giant eucalypt. *Australian Forestry*, 9(1): 25-28.
1945

HENDERSON, H.L. *The air seasoning and kiln drying of wood.* 3rd ed. Albany,
1946 New York.

HEYWARD, J. Note on a callus shoot of *Eucalyptus ovata* and *E. diversiflora.*
1933 *Proceedings of the Royal Society of Victoria.* 45: 25-27.

HILLIS, W.E. Polyphenols in the leaves of *Eucalyptus* L'Hérit: a chemotaxonomic
1966a survey. *Phytochemistry*, 5: 1075-1090.

HILLIS, W.E. Variation in polyphenol composition within species of *Eucalyptus*
1966b L'Hérit. *Phytochemistry*, 5: 541-556.

HILLIS, W.E. Polyphenols in the leaves of *Eucalyptus* L'Hérit: a chemotaxonomic
1967a survey. II. *Phytochemistry*, 6: 259-274.

HILLIS, W.E. Polyphenols in the leaves of *Eucalyptus* L'Hérit: a chemotaxonomic
1967b survey. III. *Phytochemistry*, 6: 275-286.

HILLIS, W.E. Polyphenols in the leaves of *Eucalyptus* L'Hérit: a chemotaxonomic
1967c survey. IV. *Phytochemistry*, 6: 373-382.

HILLIS, W.E. Polyphenols in the leaves of *Eucalyptus* L'Hérit: a chemotaxonomic
1967d survey. V. *Phytochemistry*, 6: 845-856.

HILLIS, W.E. & BROWN, A.G. *Eucalypts for wood production.* Melbourne,
1978 Commonwealth Scientific and Industrial Research Organization.

HILTON, R.N. Pink disease of *Hevea* caused by *Corticium salmonicolor* Berk. and Br.
1958 *Journal of the Rubber Research Institute of Malaya*, 15: 275-292.

HODGES, C.S. Personal communication.
1978

HODGES, C.S. & MAY, L.C. A root disease of pine, *Araucaria* and *Eucalyptus* in
1972 Brazil caused by a new species of *Cylindrocladium.* *Phytopathology*, 62: 898-901.

HODGES, C.S. & REIS, M.S. A influencia do cancro basal causado por *Diaporthe*
1974a *cubensis* Bruner na brotaçao de *Eucalyptus saligna* Sm. *Brasil Florestal*, 5: 25-28.

HODGES, C.S. & REIS, M.S. Identificaçao do fungo causador do cancro de *Eucalyptus*
1974b spp. no Brasil. *Brasil Florestal*, 5: 14.

HODGES, C.S., REIS, M.S. & MAY, L.C. Duas enfermidades em plantaçoes de essencias
1973 florestais exoticas no Brasil. *Brasil Florestal*, 4: 5-12.

HODGES, C.S., REIS, M.S., FERREIRA, F.A. & HENFLING, J.D.M. O cancro do eucalipto
1976 no Brasil, causado por *Diaporthe cubensis* Bruner. *Fitopatologia Brasileira*, 1: 129-170.

HODGSON, L.M. The breeding of eucalypts in South Africa. *Forestry in South Africa*,
1967 No. 8: 31.

HODGSON, L.M. Breeding of eucalypts in South Africa. *Journal of the South African*
1974 *Forestry Association*, No. 89: 13-15.

HODGSON, L.M. Some aspects of flowering and reproductive behaviour in *Eucalyptus*
1976a *grandis* (Hill) Maiden. 1. Flowering, controlled pollination methods, pollination and receptivity. *South African Forestry Journal*, 97: 18-28.

HODGSON, L.M. Some aspects of flowering and reproductive behaviour in *Eucalyptus*
1976b *grandis* (Hill) Maiden. 2. The fruit, seed, seedlings, self fertility percent selfing and inbreeding effects. *South African Forestry Journal*, 98: 32-33.

HODGSON, L.M. Some aspects of flowering and reproductive behaviour in *Eucalyptus*
1976c *grandis* (Hill) Maiden. 3. Relative yield, breeding systems, barriers to selfing and general concessions. *South African Forestry Journal*, 99: 53-58.

HODGSON, L.M. Methods of seed orchard management for seed production and ease
1977 of reaping in *Eucalyptus grandis*. *South African Forestry Journal*, 100; 38-42.

HOLDRIDGE, L.R. *Life zone ecology*. San José, Costa Rica, Tropical Science Center.
1967

HOWLAND, P. *Sowing* Eucalyptus saligna/grandis. Malawi Forest Research Institute.
1971 Research Record No. 47.

HUNT, G.M. & GARRATT, G.A. *Wood preservation*. 3rd ed. New York, McGraw-Hill.
1967

HUNT, R. & ZOBEL, B. Frost-hardy *Eucalyptus* grow well in the south-east. *Southern*
1978 *Journal of Applied Forestry*, 2(1).

INCOLL, F.S. The red gum forests of Victoria. *Australian Forestry*, 10(1): 47-50.
1946

INDIA. FOREST RESEARCH INSTITUTE. Eucalyptus *in the plains of northwest India*.
1925 Dehra Dun. Indian Forestry Bulletin No. 61.

INGLE, H.D. & DADSWELL, H.E. The anatomy of the timbers of the Southwest Pacific
1953 area. III. Myrtaceae. *Australian Journal of Botany*, 1: 353-400.

INSTITUTO BRASILEIRO DE DESENVOLVIMENTO FLORESTAL. *Programme of the introduction*
1977 *of species and provenances of* Eucalyptus *spp. in Brazil*. Belém. (Unpublished report)

INTERNATIONAL UNION OF FOREST RESEARCH ORGANIZATIONS. *The standardization of*
1965 *symbols in forest mensuration*. 2nd ed. Orono, Maine Agricultural Experiment Station. Technical Bulletin 15.

IRVINE, C.J. A note on gum vein occurrence in saplings of mountain ash (*E. regnans*).
1936 *Journal of Scientific and Industrial Research*, 9(3).

IVORY, M.H. *Heart-rot of eucalypts in Zambia*. Document, Second World Technical
1975 Consultation on Forest Diseases and Insects (New Delhi, India, 7-12 April 1975).

IVORY, M.H. Preliminary investigations of the pests of exotic forest trees in Zambia.
1977 *Commonwealth Forestry Review*, 56(1): 47-56.

JACKSON, J.K. *Silviculture and mensuration.* Rome, FAO. Savanna Forestry
1974 Research Station, Nigeria, FO:SF/NIR 16. Technical Report 7.

JACKSON, J.K. Sowing and raising eucalypts. In *Report on FAO/DANIDA Training*
1975 *Course on Forest Seed Collection and Handling, Chiang Mai.* Vol. 2. Rome, FAO.

JACKSON, J.K. Personal communication.
1976

JACKSON, J.K. Irrigated plantations. In *Savanna afforestation in Africa.* Rome, FAO.
1977a FOR:TF-RAF 95(DEN).

JACKSON, J.K. Use of fertilizers in savanna plantations. In *Savanna afforestation in*
1977b *Africa.* Rome, FAO. FOR:TF-RAF 95(DEN).

JACKSON, J.K. & OJO, G.O.A. *Provenance trials of* Eucalyptus camaldulensis *in the*
1973 *savanna region of Nigeria.* Samaru, Zaria, Savanna Forestry Research Station. Research Paper No. 14.

JACKSON, W.D. Natural hybrids in eucalypts. Part I. *E.* × *taeniola* (= *E.*
1958 *salicifolia* × *E. sieberiana*). *Papers and Proceedings of the Royal Society of Tasmania*, 92: 141-146.

JACOBS, M.R. *A survey of the genus* Eucalyptus *in the Northern Territory.* Canberra,
1935 Commonwealth Forestry and Timber Bureau. Bulletin 17.

JACOBS, M.R. *Field studies on the gum veins of the eucalypts.* Canberra, Common-
1937a wealth Forestry and Timber Bureau. Bulletin 20.

JACOBS, M.R. The knotty core of eucalypts. *Australian Forestry*, 2(1): 3-5.
1937b

JACOBS, M.R. *The fibre tension of woody stems, with special reference to the genus*
1938 Eucalyptus. Canberra, Commonwealth Forestry and Timber Bureau. Bulletin 22.

JACOBS, M.R. *Further studies in fibre tension.* Canberra, Commonwealth Forestry
1939a and Timber Bureau. Bulletin 24.

JACOBS, M.R. *A study of the effect of sway on trees.* Canberra, Commonwealth
1939b Forestry and Timber Bureau. Bulletin 26.

JACOBS, M.R. *The growth stresses of woody stems.* Canberra, Commonwealth
1945 Forestry and Timber Bureau. Bulletin 28.

JACOBS, M.R. Growth problems in a eucalypt coppice forest of poor quality.
1950 *Australian Forestry*, 14(2): 59-71.

JACOBS, M.R. The growth and regeneration of eucalypts. *Journal of the Australian*
1951 *Institute of Agricultural Science*, 17(4): 174-183.

JACOBS, M.R. Silvicultural problems in the mixed eucalypt forests of the east coast
1954 of Australia. *Empire Forestry Review*, 33(1): 30-37.

JACOBS, M.R. *Growth habits of the eucalypts.* Canberra, Forestry and Timber
1955 Bureau.

JACOBS, M.R. *Informe al Gobierno de Argentina sobre la ecologia del eucalipto.*
1959 Roma, FAO. Informe FAO/PAAT No. 1019.

JACOBS, M.R. *Eucalyptus* as an exotic. *Second World Eucalyptus Conference, São*
1961 *Paulo, Brazil, Report and documents*, 1: 380-413.

JACOBS, M.R. *The use of exotic forest trees.* Document, United Nations Conference
1962 on the Application of Science and Technology for the Benefit of the Less Developed Areas.

JACOBS, M.R. *Stresses and strains in tree trunks as they grow in length and width.*
1965 Canberra, Forestry and Timber Bureau. Leaflet 96.

JACOBS, M.R. *The genus* Eucalyptus *in world forestry.* Walker-Ames address,
1970 Seattle, Washington, College of Forest Resources, University of Washington.

JAIN, J.C. A note on *Eucalyptus* hybrid as timber. *Indian Forester,* 95, June 1969.
1969

JEHNE, W. An instance of association between *Exocarpus cupressiformis* and dieback
1972 of *Eucalyptus dives. Australian Forest Research,* 5: 51-56.

JOFFILY, K. Ferrugem do eucalipto. *Bragantia,* 4: 475-487.
1944

JOHNSON, L.A.S. Studies in the taxonomy of *Eucalyptus. Contributions of the New*
1962 *South Wales National Herbarium,* 3: 103-126.

JOHNSTON, D.R., GRAYSON, A.J. & BRADLEY, R.T. *Forest planning.* London, Faber.
1967

JOHNSTON, R.D. & MARRYATT, R. Taxonomy and nomenclature of eucalypts. Canberra,
1962 Forestry and Timber Bureau. Leaflet No. 92: 1-24.

JOLLY, N.W. The genus *Eucalyptus*: its past and future in Pacific forests. *Empire*
1949 *Forestry Review,* 28(4): 343-349.

KADEBA, O. *Nutrition of eucalypts.* Document, Nigerian Symposium on Savanna
1976 afforestation, Kaduna. Ibadan, Forest Research Institute.

KANSHIK, R.C., ZURESHI, I.M., YADAV, J.S.P. & PRAKASH, J. Suitability of soils for
1969 *Eucalyptus* hybrid (Mysore gum syn. *E. tereticornis*) in Haryana and Punjab.
Indian Forester, 95, June 1969.

KARSCHON, R. *The effect of crude oil fumes on* Eucalyptus camaldulensis *Dehn.*
1970 Bet-Dagan, Volcani Institute of Agricultural Research. Leaflet No. 38.

KARSCHON, R. Personal communication.
1976

KEDHARNATH, S. & VAKSHASYA, R.K. Estimates of components of variance, heritability
1978 and correlations among some growth parameters in *Eucalyptus tereticornis.*
In Third World Consultation on Forest Tree Breeding, Canberra. *Documents.*
(FO-FTB-77-3/17)

KEET, J.H., LACK, C.E., GREY, D.M. & SCHUTZ, C.J. *Guide to tree-planting: Eastern*
1974 *Transvaal.* Pretoria, Department of Forestry. Pamphlet 146.

KERNAN, H.S. *Reforestation in Spain.* New York, State University College of Forestry
1966 at Syracuse University. World Forestry Publication No. 3.

KERR, L.R. The lignotubers of eucalypt seedlings. *Proceedings of the Royal Society*
1925 *of Victoria,* 37(1): 79-97.

KESSEL, S.L. & GARDNER, C.A. *Key to the eucalypts of Western Australia.* Perth,
1924 Forests Department of Western Australia. Bulletin No. 34.

KESSEL, S.L. & STOATE, T.N. Irregular stocking in the Jarrah forest. *Australian*
1937 *Forestry,* 2(1): 14-18.

KING, N.L. Tree-planting in South Africa. *Journal of the South African Forestry*
1951 *Association,* No. 21.

KINGSTON, B. *Growth, yield and rotations of seedling crops of* Eucalyptus grandis
1972a *in Uganda.* Entebbe, Forest Department. Technical Note No. 193.

KINGSTON, B. *Volume tables for* Eucalyptus grandis. Entebbe, Forest Department.
1972b Technical Note No. 186.

KINGSTON, B. *A climatic classification for forest management in Uganda.* Document,
1974 10th Commonwealth Forestry Conference.

KINGSTON, B. Personal communication.
1977

KIRKPATRICK, J.B. *Geographical variation in* Eucalyptus globulus. Canberra, Forestry
1975 and Timber Bureau. Bulletin 47.

KONAR, R.N. & NAGMANI, R. Tissue culture as a method for vegetative propagation
1974 of forest trees. *New Zealand Journal of Forestry Science*, 4(2): 279-290.

KOTZE, J.J. & HUBBARD, C.S. *The growth of eucalypts on the highveld and south-*
1928 *eastern mountain veld of the Transvaal.* Pretoria.

KRIEK, W. *Report to the Government of Uganda on the performance of indigenous*
1970 *and exotic trees in species trials.* Rome, FAO. No. TA 2826.

KRUG, C.A. & ALVES, A.S. *Eucalyptus* improvement. Part I. *Journal of Heredity,*
1949 90(5): 133-139.

KUBLER, H. Role of moisture in hygrothermal recovery of wood. *Wood Science,*
1973 5(3): 198-204.

LAAR, A. VAN. *Eucalyptus saligna* in South Africa: an investigation into the silviculture
1961 and economics. *Annale van die Universiteit van Stellenbosch*, 36, Ser. A, (1).

LACAZE, J.F. La résistance au froid des *Eucalyptus*: compte rendu d'un test précoce
1962 sur *Eucalyptus gunnii* (Hook) et *E. cinerea* (FvM). *Revue forestière française,*
N° 5.

LACAZE, J.F. La résistance des *Eucalyptus* au calcaire actif dans le sol. Compte
1963 rendu d'un test précoce. *Proceedings of the World Consultation on Forest Genetics and Tree Improvement*, Vol. 1, Paper 4/8. Rome, FAO.

LACAZE, J.F. *Etude de l'adaptation écologique des* Eucalyptus. Rome, FAO. Projet
1970 No. 6, FAO Comité de la recherche forestière méditerranéenne. FO:SCM/FR 70/2/10.

LACAZE, J.F. Etude de l'adaptation écologique des *Eucalyptus*, étude de provenances
1978 d'*Eucalyptus camaldulensis* (Projet FAO No. 6). *In* Third World Consultation on Forest Tree Breeding, Canberra. *Documents.* (FO:FTB-77-2/29)

LANE POOLE, C.E. *Eucalyptus deglupta.*

LANE POOLE, C.E. Eucalypt planting in South Africa. *Australian Forestry,* 1(1):
1936 25-31.

LANE POOLE, C.E. Some notes on the survival of seedling gums. *Australian Forestry,*
1937 2(1): 25-27.

LAOS-AUSTRALIAN REAFFORESTATION PROJECT. *Manual of operations.*
1972

LARSEN, E. A study of the variability of *Eucalyptus maculata* Hook. and *Eucalyptus*
1965 *citriodora* Hook. Commonwealth Forestry and Timber Bureau. *Leaflet* No. 95: 1-23.

LARSEN, E. & CROMER, D.A.N. Exploration, evaluation, utilization and conservation
1970 of eucalypt gene resources. In *Genetic resources in plants*, ed. by O.H. Frankel and E. Bennett. Oxford, Blackwell. IBP Handbook 11.

LAURIE, M.V. Tree planting practices in African savannas. *See* FAO, 1974d.
1974

LAWRENCE, A.O. Note on gum veins. *Victorian Forestry*, 1(3): 28-33.
1936

LAWRENCE, A.O. Notes on the silviculture of *Eucalyptus obliqua* (messmate) regrowth
1939 forests in central Victoria. *Australian Forestry*, 4(1): 4-10.

LEEPER, G.W., ed. *The Australian environment.* 4th ed. Melbourne, CSIRO/
1970 Melbourne University Press.

LEROUX, P.J. Nursery techniques in low rainfall areas. *South African Forestry*
1975 *Journal*, 95: 24-31.

LEVISOHN, I. Mycorrhizal infection of *Eucalyptus*. *Empire Forestry Review*, 37:
1958 237-241.

LINDSAY, A.D. Gum veins and the silviculture of mountain ash. *Victorian Forester*,
1935 1(2).

LINNARD, W. Cultivation of eucalypts in the U.S.S.R. *Forestry Abstracts*, 230(2):
1969 199-209.

LIVINGSTON, R.S. & MCNEILL, B., eds. *Beyond petroleum.* Vol. 1. *Biomass energy*
1975 *chains.* Stanford, Calif., Stanford University.

LIZARDO, L. *Eucalypts in the Philippines.* Manila.
1956

LONERAGAN, O.W. *Crown development in jarrah and crown ratios.* (Manuscript)
1955

LOOCK, E.E.M. *Eucalyptus* species suitable for the production of honey. *Journal of*
1948 *the South African Forestry Association*, No. 16: 67-71.

LUCKHOFF, H.A. The establishment and regeneration of *Eucalyptus saligna* plantations
1955a in the coastal belt of Zululand. *Journal of the South African Forestry Association*, No. 25: 1-20.

LUCKHOFF, H.A. Two hitherto unrecorded fungal diseases attacking pines and
1955b eucalypts in South Africa. *Journal of South African Forest Research*, 26: 47-61.

LUCKHOFF, H.A. Pruning of *Eucalyptus grandis*. *Forestry in South Africa*, No. 8:
1967 75-85.

MACEDO, N. *Aspectos principais de estudo sobre pragas do eucalipto.* Brasilia,
1976 PRODEPEF. Comunicações Técnicos Nº 4.

MAGNANI, G. Diseases of *Eucalyptus*. In *Diseases of widely planted forest trees*,
1964 p. 159-167. FAO/IUFRO Symposium on Internationally Dangerous Forest Diseases and Insects, Oxford.

MAIDEN, J.H. *A critical revision of the genus* Eucalyptus. Vols. 1-8. Sydney,
1930-31 Government Printer.

MALAVOLTA, E., HAAG, H.P., MELLO, F.A.F. & BRASIL SOBR, M.O.C. *On the mineral*
1962 *nutrition of some tropical crops, 7 — eucalypts.* Berne, International Potash Institute.

MARQUESTAUT, J., THIBOUT, H. & CAUVIN, B. Essais d'introduction d'*Eucalyptus* dans
1978 le midi de la France. In *Annales de recherches sylvicoles, 1977.* Paris, AFOCEL.

MARRERO, J. El cultivo del eucalipto en ia Sierra del Ecuador. *Caribbean Forester*,
1947 7(1).

MARSH, E.K. A key to South African grown eucalypts. *Journal of the South*
1939 *African Forestry Association*, No. 3.

MARSH, E.K. How to distinguish between *Eucalyptus saligna* Sm. and *Eucalyptus*
1953 *grandis* (Hill) Maid. *Journal of the South African Forestry Association*, No. 23.

MARSH, E.K. Methods of killing eucalypt stumps. *Forestry in South Africa*, No. 2:
1963 111-119.

MARSH, E.K. & HAIGH, H. Preliminary results from provenance trials with *Eucalyptus*
1963 *saligna* Sm. and *E. grandis* (Hill) Maiden. *Forestry in South Africa*, No. 2: 127-132.

MARSH, E.K. & BURGERS, T.F. The relation between silvicultural treatment and
1967 timber quality. *Forestry in South Africa*, No. 8: 63-74.

MARTIN, B. Amélioration génétique des espèces exotiques en République populaire
1971 du Congo: les *Eucalyptus*. *Bois et forêts des tropiques*, 138: 3-26.

MARTIN, B. L'*Eucalyptus* comme exotique: récents progrès dans le choix des espèces
1978 et des provenances. *In* Third World Consultation on Forest Tree Breeding, Canberra. *Documents*. (FO-FTB-77-2/5)

MARTIN, B. & QUILLET, G. Bouturage des arbres forestiers au Congo. Résultats des
1974 essais effectués à Pointe Noire de 1969 à 1973. *Bois et forêts des tropiques*, No. 154: 41-57; No. 155: 15-33; No. 156: 39-61; No. 157: 21-40.

MARTIN, B. & COSSALTER, C. Les *Eucalyptus* des Iles de la Sonde. *Bois et forêts des*
1975-76 *tropiques*, Nos. 163-168.

MARTIN, D. Eucalypts in the British Isles with some notes on records of frost resistance.
1948 *Australian Forestry*, 12(2): 64-74.

MATHER, A.D. *Raising* Eucalyptus *seedlings and establishing* Eucalyptus *plantations*
1974 *in the hills of Nepal*. Australian Aid, Nepal Forestry Project/Kathmandu. Technical Note No. 1/74.

MCARTHUR, A.G. *Control burning in eucalypt forests*. Canberra, Forestry and Timber
1962 Bureau. Leaflet No. 80.

MCCLATCHIE, A.J. *Eucalypts cultivated in the United States*. Washington, D.C.,
1902 U.S. Department of Agriculture, Bureau of Forestry. Bulletin 35.

MÉNAGER, H. *Voyages d'études forestières et agricoles dans l'hémisphère sud*.
1950 Bordeaux, Delmas.

MÉNAGER, H. Les *Eucalyptus* dans le Rharb (Maroc occidental). *Revue internationale*
1952 *de botanique appliquée et d'agriculture tropicale*, 7, juillet-août.

MESKIMEN, G. Breaking the size barrier in containerization - "washed" *Eucalyptus*
1974 seedlings. *Proceedings of the North American Containerized Forest Tree Seedling Symposium*. Gt. Plains Agricultural Council Publication No. 68.

MESSINES, J. Sand-dune fixation and afforestation in Libya. *Unasylva*, 6(2): 50-58.
1952

METCALF, W. *Growth of* Eucalyptus *in California plantations*. Berkeley, University
1924 of California. Bulletin No. 380.

MÉTRO, A. *Compte rendu d'une mission forestière en Australie*. Cahiers des
1949a ingénieurs agronomes.

MÉTRO, A. L'écologie des *Eucalyptus*, son application au Maroc. *Mémoires de la*
1949b *Société des sciences naturelles du Maroc*, 49.

MÉTRO, A. L'*Eucalyptus sideroxylon*. Étude forestière. *Annales de la recherche*
1951 *forestière au Maroc*, 1951.

MÉTRO, A. *Eucalypts for planting*. *See* FAO, 1955.
1955

MIKOLA, P. Comparative observations on the nursery technique in different parts of
1969 the world. *Acta Forestalia Fennica*, 90.

MOGGI, G. L'infiorescenza del genere *Eucalyptus* e la sua interpretazione. *Giornale*
1963 *Botanico Italiano,* 70: 1-20.

MOONEY, O.V. The development of the eucalypts in Irish conditions. *Irish Forestry,*
1960 18(1).

MORAES, L., ALVARES DE & PINHEIRO, J. VIEIRA. *Experiencias de combate a formiga*
1951 *sauva.* Rio Claro, Cia Paulista de Extradas de Ferro, Serviço Florestal.

MOSTYN, H.P. Open tank creosoting plants in Zambia. *Commonwealth Forestry*
1966 *Review,* 124: 163-171.

MOULDS, F.R. Eucalypts and their use in semi-tropical plantings. *Tropical Woods,*
1947 No. 91.

MOURA, V.P.G. *Altitudinal variation in* Eucalyptus urophylla *S.T. Blake.* University
1977 of Melbourne. (Thesis)

MOUTIA, L.A. Notes sur l'introduction à Maurice de l'insecte: *Anaphoïdea nitens* Gir.,
1946 le parasite du charançon de l'*Eucalyptus: Gonipterus scutellatus* Gyll. *Revue agricole de l'île Maurice,* 1946.

MUELLER, F.v.M. *Eucalyptographia. A descriptive atlas of the eucalypts of Australia*
1879-84 *in 10 decades.* Melbourne, Government Printer.

MUNNS, E.N. Relative frost resistance of *Eucalyptus* in southern California. *Journal*
1918 *of Forestry,* 16(4): 412-428.

NAMKOONG, G. Inbreeding effects on estimation of genetic additive variance. *Forest*
1966 *Science,* 12(1): 8-13.

NAMKOONG, G. *Foundations of quantitative forest genetics. A text for the short*
1972 *course on Applications of Quantitative Genetics to Forestry.* Meguro, Japan, Government Forest Experiment Station.

NAMKOONG, G. Choosing strategies for the future. *In* Third World Consultation on
1978 Forest Tree Breeding, Canberra. *Documents.* (FO-FTB-77-6/1)

NARVAEZ, C.J. *Inventario de áreas forestadas en el Ecuador.* Quito, Dirección de
1976 Desarrollo Forestal.

NAUDIN, CH. Mémoire sur les *Eucalyptus* introduits dans la région méditerranéenne.
1883 *Annales des sciences naturelles,* 6.

NAVARRO DE ANDRADE, E.D. *Manual do plantador do* Eucalyptus. São Paulo,
1911 Rothschild.

NAVARRO DE ANDRADE, E.D. *O* Eucalyptus, *sua cultura e exploraçao.* São Paulo,
1928 Rothschild.

NAVARRO DE ANDRADE, E.D. *O Eucalypto.* São Paulo, Chacaras e Quintais.
1939

NEL, P.M. Breeding of eucalypts in South Africa. *Journal of the South African*
1965 *Forestry Association,* No. 54: 17-21.

NEUMANN, R. *Relationship between* Pisolithus *(Mich. and Pers.) Coker and Couch*
1959 *and* Eucalyptus camaldulensis (rostrata) *Dehn.* Bulletin of the Research Council, Israel, 70.

NEWHOOK, J.F. & PODGER, F.D. The role of *Phytophthora cinnamomi* in Australia
1972 and New Zealand forests. *Annual Review of Phytopathology,* 10: 299-320.

New materials for the manufacture of artificial silk: sulphite pulp from Tasmanian
1929 *stringybark.* London, Imperial Institute. Bulletin 27.

NICHOLAS, D.D., ed. *Wood deterioration and its prevention by preservative*
1973 *treatments.* New York, Syracuse University.

NIGERIA. SAVANNA FORESTRY RESEARCH STATION. *Planning the work for a* Eucalyptus
1971 *fuel plantation of 3,000 acres.* Ibadan, School of Forestry. Report No. 12.

NORTH CAROLINA. STATE UNIVERSITY. *Eighteenth annual report. Cooperative Tree*
1974 *Improvement and Hardwood Research Programs.* Raleigh, N.C., North Carolina State University, School of Forest Resources.

NORTH CAROLINA. STATE UNIVERSITY. *Twentieth annual report. Cooperative Tree*
1976 *Improvement and Hardwood Research Programs.* Raleigh, N.C., North Carolina State University, School of Forest Resources.

Note sur les essais d'introduction d'*Eucalyptus* en France métropolitaine. *Rapp. Fonds*
1950 *For. Nat.*, 15-16.

OFOSU-ASIEDU, A. A new disease of eucalypts in Ghana. *Transaction of the British*
1975 *Mycological Society*, 65: 285-289.

OJO, G.O.A. & JACKSON, J.K. *The use of fertilizer in forestry in the drier tropics.*
1973 Document, FAO/IUFRO International Symposium on Forest Fertilization, Paris, 1973. (FOR:FAO/IUFRO/F/73/16)

ORME, R.K. *Eucalyptus globulus* provenances. *In* Third World Consultation on
1978 Forest Tree Breeding, Canberra. *Documents.* (FO-FTB-77-2/9)

OSBORN, T.G.B. Some notes on the nomenclature of certain common species of
1937 *Eucalyptus. Proceedings of the Linnean Society of New South Wales*, 62: 73-77.

OVINGTON, J.D. *Biological and economic considerations of forest production in the*
1972 *tropics with particular reference to tropical rain forests.* Rome, FAO. FO:MISC/72/16

PALMER, J.R. A bibliography on tree improvement of *Eucalyptus* in Brazil. Action
1975 Group on Tropical Eucalypts. *Newsletter*, No. 2, September 1975: 4-8.

PÁSZTOR, Y.P. DE CASTRO. Produçao de sementes de eucaliptos. *Silvicultura em São*
1962 *Paulo*, 1: 181-187.

PÁSZTOR, Y.P. DE CASTRO. A provenance trial with *Eucalyptus pilularis* Sm. *In* Third
1978a World Consultation on Forest Tree Breeding, Canberra. *Documents.* (FO-FTB-77-2/27)

PÁSZTOR, Y.P. DE CASTRO. Growth and morphological characteristics of some Timor
1978b eucalypt provenances compared with the eucalypt known as "Brasilian alba". *In* Third World Consultation on Forest Tree Breeding, Canberra. *Documents.* (FO-FTB-77-2/35)

PÁSZTOR, Y.P. DE CASTRO & COSTA COELHO, L.C. A provenance trial with *Eucalyptus*
1978 *maculata* Hook: preliminary results. *In* Third World Consultation on Forest Tree Breeding, Canberra. *Documents.* (FO-FTB-77-2/28)

PATON, D.M., WILLING, R.R., NICHOLLS, W. & PRYOR, L.D. Rooting of stem cuttings
1970 of *Eucalyptus:* a rooting inhibitor in adult tissue. *Australian Journal of Botany*, 18: 175-183.

PAVARI, A. *Gli eucalipti.* Roma, Federazione pro Montibus. Bollettino No. 3.
1922

PAVARI, A. *Eucalipti ed acacie nella penisola iberica.* (R. Istituto Superiore Forestale
1923 Nazionale.) Firenze, Ricci.

PAVARI, A. La sperimentazione di specie forestali esotiche in Italia: risultati del primo
1941 ventennio. *Annali di Sperimentazione Agraria*, 38.

PAVARI, A. & PHILIPPIS, A. DE. Cenni monografici sugli eucalipti più importanti per
1935 la selvicoltura italiana. *L'Alpe*, No. 5-6.

PEDERICK, L.A. *The genetic resources of the Victorian eucalypts.* Victoria, Forests
1976 Commission. Bulletin 22.

PEEVALLY, A. *Cylindrocladium braziliensis.* Kew, Surrey, Commonwealth Mycological
1974 Institute. CMI Description of Pathogenic Fungi and Bacteria No. 427.

PENFOLD, A.R. & MORRISON, F.R. *Commercial* Eucalyptus *oils.* 4th ed. Technical
1944 Museum Bulletin 2.

PENFOLD, A.R. & WILLIS, J.L. *The eucalypts.* London, Leonard Hill; New York,
1961 Interscience Publishers. World Crop Series.

PERSSON, R. *World forest resources: review of the world's forest resources in the*
1974 *early 1970's.* Stockholm, Royal College of Forestry, Department of Forest Survey. Research Notes No. 17.

PERSSON, R. *Forest resources of Africa: an approach to international forest resource*
1975 *appraisals.* Part I. Country descriptions. Stockholm, Royal College of Forestry, Department of Forest Survey. Research Notes No. 18.

PETROFF, G. Étude papetière de quelques échantillons d'*Eucalyptus* congolais. *Bois et*
1965 *forêts des tropiques,* No. 103.

PETROFF, G. Une fabrique de pâte à papier en Angola: la cellulose do Ultramar
1968 portugues. *Bois et forêts des tropiques,* No. 119.

PHILIPPIS, A. DE. Note forestali di un viaggio in Palestina. *L'Alpe,* No. 7-8.
1936

PHILLIPS, M.A. & BROWN, A.H.D. Mating system and hybridity in *Eucalyptus pauci-*
1976 *flora. Australian Journal of Biological Sciences,* 29.

PIERLOT, R. *Les* Eucalyptus *au Congo belge (est et sud-est) et au Rouanda-Ouroundi.*
1953

PILLAI, S.K. *A monograph on* Eucalyptus grandis. (Council of Scientific and Industrial
1966 Research.) New Delhi, Bangalore Press.

PODGER, F.D. *Phytophthora cinnamomi* a cause of lethal disease in indigenous plant
1972 communities in Western Australia. *Phytopathology,* 62: 972-981.

PODGER, F.D. & ASHTON, D.H. *Phytophthora cinnamomi* in dying vegetation in the
1970 Brisbane range, Victoria. *Australian Forest Research,* 4: 33-36.

PODGER, F.J., KILE, G.A., WATLING, R. & FRYER, J. Spread and effect of *Armillaria*
1978 *luteobubalina* Watling and Kile in an Australian plantation of *Eucalyptus regnans. Transactions of the British Mycological Society,* 63.

POYNTON, R.J. *Notes on exotic forest trees in South Africa.* 2nd ed. rev. Pretoria,
1960 Government Printer. Bulletin No. 38.

POYNTON, R.J. Recent advances in nursery and afforestation techniques in the
1964 Rhodesias and Nyasaland. *Forestry in South Africa,* No. 4: 85-96.

POYNTON, R.J. Research on the silviculture of *E. grandis (saligna)* in the northern
1965 Transvaal. *Journal of the South African Forestry Association,* No. 52: 10-20.

POYNTON, R.J. The drought resistance of commercial timber species in the Transvaal.
1966 *Forestry in South Africa,* No. 6: 87:106.

POYNTON, R.J. *Characteristics and uses of trees and shrubs obtainable from the Forest*
1971 *Department.* Bulletin No. 39 (Third ed.). Pretoria, Government Printer.

POYNTON, R.J. *Tree planting in southern Africa.* Vol. 2, *Eucalypts.* Sth Afr. For. Res.
1979 Inst., Pretoria.

PRYOR, L.D. *The place of* Eucalyptus *in reafforestation in Lebanon. A report for the Government.*

PRYOR, L.D. *The reproductive system and hybridization of* Eucalyptus.

PRYOR, L.D. *The botany, forestry and zoology of the Australian Capital Territories on an ecological basis.* Canberra, Government Printer.

PRYOR, L.D. Some hybrids of *Eucalyptus viminalis. Australian Forestry,* 14(2).
1950

PRYOR, L.D. Controlled pollination of *Eucalyptus. Proceedings of the Linnean*
1951a *Society of New South Wales,* 76(3-4).

PRYOR, L.D. A genetic analysis of some *Eucalyptus* species. *Proceedings of the*
1951b *Linnean Society of New South Wales,* 76(3-4): 140-148.

PRYOR, L.D. Anther shape in *Eucalyptus* genetics and systematics. *Proceedings of the*
1953 *Linnean Society of New South Wales,* 78: 43-48.

PRYOR, L.D. The inheritance of inflorescence characters in *Eucalyptus. Proceedings*
1954 *of the Linnean Society of New South Wales,* 79: 79-89.

PRYOR, L.D. The genetic and systematic status of *Eucalyptus huberiana* Naudin,
1955 *Eucalyptus viminalis* Labill. and *E. aromaphloia* Pryor and Willis. *Transactions of the Royal Society of Australia,* 78: 156-164.

PRYOR, L.D. Chlorosis and lack of vigour in seedlings of renantherous species of
1956a *Eucalyptus,* caused by lack of mycorrhiza. *Proceedings of the Linnean Society of New South Wales,* 81: 91-96.

PRYOR, L.D. Ectotrophic mycorrhiza in renantherous species of *Eucalyptus. Nature,*
1956b *Lond.,* 177: 4508.

PRYOR, L.D. Selecting and breeding for cold resistance in *Eucalyptus. Silvae Genetica,*
1957 6: 98-109.

PRYOR, L.D. Species distribution and association in *Eucalyptus. In* Biogeography and
1959 ecology in Australia. *Monogr. Biol.,* 8: 461-471.

PRYOR, L.D. Inheritance, selection and breeding in *Eucalyptus. In* Second World
1961 *Eucalyptus* Conference, São Paulo, 1961. *Report and documents,* 1: 297-304.

PRYOR, L.D. Eucalyptus *in the Sudan.* (Typescript)
1964a

PRYOR, L.D. *Report to the Government of Libya on aspects of afforestation with*
1964b *particular refence to* Eucalyptus. Rome, FAO. FAO/EPTA Report No. 1863.

PRYOR, L.D. *The present and future situation with* Eucalyptus *planting in Chile.*
1965 (Unpublished report)

PRYOR, L.D. *Eucalyptus* in plantations — present and future. *In* FAO World Sym-
1967 posium on Man-made Forests and their Industrial Importance. *Documents,* 2: 993-1008. Rome, FAO.

PRYOR, L.D. *A report on the selection and establishment of tree species suitable for*
1973a *pole and fuelwood plantations in Lesotho.* Rome, FAO.

PRYOR, L.D. *A review of the genetic status of Mysore "hybrid" (or Mysore gum).*
1973b FAO/SIDA Project Identification Mission for India. Working Document No. 3. (Unpublished)

PRYOR, L.D. Personal communication.
1974

PRYOR, L.D. Eucalypts. In *The methodology of conservation of forest genetic*
1975 *resources. FAO/UNEP report on a pilot study.* Rome, FAO.

PRYOR, L.D. *Biology of eucalypts.* London, Arnold.
1976

PRYOR, L.D. Eucalypts as exotics. *In* International Training Course in Forest Tree
1977 Breeding. *Selected Reference Papers,* p. 219-221. Canberra, Australian Development Assistance Agency.

PRYOR, L.D. *Reproductive habits of the eucalypts in relation to introduction and*
1978 *improvement throughout the world. In* Third World Consultation on Forest Tree Breeding, Canberra. Invited lecture. (FO-FTB-77-0/2)

PRYOR, L.D. & BYRNE, O.R. Variation and taxonomy in *Eucalyptus camaldulensis.*
1969 *Silvae Genetica,* 18: 57-96.

PRYOR, L.D. & JOHNSON, L.A.S. *A classification of the eucalypts.* Canberra, Australian
1971 National University.

PRYOR, L.D. & KNOX, R.B. Operculum development and evolution in eucalypts. *Australian Journal of Botany.* (In press)

PRYOR, L.D., JOHNSON, L.A.S., WHITECROSS, M.I. & MCGILLIVRAY, D.J. The perianth
1967 and the taxonomic affinities of *Eucalyptus cloeziana* F. Muell. *Australian Journal of Botany,* 15: 145-149.

QUADRI, S.M.A. Nursery technique for eucalypts. *Pakistan Journal of Forestry,* 21:
1971 133-152.

RANATUNGA, M.S. Notes on the planting of forest species. *Sri Lanka Forester,* 10:
1972 103-106.

REIS, M.S. & HODGES, C.S. *Status of forest diseases and insects in Latin America.*
1975 Document, Second FAO/IUFRO World Technical Consultation on Forest Diseases and Insects, New Delhi.

REYNDERS, M. *Contribution à l'étude de l'*Eucalyptus *au Rwanda et au Burundi.*
1963 Publications de l'Institut national pour l'étude agronomique du Congo, Série technique No. 69. 98 p.

REYNDERS, M.I. *Informe sobre los ensayos de especies en zonas tropicales de México.*
1970a Chapingo, México, Escuela Nacional de Agricultura.

REYNDERS, M.I. *Terminal report.* Rome, FAO. FAO Afforestation Project, Mexico,
1970b 1967-70.

ROBERTS, H. Forest insect conditions in West Africa. In FAO/IUFRO Symposium
1964 on Internationally Dangerous Forest Diseases and Insects, Oxford. *Documents,* 1.

ROBERTSON, C.C. *A reconnaissance of the forest trees of Australia from the point of*
1926 *view of their cultivation in South Africa.* Cape Town, Government Printer.

RUGGERI, CECILIA. Primo contributo alla conoscenza cariologica del genere *Eucalyptus*
1960a (Myrtaceae). *Pubblicazioni del Centro di Sperimentazione Agricola e Forestale,* 4: 121-126.

RUGGERI, CECILIA. Secondo contributo alla conoscenza cariologica del genere
1960b *Eucalyptus* (Myrtaceae). *Pubblicazioni del Centro di Sperimentazione Agricola e Forestale,* 4: 139-150.

RUGGERI, CECILIA. Terzo contributo alla conoscenza cariologica del genere *Eucalyptus*
1962 (Myrtaceae). *Pubblicazioni del Centro Sperimentale Agricola e Forestale,* 6: 39-45.

SAMPAIO, A.N. *Improvement of the methods of culture of* Eucalyptus *in the forestry service of the Paulista Railroad Co., São Paulo.*

SAMPAIO, A.N. *Instruçoes para o plantio do eucalipto.* Tip. Jornal de Piracicaba.
1952

SAMPSON, O.R. *Growing containerized* Eucalyptus *in South Florida. Proceedings of*
1974 *the North American Containerized Forest Tree Seedling Symposium.* Lincoln, Nebraska, Great Plains Agricultural Council. Publication No. 68.

SANTORO, F.H. Panorama entomológico relacionado con la silvicultura y la tecnología
1964 forestal de la República Argentina. *In* FAO/IUFRO Symposium on Internationally Dangerous Forest Diseases and Insects, Oxford. *Documents,* 1.

SANTORO, F.H. & LABATE, P.J. Impregnación de albura verde de eucalipto con bórax.
1961 *In* Second World Eucalyptus Conference, São Paulo. *Report and documents,* 2: 1168-1175.

SASTRY, K.S.M., THAKUR, R.N., GUPTA, J.M. & PANDOTRA, V.R. Three virus diseases
1971 of *Eucalyptus citriodora. Indian Phytopathology,* 24: 123-126.

SAVORY, B.M. Boron deficiency in eucalypts in Northern Rhodesia. *Commonwealth*
1962 *Forestry Review,* 41(2).

SCARAMUZZA, L.C. *The* Eucalyptus *and the reforestation at the sugar mills.* Document,
1947 21st annual meeting of the Association of Técnicos Azucareros de Cuba. Havana.

SCHÖNAU, A.P.G. Planting espacement and pruning of *E. grandis* on a poor quality
1970 site. *Journal of the South African Forestry Association,* No. 73.

SCHÖNAU, A.P.G. *Initial responses to fertilizing* Eucalyptus grandis *at planting are*
1976a *sustained until harvesting.* Paper 16, IUFRO World Congress, Oslo.

SCHÖNAU, A.P.C. Metric site index curves for *Eucalyptus grandis. South African*
1976b *Forestry Journal,* No. 98.

SCHÖNAU, A.P.G. Initial responses to fertilizing *Eucalyptus grandis* at planting are
1977 sustained until harvesting. *South African Forestry Journal,* No. 100.

SCHÖNAU, A.P.G. & PENNEFATHER, M. A first account of profits at harvesting as a
1975 result of fertilizing *Eucalyptus grandis* at time of planting in southern Africa. *South African Forestry Journal,* 94: 29-35.

SCHÖNENBERGER, A. *Premiers enseignements des arboretum forestiers.* Rome, FAO.
1971 FO:SF/TUN 11 Rap. Tec. 5.

SCOTT, M.H. *Notes on some Australian timbers grown in South Africa.* Pretoria,
1928 South African Forests Department. Bulletin 23.

SCOTT, M.H. The use of chemically treated wooden poles for telephone and power
1946 transmission lines in South Africa. *Journal of the South African Forestry Association,* No. 13: 21-34.

SEGURA, C.B. La enfermedad rosada (*Corticium salmonicolor*) y el mal de hilachas
1970a (*Pellicularia koleroga*) sobre varias especies de *Eucalyptus* en Turrialba, Costa Rica. *Turrialba,* 20: 254-255.

SEGURA, C.B. Manchas foliares causadas por el hongo *Cylindrocladium scoparium*
1970b Morg. en *Eucalyptus* spp. en Turrialba, Costa Rica. *Turrialba,* 20: 365-366.

SEKHAR, A.C. & RAJPUT, S.S. A preliminary note on the study of strength properties
1968 of *Eucalyptus* hybrid of Mysore origin. *Indian Forester,* 94.

SESBOU, A. & NEPVEU, G. Variabilité infraspécifique du retrait avec collapse et de la
1978 densité du bois chez *Eucalyptus camaldulensis. Annales des sciences forestières,* 35(4): 237-263.

SHEIKH, M.I. Afforestation in waterlogged and saline areas. *Pakistan Journal of*
1974 *Forestry,* 24(2).

SHERRY, S.P. & PRYOR, L.D. Growth and differential frost-resistance of topoclinal
1967 forms of *Eucalyptus fastigata* D. & M. planted in South Africa. *Australian Forestry,* 31(1): 33-49.

SIMÕES, J.W. *et al.* The effects of the type of felling tool in the regeneration of
1973 eucalypts. *Forestry Abstracts*, 4495, 34.8.

SINGH, J. & RANDEV, H.S. *Eucalyptus* in Extension Forestry Programmes of the
1975 Agricultural State of Punjab. *Indian Forester*, February 1975.

SINGH, S. & KUMAR, A. Field survey on Mycorrhiza in eucalypts and pines. *Indian*
1966 *Forester*, 92: 517-520.

SKOLMEN, R.G. Personal communication.
1976

SMALL, B.E.J. Assessing the Australian *Eucalyptus* oil industry. *Forest and Timber*,
1977 13(2).

SMITH, J.E. *Eucalyptus camaldulensis* Dehnordt et *Eucalyptus tereticornis*, caractères
1963 sylvicoles et méthodes de plantation. *Bois et forêts des tropiques*, No. 87.

SOMMERVILLE, J.L. Progress of research on paper-making from eucalypts in Australia.
1931 *Paper Maker*, 81(1).

SOUTH AFRICA. DEPARTMENT OF FORESTRY. *Report of the Forest Research Institute*
1964 *1963-64*. Pretoria.

SOUTH AFRICA. DEPARTMENT OF FORESTRY. *Report on commercial timber plantations,*
1972, 74 *1970/71, 1972-73*. Pretoria, Government Printer.

SOUTH AFRICA. DEPARTMENT OF FORESTRY. *Annual report of the Department of*
1975 *Forestry for the period ended 31 March 1974*. Pretoria.

SPETTER, E. Protection of green eucalypt logs against *Phoracantha semipunctata* Fabr.
1963 In *Contributions on Eucalypts in Israel*, 2.

STERN, K. & ROCHE, L. *Genetics of forest ecosystems*. London, Berlin, Springer.
1974 Ecological Studies, Vol. 6.

STOATE, T.N. Stem distributions in irregular forests. *Australian Forestry*, 4(1):
1939 23-28.

STOATE, T.N. Crown area in irregular forest. *Australian Forestry*, 6(1): 14-20.
1941

STOATE, T.N. Jarrah stem distributions. *Australian Forestry*, 5(2): 72-77.
1950

STOATE, T.N. Silvicultural research in Australia. *Australian Journal of Science*,
1951 14(3): 80-82.

STOATE, T.N. & WALLACE, W.R. Jarrah sapling crown studies, 1928-38. *Australian*
1938 *Forestry*, 3(2): 64-73.

STONE, E.C. *A review of the Tunisian Forest Research Institute Research Program,*
1973 *April 1973*. Consultant report to Institut national de recherches forestières.

STORR, H.P. The seasoning of South African grown *Eucalyptus grandis* and *E. saligna*
1977 sawn timber. *South African Forestry Journal*, No. 102: 61-66.

STREETS, R.J. *Exotic forest trees in the British Commonwealth*. Oxford, Clarendon
1962 Press.

STUBBINGS, J.A. Raising and use of large close-rooted transplants for commercial
1958 afforestation in Southern Rhodesia. *Journal of the South African Forestry Association*, No. 32: 36-55.

STURROCK, D. *Eucalyptus* para Cuba. *Revista, Ministerio de Agricultura, Cuba*,
1946 29(3).

SUITER FILHO, W. & TAKESHI YONEZAWA, J. Survival of *Eucalyptus saligna* grafted by
1974 different methods. *New Zealand Journal of Forestry Science*, 4(2): 235-236.

SUJAN SINGH & PRATAP SINGH. Eucalyptus *diseases and insect pests in developing*
1975 *countries.* Document, Second World Technical Consultation on Forest Diseases and Insects (New Delhi, India, 7-12 April 1975).

SWAIN, E.H.F. *The forest conditions of Queensland.* Brisbane, Government Printer.
1928

TAGUDAR, E.T. Development of industrial plantations inside Paper Industries
1974 Corporation of the Philippines. In *Proceedings of the Forest Research Symposium on Industrial Forest Plantations.* Philippine Forest Research Society.

TAMBLYN, N. Problems of rail sleeper preservation in Australia. Commonwealth
1953 Scientific and Industrial Research Organization, Forest Products, *Newsletter,* Nos. 193-194.

TAYLOR, G. Climatology of Australia. *Handbuch der Klimatologie,* Bd. 4, Teil S.
1932 Australien und Neuseeland. Berlin, Gebr. Bornträger.

TAYLOR, G. *Australia.* London, Methuen.
1947

The Times concise atlas of the world. London, Times Newspaper Ltd.
1973

THORNTHWAITE, C.W. An approach toward a rational classification of climate.
1948 *Geographical Review,* 38(1).

TIMBER RESEARCH AND DEVELOPMENT ASSOCIATION. *Timber seasoning.* London.
1962

TINTO, J.C. Antecedentes sobre la impregnación de madera de eucalipto en la
1961 República Argentina, *Report of the Second World Eucalyptus Conference, São Paulo,* 2: 1176-1185.

TRABUT, L. Naturalisation d'un *Eucalyptus* en Algérie: *Eucalyptus algeriensis* Trab.
1914 *Bulletin de la Société botanique de France,* 61.

TRABUT, L. Utilisation des *Eucalyptus* dans le nord de l'Afrique. *Bulletin de la*
1921 *Station de recherches forestières du Nord de l'Afrique,* 1(6).

TROENSEGAARD, J., STOLZ, R. & LAÍNEZ CALDERÓN, C. *Proyecto siderúrgico de Agalteca.*
1973 *Breve exposición de los antecedentes, estudios realizados y experiencias con plantaciones de* Eucalyptus. (Mimeographed)

TROUP, R.S. *Exotic forest trees in the British empire.* Oxford, Clarendon Press.
1932

TRUMAN, R. Dieback of *Eucalyptus citriodora* caused by *Xanthomonas eucalypti* n. sp.
1974 *Phytopathology,* 64: 143-144.

TURNBULL, J.W. *The ecology and variation of* Eucalyptus camaldulensis *Dehn.*
1973 Rome, FAO. Forest Genetic Resources Information No. 2.

TURNBULL, J.W. Seed collection and handling in eucalypts. *Selected Reference*
1977 *Papers, International Training Course in Forest Tree Breeding,* p. 183-205. Canberra, Australian Development Assistance Agency.

TURNBULL, J.W. Exploration and conservation of eucalypt gene resources. *In* Third
1978 World Consultation on Forest Tree Breeding, Canberra. *Documents.* (FO-FTB-77-1/4)

TURNBULL, R.F. Taxonomy, harvesting, processing and utilisation of *Eucalyptus* trees
1950 in Australia. *Economic Botany,* 4(2).

TURNBULL, R.F. *Utilization of the eucalypts.* Melbourne, Commonwealth Scientific
1952 and Industrial Research Organization.

TURNBULL, V. & CLARKE, B. "Nordland" seed sower. Institute of Foresters of
1971 Australia. *Newsletter*, 12(3): 19-21.

UHLIG, S. A contribution to the mycorrhiza problem of eucalypts. *Zentralblatt*
1968 *für Bakteriologie und Parasitenkunde*, Abt. 2.122: 271-274.

UNESCO/FAO. *Bioclimatic map of the Mediterranean zone. Explanatory notes.*
1963 Paris, Unesco; Rome, FAO.

VAN BUIJTENEN, J.P., DONOVAN, G.A., LONG, E.M., ROBINSON, J.F. & WOESSNER, R.A.
1971 *Introduction to practical forest tree improvement.* College Station, Texas, Texas Forest Service. Circular 207.

VAN DER WESTHUIZEN, G.C.A. *Polyporus sulphureus*, a case of heartrot in *Eucalyptus*
1959 *saligna* in South Africa. *Journal of the South African Forestry Association*, No. 33: 53-56.

VAN DER WESTHUIZEN, G.C.A. *Cytospora eucalypticola* sp. nov. in *Eucalyptus saligna*
1965a from northern Transvaal. *Journal of the South African Forestry Association*, No. 54: 8-11.

VAN DER WESTHUIZEN, G.C.A. A disease of young *Eucalyptus saligna* in northern
1965b Transvaal. *Journal of the South African Forestry Association*, No. 54: 12-16.

VAN DER WESTHUIZEN, G.C.A. *Polyporus baudoni* Pat. on *Eucalyptus* spp. in South
1973 Africa. *Bothalia*, 11: 143-151.

Veneer from *Eucalyptus*. *Timberman*, 39(3).
1938

VENKATESH, C.S. *Pedigreed seed of two promising* Eucalyptus *species hybrids, FRI-4*
1978 *and FRI-5.* Rome, FAO. Forest Genetic Resources Information No. 6, Forestry Occasional Paper 1978/1.

VENKATESH, C.S. & SHARMA, U.K. Differential heterosis in reciprocal and interspecific
1978 crosses of *Eucalyptus camaldulensis* Dehn. and *E. tereticornis* Sm. *In* Third World Consultation on Forest Tree Breeding, Canberra. *Documents.* (FO-FTB-77-3/18)

VENKATESH, C.S. & VAKSHASYA, R.K. Effects of selfing, crossing and interspecific
1978 hybridization in *Eucalyptus camaldulensis* Dehn. *In* Third World Consultation on Forest Tree Breeding, Canberra. *Documents.* (FO-FTB-77-3/19)

VILMORIN, R. DE. Flore exotique acclimatée sur la Côte d'Azur. *Bulletin de la*
1950 *Société botanique de France*, 97(10).

VIVANCO DE LA TORRE, O. *et al.* *Croquis ecológico parcial del Ecuador.* Quito, Instituto Ecuatoriano de Reforma Agraria y Colonización.

WAHEED KHAN, M.A. *Single tree growth statistics for* Eucalyptus microtheca (*Gezira*
1966 *irrigation scheme); volume and other tables.* Forestry Research and Education Project, Sudan. Pamphlet No. 23.

WALLACE, A.R. *The Malay Archipelago, the land of the orang-utan and the bird of*
1913 *paradise. A narrative of travel with studies of man and nature.* London, Macmillan.

WALTER, HEINRICH & LIETH, HELMUT. *Klimadiagramm-Weltatlas.* Jena, Fischer
1967 Verlag.

WALTERS, G.A. Seedling containers for reforestation in Hawaii. *Proceedings of the*
1974 *North American Containerized Forest Tree Seedling Symposium.* Lincoln, Nebraska, Great Plains Agricultural Council. Publication No. 68.

WATT, G.R. *The planning and evaluation of forestry projects.* Oxford, Commonwealth
1973 Forestry Institute. Paper No. 45.

WATTLE RESEARCH INSTITUTE. *Handbook on eucalypt growing: Notes on the*
1972 *management of eucalypt plantations grown for timber in the wattle-growing regions of South Africa.* Pietermaritzburg, Wattle Research Institute.

WEBB, A.W. *The growth of mountain ash under plantation conditions.* Document,
1967 World Symposium on Man-made Forests and their Industrial Importance. Rome, FAO. FO/MMF:67-13/7.

WEBB, D.B. *The trial of exotic species in the semi-arid zone of Iran.* Oxford,
1974 Commonwealth Forestry Institute.

WERNSTEDT, F.L. *World climatic data.* Lemont, Ill., Climatic Data Press.
1972

WHITE, A.E. *Notes on reforestation cost estimates for* Eucalyptus deglupta *in Papua*
1975 *New Guinea.* Boroko, Papua New Guinea. Tropical Forest Research Note SR. 23.

WHITMORE, J.L. International provenance trial of *Eucalyptus deglupta* in Puerto Rico.
1973 In *Tropical provenance and progeny research and international cooperation,* ed. by J. Burley and D.G. Nikles. Oxford, Commonwealth Forestry Institute.

WHITMORE, J.L. & MACIA, S.F. *Eucalyptus* provenances tested in Puerto Rico: two
1975 years after outplanting. *Forest Science,* 21(4): 410-412.

WILHELMY, V. & KUBLER, H. Probe for measurement of strains inside solid bodies.
1973a *Experimental mechanics,* 13(3): 142-144.

WILHELMY, V. & KUBLER, H. Stresses and checks in log ends from relieved growth
1973b stresses. *Wood Science,* 6(2): 136-142.

WILLAN, R.L. *Fast growing tropical tree species.* Oxford, Commonwealth Forestry
1966 Institute. (Mimeographed. Limited distribution)

Wood pulp. Pulping properties of *E. maculata, E. rubida,* and *E. pilularis* from N.S.W.
1921 *Australian Journal of Forestry,* 4.

WRIGHT, J.W. *Introduction to forest genetics.* New York, Academic Press.
1976

WYK, G. VAN. Pollen handling, controlled pollination and grafting of *Eucalyptus*
1977 *grandis. South African Forestry Journal,* No. 101: 47-53.

WYK, G. VAN. Progress with the *Eucalyptus grandis* breeding programme in the
1978 Republic of South Africa. *In* Third World Consultation on Forest Tree Breeding, Canberra. *Documents.* (FO-FTB-77-3/13).

ZIMMER, W.J. *The flora of the far northwest of Victoria.* Melbourne, Forests
1937 Commission of Victoria.

FAO SALES AGENTS AND BOOKSELLERS

Algeria	Société nationale d'édition et de diffusion, 92, rue Didouche Mourad, Algiers.
Argentina	Editorial Hemisferio Sur S.A., Librería Agropecuaria, Pasteur 743, 1028 Buenos Aires.
Australia	Hunter Publications, 58A Gipps Street, Collingwood, Vic. 3066; Australian Government Publishing Service, Publishing Branch, P.O. Box 84, Canberra, A.C.T. 2600; and Australian Government Publications and Inquiry Centres in Canberra, Melbourne, Sydney, Perth, Adelaide and Hobart.
Austria	Gerold & Co., Buchhandlung und Verlag, Graben 31, 1011 Vienna.
Bangladesh	ADAB, 79 Road 11A, P.O. Box 5045, Dhanmondi, Dacca.
Belgium	Service des publications de la FAO, M.J. de Lannoy, 202, avenue du Roi, 1060 Brussels. CCP 000-0808993-13.
Bolivia	Los Amigos del Libro, Perú 3712, Casilla 450, Cochabamba; Mercado 1315, La Paz; René Moreno 26, Santa Cruz; Junín esq. 6 de Octubre, Oruro.
Brazil	Livraria Mestre Jou, Rua Guaipá 518, São Paulo 10; Rua Senador Dantas 19-S205/206, 20.031 Rio de Janeiro; PRODIL, Promoção e Dist. de Livros Ltda., Av. Venâncio Aires 196, Caixa Postal 4005, 90.000 Porto Alegre; A NOSSA LIVRARIA, CLS 104, Bloco C, Lojas 18/19, 70.000 Brasilia, D.F.
Brunei	SST Trading Sdn. Bhd., Bangunan Tekno No. 385, Jln 5/59, P.O. Box 227, Petaling Jaya, Selangor.
Canada	Renouf Publishing Co. Ltd, 2182 Catherine St. West, Montreal, Que. H3H 1M7.
Chile	Tecnolibro S.A., Merced 753, entrepiso 15, Santiago.
China	China National Publications Import Corporation, P.O. Box 88, Beijing.
Colombia	Litexsa Colombiana Ltda., Calle 55, N° 16-44, Apartado Aéreo 51340, Bogotá D.E.
Costa Rica	Libreria, Imprenta y Litografía Lehmann S.A., Apartado 10011, San José.
Cuba	Empresa de Comercio Exterior de Publicaciones, O'Reilly 407 Bajos entre Aguacate y Compostela, Havana.
Cyprus	MAM, P.O. Box 1722, Nicosia.
Czechoslovakia	ARTIA, Ve Smeckach 30, P.O. Box 790, 111 27 Praha 1.
Denmark	Munksgaard Boghandel, Norregade 6, 1165 Copenhagen K.
Dominican Rep.	Fundación Dominicana de Desarrollo, Casa de las Gárgolas, Mercedes 4, Apartado 857, Zona Postal 1, Santo Domingo.
Ecuador	Su Librería Cía. Ltda., García Moreno 1172 y Mejía, Apartado 2556, Quito; Chimborazo 416, Apartado 3565, Guayaquil.
El Salvador	Librería Cultural Salvadoreña S.A. de C.V., Calle Arce 423, Apartado Postal 2296, San Salvador.
Finland	Akateeminen Kirjakauppa, 1 Keskuskatu, P.O. Box 128, 00101 Helsinki 10.
France	Editions A. Pedone, 13, rue Soufflot, 75005 Paris.
Germany, F.R.	Alexander Horn Internationale Buchhandlung, Spiegelgasse 9, Postfach 3340, 6200 Wiesbaden.
Ghana	Fides Enterprises, P.O. Box 1628, Accra; Ghana Publishing Corporation, P.O. Box 3632, Accra.
Greece	G.C. Eleftheroudakis S.A., International Bookstore, 4 Nikis Street, Athens (T-126); John Mihalopoulos & Son, International Booksellers, 75 Hermou Street, P.O. Box 73, Thessaloniki.
Guatemala	Distribuciones Culturales y Técnicas "Artemis", 5a. Avenida 12-11, Zona 1, Apartado Postal 2923, Guatemala.
Guinea-Bissau	Conselho Nacional da Cultura, Avenida da Unidade Africana, C.P. 294, Bissau.
Guyana	Guyana National Trading Corporation Ltd, 45-47 Water Street, P.O. Box 308, Georgetown.
Haiti	Librairie "A la Caravelle", 26, rue Bonne Foi, B.P. 111, Port-au-Prince.
Hong Kong	Swindon Book Co., 13-15 Lock Road, Kowloon.
Hungary	Kultura, P.O. Box 149, 1389 Budapest 62.
Iceland	Snaebjörn Jónsson and Co. h.f., Hafnarstraeti 9, P.O. Box 1131, 101 Reykjavik.
India	Oxford Book and Stationery Co., Scindia House, New Delhi 110001; 17 Park Street, Calcutta 700016.
Indonesia	P.T. Sari Agung, 94 Kebon Sirih, P.O. Box 411, Djakarta.
Iran	Iran Book Co. Ltd, 127 Nadershah Avenue, P.O. Box 14-1532, Teheran.
Iraq	National House for Publishing, Distributing and Advertising, Jamhuria Street, Baghdad.
Ireland	The Controller, Stationery Office, Dublin 4.
Italy	Distribution and Sales Section, Food and Agriculture Organization of the United Nations, Via delle Terme di Caracalla, 00100 Rome; Libreria Scientifica Dott. Lucio de Biasio "Aeiou", Via Meravigli 16, 20123 Milan; Libreria Commissionaria Sansoni S.p.A. "Licosa", Via Lamarmora 45, C.P. 552, 50121 Florence.
Jamaica	Teacher Book Centre Ltd, 95 Church Street, Kingston.
Japan	Maruzen Company Ltd, P.O. Box 5050, Tokyo International 100-31.
Kenya	Text Book Centre Ltd, Kijabe Street, P.O. Box 47540, Nairobi

FAO SALES AGENTS AND BOOKSELLERS

Korea, Rep. of	Eul-Yoo Publishing Co. Ltd, 112 Kwanchul-Dong, Chong-ro, P.O. Box Kwang-Whamoon No. 363, Seoul.
Kuwait	Saeed & Samir Bookstore Co. Ltd, P.O. Box 5445, Kuwait.
Luxembourg	Service des publications de la FAO, M.J. de Lannoy, 202, avenue du Roi, 1060 Brussels (Belgium).
Malaysia	SST Trading Sdn. Bhd., Bangunan Tekno No. 385, Jln 5/59, P.O. Box 227, Petaling Jaya, Selangor.
Mauritius	Nalanda Company Limited, 30 Bourbon Street, Port Louis.
Mexico	Dilitsa S.A., Puebla 182-D, Apartado 24-448, Mexico 7, D.F.
Morocco	Librairie "Aux Belles Images", 281, avenue Mohammed V, Rabat.
Netherlands	Keesing Boeken B.V., Hondecoeterstraat 16, 1017 LS Amsterdam.
New Zealand	Government Printing Office: Government Bookshops at Rutland Street, P.O. Box 5344, Auckland; Alma Street, P.O. Box 857, Hamilton; Mulgrave Street, Private Bag, Wellington; 130 Oxford Terrace, P.O. Box 1721, Christchurch; Princes Street, P.O. Box 1104, Dunedin.
Nigeria	University Bookshop (Nigeria) Limited, University of Ibadan, Ibadan.
Norway	Johan Grundt Tanum Bokhandel, Karl Johansgate 41-43, P.O. Box 1177 Sentrum, Oslo 1.
Pakistan	Mirza Book Agency, 65 Shahrah-e-Quaid-e-Azam, P.O. Box 729, Lahore 3.
Panama	Distribuidora Lewis S.A., Edificio Dorasol, Calle 25 y Avenida Balboa, Apartado 1634, Panama 1.
Paraguay	Agencia de Librerías Nizza S.A., Tacuarí 144, Asunción.
Peru	Librería Distribuidora "Santa Rosa", Jirón Apurímac 375, Casilla 4937, Lima 1.
Philippines	The Modern Book Company Inc., 926 Rizal Avenue, P.O. Box 632, Manila.
Poland	Ars Polona, Krakowskie Przedmiescie 7, 00-068 Warsaw.
Portugal	Livraria Bertrand, S.A.R.L., Rua João de Deus, Venda Nova, Apartado 37, Amadora; Livraria Portugal, Dias y Andrade Ltda., Rua do Carmo 70-74, Apartado 2681, 1117 Lisbon Codex; Edições ITAU, Avda. da República 46/A-r/c Esqdo., Lisbon 1.
Romania	Ilexim, Calea Grivitei N° 64-66, B.P. 2001, Bucharest.
Saudi Arabia	University Bookshop, Airport Street, P.O. Box 394, Riyadh.
Senegal	Librairie Africa, 58, avenue Georges Pompidou, B.P. 1240, Dakar.
Singapore	MPH Distributors (S) Pte. Ltd, 71/77 Stamford Road, Singapore 6; Select Books Pte. Ltd, 215 Tanglin Shopping Centre, Tanglin Road, Singapore 1024; SST Trading Sdn. Bhd., Bangunan Tekno No. 385, Jln 5/59, P.O. Box 227, Petaling Jaya, Selangor.
Somalia	"Samater's", P.O. Box 936, Mogadishu.
Spain	Mundi Prensa Libros S.A., Castelló 37, Madrid 1; Librería Agrícola, Fernando VI 2, Madrid 4.
Sri Lanka	M.D. Gunasena & Co. Ltd, 217 Olcott Mawatha, P.O. Box 246, Colombo 11.
Sudan	University Bookshop, University of Khartoum, P.O. Box 321, Khartoum.
Suriname	VACO n.v. in Suriname, Dominee Straat 26, P.O. Box 1841, Paramaribo.
Sweden	C.E. Fritzes Kungl. Hovbokhandel, Regeringsgatan 12, P.O. Box 16356, 103 27 Stockholm.
Switzerland	Librairie Payot S.A., Lausanne et Genève; Buchhandlung und Antiquariat Heinimann & Co., Kirchgasse 17, 8001 Zurich.
Tanzania	Dar es-Salaam Bookshop, P.O. Box 9030, Dar es-Salaam; Bookshop, University of Dar es-Salaam, P.O. Box 893, Morogoro.
Thailand	Suksapan Panit, Mansion 9, Rajadamnern Avenue, Bangkok.
Togo	Librairie du Bon Pasteur, B.P. 1164, Lomé.
Trinidad and Tobago	The Book Shop, 22 Queens Park West, Port of Spain.
Tunisia	Société tunisienne de diffusion, 5, avenue de Carthage, Tunis.
United Kingdom	Her Majesty's Stationery Office, 49 High Holborn, London WC1V 6HB (callers only); P.O. Box 569, London SE1 9NH (trade and London area mail orders); 13a Castle Street, Edinburgh EH2 3AR; 41 The Hayes, Cardiff CF1 1JW; 80 Chichester Street, Belfast BT1 4JY; Brazennose Street, Manchester M60 8AS; 258 Broad Street, Birmingham B1 2HE; Southey House, Wine Street, Bristol BS1 2BQ.
United States of America	UNIPUB, 345 Park Avenue South, New York, N.Y. 10010.
Uruguay	Librería Editorial Juan Angel Peri, Alzaibar 1328, Casilla de Correos 1755, Montevideo.
Venezuela	Blume Distribuidora S.A., Gran Avenida de Sabana Grande, Residencias Caroni, Local 5, Apartado 70.017, Caracas.
Yugoslavia	Jugoslovenska Knjiga, Trg. Republike 5/8, P.O. Box 36, 11001 Belgrade; Cankarjeva Zalozba, P.O. Box 201-IV, 61001 Ljubljana; Prosveta, Terazije 16, P.O. Box 555, 11001 Belgrade.
Zambia	Kingstons (Zambia) Ltd, Kingstons Building, President Avenue, P.O. Box 139, Ndola.
Other countries	Requests from countries where sales agents have not yet been appointed may be sent to: Distribution and Sales Section, Food and Agriculture Organization of the United Nations, Via delle Terme di Caracalla, 00100 Rome, Italy.

P-32
ISBN 92-5-100570-2

Tipo-lito-fotocomposizione Sagraf - Napoli

MAXWELL RALPH JACOBS

Dr Maxwell Ralph Jacobs, the main author of this new edition of *Eucalypts for planting*, died in October 1979. One of Australia's most distinguished foresters, he was, when he retired after 44 years in the public service, Director-General of the Forestry and Timber Bureau and Chairman of the Standing Committee of the Australian Forestry Council.

His forestry education had the advantages of great diversity, with studies at Adelaide, Oxford, Tharandt and Yale universities, and he always maintained an intense interest in international forestry. He undertook a number of forest consultancies, including missions for FAO to Argentina, India and Brazil.

In his early years he became greatly interested in the eucalypts and in research on their growth. Much of this work was consolidated in his best-known publication, *The growth habits of the eucalypts* (1955). He was therefore the ideal man to undertake the preparation of this new edition of *Eucalypts for planting*, which he regarded as the most important work of his life.

P-32
ISBN 92-5-100570-2