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International Development Research Centre

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PROCEEDINGS OF A
WORKSHOP ON
TAXONOMY AND SEED HANDLING
OF
AUSTRALIAN TREE SPECIES IN
EASTERN AND SOUTHERN AFRICA

Harare, Zimbabwe, 08-12 July 1985

Organized by the International Development Research Centre (Canada) in collaboration with the Zimbabwe Forestry Commission, the Regional Forest Seed Centre of Zimbabwe, and the Australian Centre for International Agricultural Research.

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The International Development Research Centre is a public corporation created by the Parliament of Canada in 1970 to support research designed to adapt science and technology to the needs of developing countries. The Centre's activity is concentrated in five sectors: agriculture, food and nutrition sciences; health sciences; social sciences; information sciences; and communications. IDRC is financed solely by the Parliament of Canada; its policies, however, are set by an international Board of Governors. The Centre's headquarters are in Ottawa, Canada. Regional offices are located in Africa, Asia, Latin America and the Middle East.

CONTENTS

FOREWORD

The IDRC-funded regional seed centre (R.S.C.) project in Zimbabwe started in late 1984. It is the result of a workshop in Harare in January of that year, that brought together forestry researchers and policy-makers of eastern and southern Africa to discuss collective action on the problem of seed procurement.* Based on their recommendation that a regional centre should be established, IDRC, at the invitation of the Government of Zimbabwe, agreed to support the expansion of the Foresty Commission's seed centre to serve the region in a coordinating role.

Membership in this cooperative venture is informal and open to any country willing to share information on species performance and seed technology and to work actively with other African states to solve common seed problems. Participation in centre-related activities and in the work of the centre automatically confers membership.

One of the major functions of the R.S.C. is to help standardize seed technology procedures by organizing workshops, seminars and training courses for the technical personnel of national seed centres. This publication is a result of such a workshop which included researchers from Ethiopia, Kenya, Malawi, Mozambique, Swaziland, Tanzania, Uganda, Zambia and Zimbabwe.

Besides being a forum for the exchange of information on a common problem, workshops, conferences and similar activities promote understanding and goodwill among researchers which last long after the workshop has ended. Such activities are considered by IDRC to be an important means of supporting countries to build research capacities and innovative skills to solve their own problems in their own way.

* Proceedings of a Workshop to Discuss the Establishment of a Regional Forest Seed Centre; June, 1985 (available on request from IDRC-Nairobi).

IDRC acts in concert with many organizations to make these gatherings possible. This particular workshop was very effectively organized by the staff of the Forest Research Centre (Zimbabwe Forestry Commission) under the direction of the Divisional Manager, Mr. Lyn Mullin, with the able assistance of Mr. Richard Seward, project leader of the regional seed centre. An advisory committee consisting of Messrs Mullin and Seward, Mr. Aaron Mubita, geneticist with the Zambian Forestry Department and Ato Berhanu Hika, Director of Forest Research of the Ethiopia Forest Service provided valuable input on the agenda to ensure regional needs were met. I am grateful to all these people who devoted their time and expertise on behalf of the countries of the region.

Because of the importance to African countries of Australian species of Eucalyptus, Acacia and Casuarina in fuelwood and roundwood production (poles and posts), in environmental protection and amelioration, and in agroforestry systems, the focus of this first R.S.C. workshop was on the taxonomy of these genera and the procedures for the collection, handling, testing and storage of their seed. Without the presence of three prominent Australian scientists of the Division of Forest Research, C.S.I.R.O. (Commonwealth Scientific and Industrial Research Organization), the workshop would have been extremely difficult, if not impossible, to hold. IDRC and the Zimbabwe Forestry Commission warmly acknowledge the generous support of the Australian Centre for International Agricultural Research (A.C.I.A.R.) for making it possible for Mr. Doug Boland (CSIRO-Canberra), Dr. Ken Eldridge (CSIRO-Canberra) and Mr. Ian Brooker (CSIRO-Perth) to attend.

The papers contained in this publication are state-of-the art on the subjects of taxonomy and seed technology of Australian species and represent an important contribution to the work of the regional seed centre in Zimbabwe.

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SELECTION OF SPECIES AND PROVENANCES FOR TREE INTRODUCTION

By D.J. Boland

Introduction

All tree planting programmes require clearly stated objectives before planting commences with all economic, staff and time-frame constraints being carefully analysed and documented. A study of the expected goals and final results of similar projects, including personal visits if possible, are desirable pre-planting exercises. A properly conceived programme is vital if the pitfalls of rushing in and expecting too much too soon are to be avoided.

The selection of species is still not a precise science and is largely reliant upon personal knowledge, judgements and experience augmented by literature reviews. Thorough knowledge of the planting site, the proposed end-use of the trees and of the range of potentially suitable species available is required. Few individuals or groups have all this knowledge and it is essential that a research component involving species, seed sources and also management and silvicultural options be built into any new program. Although there have been instances where a single species has been chosen and planted widely from the start one should be aware that new "miracle" species often have not been adequately tested and may not meet the project's expectations. Prospects for national, bilateral or international co-operation with species trials should be explored as the benefits can be great and the experience rewarding and stimulating to the workers involved.

The problem of selecting tree species for non-industrial uses in developing countries has been made more difficult because of the recent world awareness of the importance of forestry to rural development and the pressure to achieve some useful results quickly. There is often a lack of experienced forestry staff for the work involved. Reliable information on ecological, silvicultural and utilisation characteristics of many potentially valuable species is still unavailable and hampers species selection. Typically, emphasis is still given to fast-growing trees for fuelwood, shelter and other agroforestry uses but as more detailed knowledge of species is acquired it may be possible to trade-off species with rapid growth for those with slower growth but which have greater resistance to drought, fire or pests, lesser water and nutrient requirements, or providing more valuable wood products. Compounding these problems is the difficulty in properly evaluating species' performance, especially for those species providing more than one product or benefit.

The aim of this chapter is to give a short history of tree introduction, including the conflict which may arise when exotic species are favoured over trees native to the region. The qualities required of woody species to provide fuelwood, roundwood (poles and posts), fodder, live fences, windbreaks, shade, soil improvement and protection are examined as these are the major requirements for species within the scope of this book. Procedures for evaluating planting sites are discussed followed by a brief review of current methods used for the selection of species and seed sources (provenances).

HISTORY OF TREE INTRODUCTION

1. A world overview

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

There are similar examples of food tree crop introduction in tropical regions. Baob trees (*Adansonia digitata*) were reputedly introduced into India from Africa by either Arab traders or Indian seafarers in the 7th or 8th century (Vaid, 1978) while the Makassan trepangers (Indonesian fishermen) brought tamarind (*Tamarindus indica*) to the northern coasts of Australia before European colonisation (Macknight, 1976). The Indonesian clove tree (*Eugenia aromatica*), a food spice whose properties were known from early times (at least 300 B.C. in China) has been cultivated outside Indonesia for about 200-300 years (Cobley, 1956). The oily seeded candlenut (*Aleurites moluccana*) and the breadfruit (*Artocarpus incisor*) are examples of species that were probably spread widely by the Pacific Islanders prior to European settlement.

By comparison, the history of tree introduction for non-food purposes is much more recent. The Romans are believed to have introduced the shrubby plant Rhus coriarea into Spain to use its leaves as a tannin source (Gonzalez, 1982), while in East Africa Arab dhow captains planted Casuarina equisetifolia to mark harbour entrances clearly (Perry and Willan, 1957). Though native trees were used in situ for a wide range of non-food uses such as shelter, weapons and handicrafts, it was not until the 19th century that scientifically managed plantations of native and exotic species were established. The plantations provided wood products such as sawn timber, fuel for railways and more recently, paper pulp. Extensive plantations of exotic pines and eucalypts were planted widely during the 20th century for industrial wood and this development overshadowed the need, especially among developing nations, to cultivate trees for other purposes such as fuelwood. There was realization by the 1970s of the detrimental impact that the exploding world population was having on woody vegetation. Excessive cutting of fuelwood, overgrazing and more widespread shifting cultivation have led to the serious degradation of the native tree flora in many areas.

The scientific techniques and methodology employed in species selection, introduction and breeding developed for industrial plantations can be adapted for selecting trees for non-industrial uses. It is necessary to change only the selection criteria and some of the management techniques. There is no doubt that the range of species available for selection is greatly increased because of the diversity of products and because tree size, stem straightness and wood quality, are no longer such vital factors. Small, rapidly-growing trees and shrubs are often more suitable than large trees for village or farm planting.

The major research effort in any tree improvement programme involving tree species for the so-called "non-industrial" uses must be in the initial species screening stage. Unfortunately this is made difficult by the serious lack of basic information on suitable species to be included in trials. Once field trials have commenced basic attributes such as growth rate and tree form can be determined. If the species seems promising it should be tried in, say, multicrop situations to examine field performance more closely. There is no point in continuing classical tree improvement pathways until it is certain the species is worthy of further research investment.

Despite the benefits which can be derived from planting exotics, there exists in some countries a belief, mainly among environmental groups, that native trees only should be planted. Forest history has never supported this strident view. However these groups maybe motivated by nationalistic, spiritual or other worthy motives and their influence can have considerable adverse political impact. Examples include opposition to planting eucalypts in India and Burma because of their supposed excessive water requirements and in Spain because of the putative poisonous effect of leached leaf oils on soil micro-organisms.

Criticisms of exotics may be justified on other grounds especially in cases where a poorly adapted species has been used for large-scale planting. In southern Spain for example, the drought susceptible *E.globulus* has been widely planted in dry areas where the stressed plants are attacked by the longicorn beetle (*Phoracantha semipunctata*), causing widespread growth retardation and even death. Similarly, black wattle (*Acacia mearnsii*), an otherwise valuable tree for tannin, roundwood, fuelwood and pulp, has escaped from cultivation and become a weed in certain parts of South Africa and elsewhere. These examples suggest that species must be chosen carefully by species introduction officers and plantation planners who have a long term social responsibility for the consequences for their decisions. While it is highly desirable to promote native trees in cultivation and to include them in trials, the long history of successful exotic introduction suggests that one should not be too timid in searching for and testing a wide-range of new and potentially valuable species.

2. A brief perspective of the Australian forest resource

While much is known of northern hemisphere trees, those of Africa, Australia and South America are less well-documented due largely to language, cultural and developmental difficulties. This does not imply that the native populations were unaware of the value of trees and shrubs occurring in their regions. In fact the hunters and gatherers relied very heavily on their local knowledge of plants and used them for food, medicine and shelter. The Australian Aborigines lived on the continent for some 30 000 - 40 000 years before the arrival of Europeans in the late 18th century and had an intimate knowledge of the plants and animals that made up the Australian landscape. At least 170 central Australian plant species were utilised by the Aborigines (Latz and Griffin, 1978). The seeds of acacias such as *A.holosericea*, *A.cowleana* and *A.victoriae* provided valuable protein while sugars were obtained from acacia gum exudates or from the nectars of Hakea and Grevillea flowers. Medicines were prepared from many woody plants and the leaves of species such as corkwood (Duboisia myoporoides) and various acacias were used to stun fish in waterholes. European settlement and the subsequent export of seeds of eucalypts, acacias, grevilleas and other native plants around the world exposed a wealth of interesting species with a wide spectrum of uses.

Australia is rich in species with characteristics suitable for fuelwood and other purposes. The Australian region appears to have the widest array of primitive angiosperm families in the world (Webb and Tracey, 1981) and this suggests a relatively long period of preservation of environments. In addition the recent and relatively benign activities of Aboriginal man (except for fire) and the lack of destructive wild animals meant that the forest estate was relatively diverse and well protected when European man arrived. There is no doubt that a good reservoir exists in Australia of a wide range of new trees and shrubs for fuelwood and other purposes. This is particularly so in the northern part which has a climate similar to that of many countries having a serious need for appropriate tree species and a wide range of poorly explored but promising species.

WHY EXOTICS HAVE BEEN OFTEN SUCCESSFUL

As a general rule, exotics have proved very successful in most countries, out-performing native trees in cultivation. Notable exceptions have occurred; for example, trials of over 600 exotic and native species in the Pacific northwest of the United States indicated that only native species such as Douglas fir, were suitable for plantations (Silen, 1962). Further investigation is required if the reasons for the successful performance in plantations of natives (compared with exotics) is to be understood. While exotics usually grow faster than native species it is curious that only a small number of exotic species have grown exceptionally well. Pinus radiata in temperate regions and E.grandis in subtropical areas are examples.

The poor performance of native trees in cultivation may be related to the lack of genetic diversity in their ancestors. It may also be related to the paucity of species in the original forest from which new species could evolve as environmental conditions changed. In Europe for instance, the recent ice age squeezed and reduced the forest flora against latitudinally-oriented high ranges thus severely limiting the forest resource left to evolve and adapt on the young fertile soils deposited after the ice retreated. Similarly in southern Africa, it is surprising that few species were able to evolve for the veldt from the neighbouring lowland forests. The precise reasons for this latter situation is difficult to ascertain but is possibly related in part to the lack of genetic diversity in the original forest from which particular specially adapted species could evolve.

The question posed is why an exotic will grow faster than a native when cultivated together on the same site ? The answer must be related in part to the selection pressures operating on the available original flora, directing the evolution of new species and moulding adaptive biological responses to the changing environment. In this sense no two areas in the world would ever be exactly similar and plants evolving in one site under fiercer competitive conditions involving a wider or better range of progenitors over a longer time period must be at an advantage. These new species when transferred by man to other similar environments would then have a competitive edge over native plants in the area. In Australia it is possible to suppose that eucalypts evolved from rainforest progenitors growing on more fertile soils. Eucalypts were successful in colonising sites having relatively lower moisture regimes and less fertile soils. In addition they developed biological responses such as coppice and lignotuberous mechanisms to withstand drought and fire, and an indeterminate shoot pattern to take advantage of favourable conditions for rapid growth. Such responses make them ideal plantation trees.

In exotic situations, many of the restrictive environmental factors affecting growth in a native forest are drastically modified. For instance, the land is often cultivated, the soil fertilized and seedlings planted during the most favourable time of the year. It is also often found that when trees are removed from their indigenous pests and diseases they perform better. Plantation rotation lengths are usually shorter than the interval between past episodic climatic events that may have determined the present character and composition of the native flora.

All these factors, individually and in combination, are some important reasons for exotic tree species performing better than native trees when cultivated together.

QUALITIES REQUIRED OF SPECIES FOR AGROFORESTRY AND FUELWOOD

Agroforestry is defined as "a group of land management techniques implying the combination of forest trees with crops, or with domestic animals, or both. The combination may be either simultaneous or staggered in time and space. The goal is to optimise per unit of area production whilst at the same time respecting the principle of sustained yield" (Combe and Budowski, 1979). Trees and shrubs are the dominant feature of mature agroforestry systems and in choosing species for a system it is necessary to decide: (1) what species ? (2) how many trees ? (3) how should the trees be arranged ? To resolve these questions one must understand and appreciate those characteristics which may, on the one hand, enhance the value or on the other diminish their suitability for any particular agroforestry system (Huxley, 1983). Technical, managerial and socio-economic considerations must all be addressed.

Agroforestry is not a new concept and it has been practised by many groups of people in various ways over long periods of time, e.g. shifting cultivation in the tropics. Agroforestry is especially relevant where land is scarce and when there is a great shortage of forest products in intensively worked agricultural areas. For example, in the densely settled central area of Java, an average of 85% of all fuelwood for domestic rural consumption comes from farmland plantings of multipurpose trees. Nevertheless, as King, (1979) has correctly commented, agroforestry is equally important in fragile or marginal environments.

It has become common practice to talk of 'multipurpose trees' implying that a single tree should be capable of producing a range of products. A multipurpose tree, has been defined, in relation to agroforestry '...a tree which clearly constitutes an essential component of an agroforestry system or of other multipurpose landuse systems. Regardless of the number of its potential or actual uses,a multipurpose tree has to have the capacity to provide in its specific function(s) in the system a substantial and recognisable contribution to the sustainability of yields, to the increase of outputs and/or reduction of inputs, and to the ecological stability of the system. Only a tree which is kept or maintained or introduced into an agroforestry system specially for one or more of these purposes qualifies as a multipurpose tree' (Burley and Von Carlowitz, 1984). This goal of using a single species to produce several products is commendable but it must be realised that the managed production for one product may influence, possibly adversely, the production of another. In dehesa farming of Quercus ilex in Spain, the lopping of branches for fodder and fuelwood is said to increase acorn production for pig farming but presumably this reduces wood production. Similar management decisions are described by Poulsen, (1983) in Kenya who notes the practice of pruning Grevillea robusta windbreaks for fuelwood to reduce shade and moisture competition with neighbouring agricultural crops.

The complexity of agroforestry systems is also highlighted by multicropping systems in Kerala, India. In high rainfall sites and good soils, emphasis is placed on vertical stratification of crops. Here coconuts, tropical fruit trees, climbing plants and cereal crops are grown in mixtures or admixtures so that each occupies a given horizontal stratum within the field so that all crops can benefit to some degree.

This section examines a restricted list of special uses for which tree species may be required but in doing so attempts to cover the major uses of species falling within the scope of this book. The unifying concept of agroforestry is discussed briefly but the tree introduction officer is referred to more comprehensive texts for a more detailed examination of this topic.

(1) Fuelwood

Fuelwood is required by both industrial and non-industrial nations but need is much greater in developing countries where domestic fuelwood is often essential for cooking and heating. Charcoal has an advantage over wood as a fuel in that larger diameter logs can be utilised in its production and transport and storage problems are minimised for city markets. Native people who traditionally obtain fuelwood from indigenous species whose burning and smoke properties are well-known, are often extremely reluctant to change to exotic woods for a number of psychological or practical reasons. These preferences must be considered in the selection of species for fuelwood.

The qualities needed for fuelwood can be divided into the physical properties of the wood and silvicultural/environmental properties of the species. Thornless trees or shrubs with small stem diameters are easier to cut with primitive implements and to transport. The wood should be easy to split and have a low moisture content or be relatively fast drying as considerable heat is lost in burning moist wood. For health reasons, smoke should be minimal and non-toxic (see Poynton, 1984) as ventilation is traditionally poor in most native houses. Sherpas in Nepal suffer respiratory problems resulting from home fires in confined spaces. However, in these same homes, the smoke has helped extend the lives of beams and thatched roofs by inhibiting insect attack. For safety reasons wood should not spit or spark while burning. Calorific values are not available for most species but there is usually a positive correlation between high wood density and heat produced per unit weight (calorific value). A negative correlation often exists between fast growth rate and density so that fast-grown trees have inferior burning qualities compared to those which have grown more slowly. The best firewood burns slowly, producing good heat from glowing coals. Some acacias have particularly good burning properties and casuarinas are also highly regarded firewood species.

Desirable silvicultural and environmental properties of fuelwood species are given by Burley (1978) and NAS (1980). These include:

a) rapid growth, even on poor soils;
b) ability to stabilise and improve the environment;
c) minimal management requirements;
d) disease and pest resistance;
e) ability to coppice;
f) hardiness to survive drought and other ecological stresses; and
g) suitability for multiple use.

Most of these qualities are not related solely to the use of trees for fuelwood.

(2) Roundwood (Poles and Posts)

It is worthwhile to review some of the uses of poles and posts as these products are very important for home building and fences in many developing countries. Despite the importance, surprisingly little has been written about the management of trees for roundwood production or the use of roundwood timbers.

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

Poles are in great demand for rural house construction especially as rafters which can bear heavy cross loads. In Africa, black wattle (Acacia mearnsii) or eucalypts are often used as house poles. In urban areas, poles are required for scaffolding and it is not uncommon in India to see tall buildings surrounded by a maze of bamboo, eucalypt or casuarina poles.

Poles are often required in mining areas. In Zimbabwe there is a requirement for thin poles to ram explosives into specially drilled holes and there is an extensive use for poles for 'mat-packs' (solid piles of logs wired together and stacked horizontally) in South African gold mines. The Chinese use the majority of produce from eucalypt plantations as props in mines.

In developing countries, posts are required for house walls and supports. In both developed and developing countries posts are used for fencing, for marine piles (the principal use of C.junghuhniana in Thailand is for marine piles) and for the construction of wharves,etc.

Qualities of species for suitability as poles can be divided into wood and silvicultural characteristics. Poles should be:

a) durable;
b) light;
c) capable of taking high cross loads (high strength to diameter ratios for a given length is vital);
d) have minimal spirality to avoid opening up when in use;
e) resistant to termites and other wood borers easily; or
f) capable of taking preservatives easily.

The tree should be:

a) straight, having strong apical dominance;
b) fewer thin branches and preferably self-pruning without leaving knots that cause weakness;
c) little taper from bottom to top; and,
d) the bark should strip easily.

For a discussion of the utilisation of eucalypt roundwood see Hillis and Brown, (1978).

Similar properties are required of posts. Larger diameter sizes are usually required and they should be durable in the ground or in water, and be able to take high end loads, e.g. if used as house bearing posts. The wood of many acacias is very durable and suitable for fencing. Acacia acuminata, for example, is extensively used as fence posts across the southwest of Western Australia.

(3) Fodder

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

Management problems have rarely been examined. Fodder trees have to be carefully protected during their early years from all forms of livestock, especially goats. Trees should produce large crowns above livestock reach. The crowns must be capable of severe lopping during periods of high environmental stress. Alternatively, in intensively managed agricultural areas, trees can be grown totally protected and the leaves then harvested and fed to livestock, e.g. Leucaena leucocephala.

(4) Live Fences

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

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

(5) Shade

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

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

(6) Windbreaks

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

There are several outstanding examples of successful windbreaks around the world. Since 1949, a 3000km long windbreak of *Casuarina equisetifolia* has been established in China along the coast bordering the South China Sea. This has provided shelter for crops growing on the leeward side and has also stabliised drifting sand in the area (Turnbull, 1983). In Egypt, *Casuarina* shelterbelts have also been grown to protect agricultural land mainly from wind erosion (El-Lakany, 1981). In New Zealand, windbreaks of *Pinus radiata* effectively provide shelter for stock from cold winds. The windbreaks are often trimmed on their sides and tops to prevent too much shading of pastures and occasional selected trees are pruned for sawlog production. By comparison, the extensive windbreaks of *Eucalyptus cladocalyx* in southern Australia and of *E.diversicolor* in parts of South Africa have only a limited useful life because of the shedding of the lower limbs. These examples suggest that species selection is important and that windbreaks can be modified or manipulated.

Some of the qualities required are:

a) tolerance of harsh environmental conditions;
b) a bushy deep crown but allowing some wind penetration;
c) delayed shedding of lower limbs;
d) wind firmness of roots;

e) rapid growth if early protection required;
f) long life;
g) pest and disease resistant. They should also not harbour pests of neighbouring crops; and,
h) roots not competing excessively for water and nutrients with adjacent crops.

(7) Soil protection - erosion control

Trees are often required to prevent soil loss through wind or water action and often very hardy trees for poor sites are required. The basic idea is to prevent soil movement by root-binding the soil, preventing direct impact of raindrops or by increasing the percolation of water through the soil. Leaf fall also provides a ground cover to further protect the soil.

Casuarina equisetifolia has helped to stabilise coastal sand dunes in India by binding the sand with numerous fine roots and preventing sand movement by the heavy and continuous shedding of branchlets which form a thick and slowly decomposing interlocked mulch on the sand surface (Kondas, 1983). In South Africa, North Africa and the Middle East, *Acacia saligna* was introduced and used extensively and successfully to control sand-drifts but in South Africa it has now become a noxious weed (Anon, 1980b). In Argentina, *Casuarina cunninghamiana* has been used successfully to control streambank erosion in the delta region of the Parana river (Mendonza,1981). In high rainfall areas of Java, *Acacia auriculiformis* produces dense foliage thus providing ground cover while their extensive root system helps bind the soil (NAS, 1980). *Melaleuca quinquenervia* was planted in swampy and bog areas of Hawaii resulting from clearing of the natural vegetation to help stabilise the soil surface and to increase water penetration.

Common tree qualities sought for erosion control are:

a) fast and healthy growth under adverse conditions;
b) spreading crowns;
c) vigorous root system with soil binding properties;
d) either vigorous vegetative reproduction, e.g. root suckers, or heavy natural seed fall and natural seedling development *in situ* without the tendency to become a weed;
e) trees having roots with high strength values - especially in areas prone to land slip; and,
f) fire tolerance.

(8) Soil improvement

This usually involves planting trees to increase the nitrogen content of the soil. Nitrogen-fixing species contain nitrogen-fixing organisms (Rhizobium or Frankia) in their roots and have the ability to return nitrogen to the soil through root decomposition or leaf fall. Such species may be rotated with other crops or grown as mixtures such that one may benefit from nitrogen and the other perhaps from shade. On the sandy west coast of the North Island of New Zealand, ground lupins are sown first and are essential for the successful establishment of Pinus radiata on these sites. In East Java, farmers sometimes rotate agricultural crops with plantations of Calliandra calothyrsus and in the highlands of New Guinea, Casuarina oligodon is planted amongst cash crops such as coffee to provide shade and to improve soil fertility (Thiagalingam, 1983). Green manure is prominent in some countries and leaves of Leucaena leucocephala are said to rival animal manure in nitrogen content (NAS, 1980) and can be collected and dug into fields for agricultural crops.

There is considerable international interest in growing mixtures of leguminous and non-leguminous species. Large experimental trials have been established in Hawaii examining total biomass productivity with mixture of E.saligna and either Sesbania grandiflora or Cassia siamea. There are few successful examples of species mixtures around the world.

Soil improvement can also occur through the transfer of nutrients from the lower solum (that may move there through leaching or released by decomposing parent materials) to soil surfaces where they are available to crop and pasture plants. Certain plant mycorrhizal associations are also able to tap refractory phosphate thus improving available phosphorus levels in phosphorus fixing soils.

SITE ASSESSMENT

Procedure for evaluating the planting site

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

1. Physical, edaphic and vegetational factors of the land

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

Maps at a scale of at least 1:100 000 or 1:50 000 of the planting area are essential. These should indicate latitude, altitude and small detailed topographical features, e.g. aspect, slope, swamps, rivers, rocky hilltops. Other maps showing soil type, native vegetation and land use should be obtained or compiled. Special biotic characteristics, e.g. in South Africa, snout-beetle attack for eucalypts is more common at higher altitudes, can be noted.

2. Climatic factors

It is recognised that meteorological stations are rarely located at proposed plantation sites and that some extrapolations are needed. Where possible, Burley and Wood,(1976) suggest that the following data should be assessed for each site type:

a) mean annual total preciptation;
b) mean monthly precipitation;
c) mean annual temperature;
d) mean monthly relative humidity percentage;
e) mean monthly temperature;
f) mean daily minimum temperature for the coldest month;
g) absolute minimum temperature recorded;
h) mean daily maximum temperature of the hottest month;

i) absolute maximum temperature recorded;

j) mean range of temperature;

k) mean monthly wind speed at 2m above ground level; and,

l) the number of years of observation for each of the above should be recorded.

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

In recent years, more complex climatic indices indicating likely or anticipated crop growth have been developed so that more precise matchings can be made between a plant in its natural range and its performance in an exotic situation. This has been applied for crops (see Fitzpatrick and Nix, 1970) to determine suitable areas for growth. A further programme has been developed whereby the climate at any particular point in any country can be matched with those areas of Australia having an approximately similar climate and this provides a guide to the selection of provenances of particular species within the designated climatic zone (see Booth, 1985).

3. Mapping site types

Once the physical, edaphic, vegetational and climatic factors have been established, the various site groupings can be mapped out. This should be done on topographic maps and positions for species trials can then be selected in advance of actual species introductions. These positions may be located randomly within each site type or determined precisely because of other constraints, e.g. easy access, land available for trials, ease of protection, the fragmented nature of the planting area, etc. These practical considerations are almost always overriding factors in any introductory work.

PROCEDURES FOR SELECTION OF SPECIES AND PROVENANCES

This stage should proceed in a logical and systematic manner once the species qualities and site conditions have been determined. Two serious problems traditionally impede progress; they are lack of knowledge of suitable species and availability of seed.

1. Local appraisals of species near the planting sites

Both native and previous exotic introductions should be carefully examined. All relevant local literature should be consulted and appropriate people contacted.

(1.1) Native trees

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

(1.2) Local exotics

It is rare for any country these days not to have some promising exotic trees. Often these may be found in botanic gardens, on farms, alongside streets, in parks and around old established farmhouses. A survey of these trees should be made as early as possible. This should provide information on species to plant, countries where suitable species may be found, or indeed, taxonomic groups of species worthy of further study, e.g. if one member of a particular genus is performing well then others should be tried, particularly species from similar environments.

2. Selection of exotics

The most commonly employed method for selection is environmental matching. This may involve examining native trees in their home climatic environments or their performance in trials as exotics in other countries with similar environmental conditions. It is preferable that this latter step be taken first. For example, information on exotics can be gathered from Streets, (1962) for a wide range of species grown in the British Commonwealth, from Poynton, (1979) and FAO, (1979) for eucalypts and from NAS, (1979) for tropical legumes. For information on specific topics one can consult NAS, (1980, 1983) for fuelwood species or FAO, (1963) for tree species and planting practices in arid zones.

(2.1) Climatic Matching

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

One serious disadvantage with climatic matching is that some species are very plastic and perform well way outside their natural climatic range, e.g. *E.robusta* performs well from tropical to nearly temperate parts of Brazil. Other species may have their natural range severely restricted, by say fire, thus invalidating climatic matches. More serious however is the lack of information available on potential tree crops within climatic ranges.

(2.2) Information Exchange

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

(2.3) Development of data banks on individual species

The concept of developing modules of information on species has been recently promoted by Hackett, (1983), especially for agricultural crops, but it is equally relevant to tree crops. The object is to compile, for all crop plants, standard lists of information divided into packages (or modules) for each data set (e.g. weed properties, use for food, etc.). This information can be stored in computers and extracted through use of software termed "relational data bases". Alternatively information may be made available in the form of punched cards for manual sorting. Species are then selected according to special criteria, e.g. frost resistance. Webb *et al.*, (1980) produced the first forestry data set when they compared up to 82 characters for about 125 of the world's most important forest trees.

STAGES OF SPECIES INTRODUCTION AND ASSOCIATED TREE IMPROVEMENTS

The stages (phases) developed for the selection of species and provenances for industrial plantations need modifying according to objects of planting trees for non-industrial use. Some of the steps have been adapted from Burley and Wood, (1976). Some simple, safe steps include an arboretum phase, a species elimination phase, a species testing phase, a species proving phase and a species provenance phase. In sophisticated programs a tree breeding phase involving individual tree selections and controlled crossing can be developed after the provenance phase. Some of the following steps are conducted simultaneously.

1. Arboretum phase

This is one of the most interesting and stimulating phases of tree introduction but unfortunately it is usually the most poorly set-up and understood. The aim is to test a few individuals of a wide range of species. Demonstration value is important, so siting the trial near roadsides or towns is desirable. These trials have long-term value and must be properly maintained for many years.

2. Species elimination phase

The aim is to examine a large number of species in small plots with the purpose of eliminating unsuitable species. The most promising species should be selected. If several species are promising, then more tests with a selected few over a wider range of sites may be useful in establishing the most versatile species. Care should be given to using the best known seed sources or the optimal climatic matchings.

3. Species proving phase

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

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

4. Species provenance phase

Once an important species has been determined a provenance trial can be commenced. This may be a limited regional trial or intensive range-wide trials involving all possible provenances.

5. Final testing stage

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

In all of these stages, correct identification of seed sources is vital. As the programme develops considerable thought has to be given to establishing seed stands or seed production areas to ensure the production of high quality improved seed. Procedures for eucalypts are documented by Boland *et al.*, (1980).

PROCEDURES FOR SELECTING SEED SOURCES FOR SPECIES AND PROVENANCE TRIALS

The amount of effort required in securing seed for introduction is related to the introduction officer's professionalism ("not any seed will do" type of concept) and the stage reached in the tree introduction programme. For arboreta and species elimination trials, wide-ranging provenance collections are not warranted but nevertheless great care should be exercised in the choice of a provenance to represent a species. Unfortunately many trials are hampered because of difficulty in procuring, in time for the planting season, supplies of authenticated seed of known origin and viability. These general problems have been discussed vigorously by Turnbull, (1984). One serious problem, and a common practice, is the introduction of seed from exotic plantations in other countries whereby the seed collected may be of narrow genetic base, of hybrid origin, or even consist of a mixture of different species.

World practice suggests that the bulk of forest tree seed is normally obtained through commercial seed suppliers, private individuals or government agencies. Obviously there is a great variation amongst these suppliers in information supplied and quality of seed collected. There is a great need for the establishment around the world of reliable seed banks similar to the generic seed collection banks for Eucalypts in Australia and Pinus in Mexico and England. Alternatively, well maintained country wide or regional seed banks dealing with a wide range of species for research purposes should be established. In other cases, provenances collection of species of special interest have been arranged by international bodies, e.g. Acacia aneura (FAO) and Eucalyptus grandis (IUFRO). For a guide to seed firms and organisations one can consult the FAO, (1975) tree seed directory but always "let the buyer beware". For research purposes, seed with inadequate documentation of origin etc. is worthless.

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

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

1. The provenance concept and nomenclature

The concept of provenance having a genetic and evolutionary basis has dominated forestry thinking for some time. The concept of provenance implies that genetic patterns of variation are associated closely with the ecological conditions in which the species evolved. Application of the concept involves recognition of intraspecific variation patterns in particular characteristics and classification of forest reproductive material according to its geographical origin (Turnbull and Griffin, 1985). The term 'provenance' is applied frequently to the original geographic source of seeds or propagules. Most provenances are labelled by locality names but often regions are confused with provenances, e.g. Coffs Harbour *Eucalyptus grandis* covers a huge region and many provenances. There is a definite international need to standardise nomenclature of provenance. Standardisation would avoid the problem which has become evident in eucalypts where several different locality names have been applied to the same small stand of trees. One way around the problem is to request locational details such as latitude, longitude and altitude.

2. The natural distribution of trees and the spatial arrangement of provenances

The natural distribution of any given species is only temporarily static and many have expanded or contracted in accordance with changes in the environment over many years. During this process some stands are eliminated or have survived in favourable isolated locations thus leading to fragmentation in the overall distribution. From such isolation, populations evolve through selective breeding, to adapt to local conditions for survival and growth. This adaptation may be for extreme or infrequent episodic events or for rapid growth under optimal conditions.

Studies have shown that considerable genetic variation in morphological and physiological traits may exist over the distributional range of forest tree species. Generally the wider the natural distribution the greater the amount of variation. This variation may be graded over a gradual change in environment or else may be dramatic over short distances due to sudden changes in say edaphic factors, e.g. soil type. These aspects of variation highlight the need for careful selection of natural population for species introduction.

In Australia there have been only a few major studies of geographic variation in native trees. Most have been in *Eucalyptus* because of its commercial importance. In this genus the patterns of variation may be regional, e.g. *E.camaldulensis* (Pryor and Byrne, 1969) or graded with altitude, e.g. *E.pauciflora* (Pryor, 1956). Less intensive studies have been made in a few non-eucalypts, e.g. *Brachychiton populneus*, where regional differences were also found (inland populations were morphologically distinguishable from more coastal populations). Few studies are available of geographic variation of trees from the northern parts of Australia but no doubt the increasing severity of the dry season from coastal to inland regions would be important as would also be changes in soil types and perhaps fire frequency.

Given our basic knowledge of the importance of variation one would expect a quite precise response between a particular natural population and its performance in an exotic situation (referred to as site/genotype interactions). This would imply that population selection is relatively simple but this is usually not so. Site/genotype interactions are very important in some species e.g. *Pinus contorta* provenances are latitudinally dependant in say, Sweden. In other species there are examples where site/genotype interactions are not so important and populations from certain sites have performed well over a wide range of environmental locations e.g. Sudeten provenances of larch (*Larix decidua*) has performed well in many European locations (Giertych, 1979). This phenomenon is found in the Petford provenance of *E.camaldulensis* in many tropical countries and may be more common for Australian species than is presently recognised. The obvious advantage is that where provenances have been identified as being very plastic they should always be included in trials as markers to species performance. It also means that fewer provenances need to be used to assess species performance at a given site.

FUTURE

Species selection will remain an imprecise science, although once suitable species have been established, traditional tree improvement practices can be vigorously and methodically applied. More information will be produced on the lesser known Australian species in the next few years. New selection techniques involving glasshouse screening of wide arrays of species for particular attributes could be attempted. Work will continue on developing models whereby discriminators of plant growth for particular species in their natural range can be used to determine equivalent environmental sites elsewhere to which plants could be introduced with a reasonable probability of success. The major problem at present is obtaining good information on a wide range of lesser-known trees and securing well-authenticated seed supplies from the most appropriate provenances.

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SEED COLLECTION TECHNIQUES

by D.J. Boland

Seed collection involves a wide range of activities from the initial planning of collections through to seed extraction from the fruit. The term seed collection is not particularly appropriate as it is usually the fruit that are first collected from which seed is later extracted. The aim here is to cover briefly a range of activities connected primarily with research collections in natural stands such as planning the trip, timing of collections, sampling of trees, seed collection methods and extraction. Most available published information relates to seed collection of temperate species but increasingly attention is being given to seed collection in tropical species for which a lot less is known.

This account on seed collection techniques ranges widely from Australian to world techniques to provide a broad account of problems and solutions to seed collection in numerous species. It is hoped that the lessons and knowledge gained can be adopted or modified to suit conditions experienced by seed collectors in East Africa.

PLANNING AND TIMING OF COLLECTIONS

Considerable effort should be put in to the planning and timing of seed collections. A successful mission is usually one which has been well planned. Some typical specific questions to consider during the planning stage include:

(i) determination of species to be collected and the objectives of the collections;

(ii) location of all published material on the species that may relate to past seed collection experiences;

(iii) documentation of all known occurrences of the species. In *Eucalyptus* in Australia we are greatly assisted by Eucalist which is a computer retrieval program listing all sites where a particular species has been collected in the past (Appendix 1);

(iv) determination of seed maturation times and gathering information on the periodicity of crops;

(v) preparing seed collection equipment;

(vi) obtain any necessary permits to visit forest areas, national parks, etc; and,

(vii) preparation of pro-forma sheets for detailed field collection notes on stand and individual seed trees (Appendix 2).

SAMPLING

In any collection programme the collector must consider the range of available strategies that could be adopted to sample a species over its natural distribution. In this regard the two most important concepts to the seed collector are the concepts of how to sample populations and how to sample trees within populations. The first concept involves provenance which can be defined as the source of the material collected and is usually designated by the place name of the collection site. In this account we shall consider seed collections for species introduction trials and for species provenance trials.

1. Species introduction trial

Edwards, (1963) suggested that for an unknown species several provenances should be tried, including at least one from:

(a) Optimum site. A sample taken from the part of the natural distribution where a species exhibits its optimal development can be valuable but because of genotype-environment, interaction, the phenotype in the natural stand may bear little relationship to the performance of the tree under different conditions. In western America the largest and straightest *Pinus contorta* trees are found at high altitudes in the Sierra Nevada ranges, the coastal low altitude trees are small and frequently of poor form. However, plantations of this species in Europe, New Zealand etc., have proved that it is the inter-provenances which give the most productive forests.

(b) Matching site. The sampling of 'matching' sites involves a study of the environmental factors throughout the species natural range and attempting to locate an area, or areas, where there is a similarity with the site where the trial will be established.

(c) Marginal site. Populations near the boundaries of the natural distribution are often growing under environmental conditions which differ from those where the main populations occur. Other, often severe, selection pressures may operate on the margins which can produce populations physiologically and morphologically very different from the other populations. Marginal populations which tolerate a greater frequency of droughts are likely to be more adaptable to drier areas than the other populations. The idea of marginal sites assumes that the limits of distribution of a species are the result of limiting climatic or edaphic factors and that populations close to the boundary are those which have had maximum selection intensity applied to them through the limiting conditions. The sampling of marginal sites is very important when determining the extent of genetic diversity in a species.

The sampling of 'optimum sites', 'matching sites' and 'marginal sites' is generally carried out in an attempt to save resources such as time, labour and land which are required for complete provenance trials. It is applicable if there are a large number of possible species for a site and when some indication of the species potential is required. The choice of seed sources for initial screening trials of introductions requires careful study of the natural distribution of the species and the environmental factors operating within the range.

2. Provenance trials

(a) Strategy for sampling provenances

Where there is some indication that a species may be of value on a particular site, but the extent of the variation in it largely unknown, it is usual to conduct range-wide provenance trials using many seed sources widely scattered throughout the existing range. The number of seed sources sampled will depend on the extent of the natural distribution, the genetic diversity of the species, and the resources available to sample and carry out the research.

When a species is being sampled for the first time and where little or nothing is known of the variation pattern sampling frequency should not be high. Samples are taken at rather widely separated intervals through relatively large areas. This type of sampling has been referred to as coarse-grid sampling and the purpose is to determine the major features of distribution patterns.

Coarse grid sampling has been used often in sampling many of the tropical pines or the eucalypts for the first time. The aim is to collect from populations which will represent the major variation in the species. Practical difficulties such as lack of access to part of the species range may rule out sampling on a regular grid or strip pattern. Often there is no regularity of distance or direction between successive sampling sites. The number of populations to be sampled is determined in advance in accordance with the time available. The samples are usually taken from near established roads or tracks in an irregular pattern determined by stand differences, and marked changes in ecological or topographical situations. Aerial photographs can sometimes be used to save time in picking out possible collection sites in unknown country or in difficult terrain.

A variation of the coarse grid system which takes advantage of a known distribution of the species, makes some concessions to ease of access and is less subjective is described by Green, (1971). Sampling localities for a study designed to provide basic genetic variation information in Eucalyptus obliqua were selected systematically by superimposing a 70-mile square grid on a map of the known range of the species. With some adjustments, twenty-two generalised locations where the species was known to occur were obtained. These locations were visited and precise localities chosen according to the abundance of seed crops, the absence of serious disturbance, and convenient access.

Given that only a certain amount of time and money is available to make seed collections of say 400 trees for any given species across its natural distribution, then some hard decisions have to be made on whether to sample few provenances with relatively large number of individuals per provenance or many provenances from diverse sites but with few individuals per provenance. Most collections involve this sort of rational and the decision to make is difficult. The central question is whether greater variation is among rather than within a provenance. The answer is not always clear-cut.

Once we have selected each provenance the next step is to seriously consider our selection of seed trees within the provenance.

(b) Strategy for sampling trees within provenance

The actual trees to collect from will depend on the object of the collection. IUFRO has provided some recommendations on collections from individual trees (FAO, 1969).

(1) Collect from not worse than dominant and co-dominant trees of average quality, within 'normal' rather than 'plus' stands. Collections from superior phenotypes, if made, should be kept separately;

(2) Collect from a minimum of 10 trees, preferably from 25 to 50 in the stand. If the stand is very variable, increase the number of trees.

Record the number of trees and the approximate percentage which they form of the stand;

(3) Seed trees to be at least seed fall distance apart from each other. A distance of 100m has been adopted for Pseudotsuga. This is to reduce the risk of collecting from half-sib parents. In Australia a minimum distance of twice tree height is used as a practical rule of thumb for Eucalyptus (Boland *et al*., 1980),

(4) Individual seed trees to be marked,

(5) Collect equal numbers of cones, fruits or seeds per tree, and,

(6) In normal first-stage provenance collections, seed from individual trees may be mixed together. If special studies on individual genotypes are to be done, seed from each tree should be kept separate.

In some collections the botanical identity of some individuals can be difficult to resolve in the field and for this reason it is a good policy to keep individual seedlots and voucher botanical specimens. Once specimens are identified, seed from individuals within a provenance can be bulked. This concept is important for eucalypts and acacias in Australia, for dipterocarps in S.E. Asia and for pines in Central America where differences between species within genera can be difficult to discern in the field.

SEED COLLECTION METHODS AND EQUIPMENT

There is a great variety of methods and equipment available for collection of fruits and the choice depends on a number of factors which, following Robbins *et al*., (1981), may be summarized as follows:

(a) Relative size and numbers of the fruiting units. In the case of 1 - 3 large seeds inside a dehiscent or indehiscent fruit (e.g. Aesculus, Tectona), collection can be done most easily by awaiting natural fall of seed or fruit and collecting from the ground;

(b) Characteristics of the fruit: size, number, position and distribution of fruits and resistance of peduncles to shaking, pulling, breaking or cutting, interval between ripening and opening;

(c) Characteristics of the tree: diameter, shape and length of bole, bark thickness; shape of crown; size, angle, density and resistance to breakage of branches; density of foliage and depth of crown;

(d) Characteristics of the stand: distribution and stocking of trees (e.g. isolated trees, open or dense stand, density of understorey and ground vegetation); and,

(e) Characteristics of the site: slope, accessibility.

The various methods of collection may be classified into the following: (1) Collection of fallen fruits or seeds from the forest floor; (2) Collection from the crowns of felled trees; (3) Collection from standing trees with access from the ground; (4) Collection from standing trees with access by climbing.

1. Collection of Fallen Fruits or Seeds from the Forest Floor

(a) Natural seedfall

Collection from the forest floor of fruits which have fallen after natural ripening and abscission is common practice with a number of large-fruited genera. It is cheap and does not require highly skilled labour. Temperate genera commonly collected from the ground are *Quercus*, *Fagus*, *Castanea* and tropical genera include *Tectona*, *Gmelina*, *Triplochiton* and several genera among the dipterocarps. *Eucalyptus globulus* fruits are collected from the ground in Spain but never by this means in Australia.

The main disadvantages of collection from natural fruit shedding are the risks of collecting immature, empty or unsound seeds, of seed deterioration or premature germination if collection is delayed, and uncertainty in identifying the mother trees from which seed is collected. Seeds in the first fruit to fall naturally in the season are often of poor quality (Morandini, 1962; Aldhous, 1972). In Thailand shedding of teak fruit starts in March, but observations have shown that the most viable fruits are shed in the latter part of the season, so collection is usually postponed until April (Hedegart, 1975). Clearing the forest floor of vegetation and debris and laying sheets can help. If carefully timed, this operation will also eliminate much of the risk of collecting empty or non-viable seed. Sound fruit should be gathered as soon as possible after they have fallen to avoid damage or losses from insects, rodents or fungi and premature germination. This is of particular importance in the moist tropical forest. Observations have indicated that many of the seeds of the more important dipterocarps lose their viability within a few days of shedding and studies on *Shorea platyclados* in Malaysia demonstrated that seedlots collected from the ground included considerably more defective seeds than lots collected from the standing tree (Tang, 1971). Collection from the ground must, therefore, be perfectly timed with seedfall.

In the Jari region of Amazonia in Brazil, Woessner and McNabb, (1979) found that collection of green or yellow fruit of Gmelina arborea from the forest floor gave the best results in operations for collecting about 10 000kg of seed a year. They could be stored temporarily in sacks during transit from the field to the fruit processing depot, without serious loss of viability. Older brown or black fruit ferment and heat in the sacks and rapidly lose viability. Collecting teams are instructed to collect only the fresh green and yellow fruit. 50kg of fruit can be collected per man in an 8 hour working day and yield about 3kg of dried stones. Similar results have been obtained in Malaysia where green and yellow fruit collected from the ground gave over 90% germination, but brown fruits, on the other hand, produced only 53% (Mohammad and Ibrahim, 1980).

Seeds of some hard-coated species may remain viable on the forest floor for years, especially in temperate conditions. In Hungary, seed of Robinia pseudoacacia is collected from the forest floor under 30-year-old stands in the Pusztavacs forest district (Keresztesi, 1979). In South Africa, seed of Acacia mearnsii can remain viable for several years on the ground under seed orchards and collected at any preferred time.

(b) Manual shaking

Trunks of small trees and low branches may be shaken directly by hand. Higher branches may be shaken by means of a long pole and hook or by a rope. This method has produced good results in Cordia alliodora and Cedrela species. Several arid zone Australian acacias are also treated in this fashion.

(c) Use of a rope

Involves an initial operation to pass the rope over the branch to be shaken. The same method is used to hoist a saw or pulley into the crown. A thin line is attached to a weight which is projected over the branch by hand or by cata= pult. For higher branches the line may be attached to an arrow, which is shot from a bow, or to an iron rod shot from a calibre .22 rifle. A light nylon line such as a fishing line of 50lbs (23kg) breaking strain is suitable and the weight or projectile used should be heavy enough to drop to the ground pulling the line with it over the branch. Once the end of the line has reached the ground, the weight or arrow can be detached and a nylon cord of 3-4 mm attached instead; the line is drawn back over the branch, pulling the cord with it. The two ends of the loop can then be pulled together to shake the branch. The cord should be positioned towards the end of the branch where it will have the maximum shaking effect and not close to the bole where the branch is thickest.

(d) Collection of seed after dispersal

This usually involves nets or sheets to catch falling seeds and has been used to collect seed of *Acacia aneura* in central Australia (Doran *et al*., 1983).

(e) Animal caches

Animals sometimes gather together cones or fruit as a food supply and these caches may be raided for the seed, but this source of seeds is confined to limited areas. Squirrel caches are an important source of coniferous seed in western North America. Squirrels usually locate their caches year after year in the same places. Typically, they are found in damp areas near springs, small creeks or marshes, on northern exposures, and in decayed wood or duff or around old fallen trees. A single cache may contain from a few cones to many bushels. Fresh cones on the ground are a sign of squirrel activity; piles of cone scales and cores may indicate a nearby cache (Stein *et al*., 1974, Dobbs *et al*., 1976).

Ants sometimes gather seeds together and in North Africa they have been observed to accumulate large piles of *Acacia* seeds. Any seeds collected from rodent or insect caches should be tested for soundness by cutting test or other means.

2. Collection from the Crowns of Felled Trees

One method of collecting large amounts of seed is to synchronise it with normal commercial fellings carried out during the seed ripening season. There are obvious advantages in this but some disadvantages include:

- (i) lack of choice of trees to collect from;
- (ii) shedding already occurring after felling and before collections commence(this is common in eucalyptus); and,
- (iii) mixture of crowns after felling making it difficult to maintain purity to species and individuals.

The collection of fruit from wind-thrown trees is generally undesirable, as little selection can be applied and there may be a bias towards trees with characteristics which pre-dispose them to wind damage.

3. Collection from Standing Trees with Access from the Ground

(a) By Hand

In the case of shrubs or low-branched trees, fruit can be picked directly from the branches by the collector while standing on the ground (Morandini, 1962). Examples are Crataegus, Sorbus and Ilex spp. in temperate zones (Aldhous, 1972), the smaller acacias and mallee eucalypts in Australia and many of the small drought-resistant species of the arid and semi-arid zones. Smaller fruit are generally harvested directly into a basket, bag, bucket or other container held or worn by the picker (Stein *et al.*, 1974).

(b) Cutting, breaking and sawing

For branches out of arm's reach, a variety of long-handled tools is available to enable the collector to reach the fruit from the ground. A pole and hook may be used to pull branches down within reach. Long-handled rakes, saws, hooks or pruning shears are used to pull off or sever individual fruit or fruit-bearing branchlets. Light, rigid bamboo, aluminium or plastic poles 4-6m in length are common. In order to reach beyond the 6-8m range of single poles, multistage telescopic poles with a shear on the end have been developed. Robbins *et al.*, (1981) have noted that, in some species, fruit or cones on the lowest branches may yield little seed, because of lack of pollination in that position, and that it is therefore preferable to collect fruits from at least halfway up the crown. Ability to use long-handled tools efficiently from the ground is much affected by the density and form of the crown in individual trees.

A rope can be thrown or pulled over a branch to break off the seed-bearing branch rather than to shake it. A thicker rope is needed than for shaking. The method is not recommended for general use. It damages the tree, allows access to pest and diseases and, in the case of pines and other species which take two years to mature their seeds, destroys the next year's seed crop while collecting the current year's.

Several types of flexible saw have been used successfully to sever branches from the ground. One model, described by Anon., 1979, consists of 3ft long flexible cutting cable fitted with precision-set carbon steel teeth and two 35ft polypropylene control lines. A sand-filled safety weight is used to project one of the control lines over the branch. An earlier model, the "commando saw", now no longer in production, was effective in severing eucalypt branches in Australia (Boden, 1972). Two operators could bring down branches up to 20cm in diameter quickly and easily.

The method is not applicable to trees with acutely angled branches such as *Eucalyptus tereticornis*. The other limitation depends on the efficiency of projecting the line over the desired branch.

(c) Use of rifle

Another method of severing seed-bearing branches is to shoot them down with a large calibre rifle. The method was successfully used to shoot out the tops of white spruce trees in seed production areas in north eastern U.S.A. (Slayton, 1969). The topping of the trees was found to be not only less expensive than climbing but also the cones could be collected at the best stage of development because of the short time in which the operation could be completed. More recently, shooting off branches or tops from a helicopter has yielded promising results in Canada.

In Australia the collection of small samples of eucalypt and *Araucaria* seed from tall trees has been accomplished efficiently using a .222 or .243 or .308 calibre rifle with x4 telescopic sights (Boland *et al*.,1980). Branches up to 15cm diameter could be brought down. "Pointed soft-point" ammunition is more effective than "hollow-point" when used with a .308 rifle.

A disadvantage of the rifle method is that very strict safety precautions must be observed and that there are limitations to where a rifle may be used, for example, not near roads or built up areas. Also crowns of some species such as *Araucaria* and *Picea* may be considerably damaged by this technique.

In shooting down branches it is usually necessary to steady the rifle on a tripod or to rest the stock against a tree or the side of a vehicle. A clear line of sight is required and this can be a limiting factor in dense forests. It is usually best to shoot at right angles to the branch and to sever the bark on the underside with the first shot to avoid branch hang-ups. The bark on the upper side is then cut and finally shots are placed at intervals across the branch. It is important to select branches which will fall unobstructed to the ground. Horizontal branches are more readily detached than ascending branches. The shots should be positioned to take advantage of branch leverage. The method is best suited for collecting research quantities of seed from a heavy seed crop clustered on branches or tops too inaccessible to be conveniently reached by other means.

4. Collection from Standing Trees with Access by Climbing

There is a limit to the height to which long-handled tools can be used for collecting seeds or fruit from the ground. Near that limit the operation consumes much time and energy but produces little seed. For tall trees which cannot be felled therefore, climbing is often the only practical method of collecting. Some men are excellent natural climbers, while good training and good equipment can render collection by climbing an efficient and safe, albeit energetic, operation. For convenience the operation may be described under the following sections: (a) Climbing into the crown by way of the bole, (b) Climbing into the crown directly, (c) Climbing and picking of fruits within the crown.

(a) Climbing into the crown by way of the bole

(1) Climbing with minimum equipment. Climbing without mechanical aids is practised in a number of countries. In the Philippines some seed collectors climb barefooted or with the help of a rope which ties both feet together and presses them against the trunk of the tree (Seeber and Agpaoa, 1976). Other modifications are for the climber to cut successive notches in the bole with a hand-axe to support his feet, or to hammer in a series of iron spikes about 20cm long which are later withdrawn for re-use as he descends. Both of these methods are physically exhausting, whether or not a safety belt is used, and do some damage to the tree. Climbing tall branchless boles with hands and feet involves a considerable safety hazard and the risks may tempt climbers to prefer collecting from the most easily climbable trees which are often silviculturally the least desirable. It is preferable to introduce one or other of the special climbing aids now available.

(2) Climbing irons or spurs, which are attached to the climber's boots, offer a light and inexpensive means of safer and more efficient climbing, if combined with safety belt, strap and line, safety helmet of glass fiber and heavy leather gloves. The lightness of

the spurs (less than 1kg a set) makes them particularly suitable for use in inaccessible stands in roadless country, where all equipment must be carried on foot. They have been found to be the most efficient method for climbing trees of Pinus kesiya and P.merkusii in Thailand, (Granhof, 1975) and for P.caribaea and P.oocarpa in Honduras and are in common use in many countries, especially for conifers (Robbins *et al*., 1981).

The main disadvantage of spurs is the damage they do to the bark, particularly of thin-barked species. If climbing is only occasional, this should not be excessive, but frequent climbing of the same tree, e.g. for pollination and seed collection in seed orchards, is liable to cause an unacceptable degree of damage; other climbing methods should then be preferred.

(3) Ladders. For heights from about 8 to 40 metres, vertical scaling ladders in several sections provide safe and convenient means of climbing the bole to the live crown. They can be made of a variety of materials including wood, aluminium, magnesium alloy, etc., but each section must be light enough to be easily pulled up by the climber. The legs of the bottom section can be placed on adjustable platforms for greater stability. The length of each section varies between 1.8 and 3m and its weight should not exceed 3-5kg.

(4) The Swiss tree bicycle or "Baumvelo" is a device for climbing tall straight trees which are branch-free to the live crown. It is lighter to transport than sectional ladders but heavier than climbing irons. It does no damage to the tree. It is suitable for use on stems with diameters ranging from about 30-80cm.

EXTRACTION

Once fruit have been collected and transported back to base, the next step is to extract the seed. Extraction methods are determined mainly by the characteristics of the fruit. Fleshy fruit are treated by a depulping process which usually involves a combination of soaking in water with pressure or gentle abrasion. Cones and other wood or leathery fruit are first dried until cone scales open or seeds become detached from the placenta of the fruit, and then treated manually or mechanically by tumbling or threshing in order to separate the dry seeds from the dry fruit.

Some indehiscent fruit, mainly nuts, achenes and winged samaras, do not require extraction but are stored or sown as fruits. Some species with seeds covered by a thin fleshy covering may be dried and sown with the dried skin intact (Stein *et al.*, 1974). Drying under cover with frequent turning of the fruits is appropriate. Examples are *Vitex parviflora* in the Philippines (Seeber and Agpaoa, 1976), *Crataegus* in temperate regions (Goor and Barney, 1976) and *Podocarpus* spp. and *Maesopsis eminii* in Africa.

Bonner, (1978) has classified hardwood seeds into three classes according to their requirements for pre-storage handling and storage. The classes are: (1) seeds that must be dried for extraction and for storage; (2) seeds that must be kept moist at all times, both during cleaning and during storage (i.e. recalcitrant species); and, (3) seeds that must be kept moist for extraction, then dried for storage. Bonner's table for some important hardwood genera classified in this way is reproduced in Table 1.

1. Depulping

Depulping of fleshy fruit should be done soon after collection to avoid fermentation and heating. Small lots of seed are usually macerated by hand. After soaking, the flesh is hand squeezed or mashed by a wooden block, rolling pin or fruitpress. Alternatively, flesh may be macerated by rubbing it against or through a screen (Stein *et al.*, 1974). The pulp and skins can usually be separated from the seed by washing through appropriate sieves or by differential flotation in a deep bowl through which a slow stream of water is flowing (Aldhous, 1972). The seed sinks while the pulp rises to the surface.

Table 1. Some important hardwood genera classed according to the pre-storage handling requirements of their seeds.

dry for extraction and storage 1.	always keep moist 2.	moist for extraction and dry for storage 3.
Acacia	Acer (some species)	Gmelina
Acer (some species)	Aesculus	Malus
Ailanthus	Castanea	Melia
Alnus	Corylus	Morus
Atriplex	Dipterocarpus	Nyssa
Betula	Hopea	Olea
Carpinus	Juglans	Prunus
Carya	Quercus	Rosa
Casuarina		Sorbus
Cedrela		Ziziphus
Eucalyptus		
Fagus		
Fraxinus		
Gleditsia		
Liquidambar		
Liriodendron		
Nothofagus		
Platanus		
Populus		
Robinia		
Syringa		
Tectona		
Tilia		
Triplochiton		
Ulmus		

In the Philippines, the fleshy fruit of *Aleurites* spp., *Canarium ovatum*, *Syzygium cumini* and other species are placed in barrels or cans with water. After a day or two the pulp becomes soft. The fruit are then mashed carefully with a tamper without crushing the seeds. When plenty of water is added, the pulp will float while the seeds sink to the bottom (Seeber and Agpaoa, 1976). This method is also suitable for the fruits of *Gmelina arborea*, *Azadirachta indica*, *Octoea usambarensis* and *Cinnamomum camphora* and for the syncarps of multiple fruits of *Chlorophora* and *Morus*. Because of the minute size of the seeds of *Anthocephalus chinensis* (2.6 million per kilo), a special technique is needed to extract them from the fleshy fruit. The outer portion of the fruit, which contains the seeds, is rubbed lightly against a 1/2 inch (12.5mm) wire mesh. The mixture of pulp and seeds which passes through is placed on a screen box with a 1/16 inch (1.5mm) mesh. The operators pour water over the mixture while rubbing it carefully by hand, so that the seeds together with some fine pulp pass the screen and drop into a water-filled container below. The seeds sink while the fine pulp remains afloat. If the floating pulp still contains seed, it is returned to the screen box and the operation is repeated (Seeber and Agpaoa, 1976). In the Jari project in Brazil, fruit of *Gmelina arborea* are depulped by macerating them against a wire mesh or mechanically by the use of a modified coffee depulper (Woessner and McNabb, 1979). Thorough cleaning of the stones is important. It has been found that thoroughly cleaned stones gave 10% better germination than depulped but unclean stones. Fresh green fruits sown whole without depulping gave only 10% germination while whole fruits sown after a period of drying failed to germinate. The stones may be cleaned in water or a combined cleaning and drying operation may be carried out in a rotating baffled steel cylinder which reduces the moisture content to 8-10% after 20 hours at 45°C.

Removal of the pulp from drupes of *Vitex parviflora* in the Philippines has improved germination, both in full-size green fruits and in the riper purple fruit (Umali-Garcia, 1980). The best improvement was from 26% whole green fruit to 65% de-pulped green fruit and the least from 38% whole purple fruit to 52% de-pulped purple fruit.

Seeds may be washed free of flesh hydraulically. Fruit is placed in a mesh bag or wire basket and subjected to a stream of water from a high-pressure nozzle until all of the flesh and most of the skins are washed away (Stein *et al.*, 1974).

After separation, orthodox seeds should be carefully air dried under cover, with frequent turning. Thereafter they can go forward for shipment to the nurseries or for treatment to adjust moisture content to the correct value for the species, before storage.

Where large quantities of fruit have to be depulped, various designs of machine are available. They include feed grinders, concrete mixers, hammer mills and macerators. Most machines only free seeds from the flesh; a part or all of the residue must be removed in later cleaning. The Dybvig separator, however, pulps the flesh and fully cleans the seeds in one operation (Stein *et al.*, 1974). Small quantities of small-seeded fleshy fruit can be processed speedily by use of an electric mixer.

2. Drying of Fruits without Artificial Heat

Drying, using either natural or artificial heat sources, must be used in the extraction of seeds of many important tree species and is almost always used for the cones of pines and other conifers and the capsules of eucalypts. Drying should imitate the natural drying process so that the fruit are subjected to progressive drying which causes a continuous release of moisture. Air coming in contact with the fruit must always be drier than the fruit and this can be obtained by continuous circulation of air.

(a) Drying under cover

This is the slowest and least severe method of drying fruit for seed extraction. Fruit must be in well ventilated rooms, spread thinly, stirred regularly if on a solid surface or, preferably, placed on trays with a wire mesh bottom to allow all-round air circulation.

Air-drying under cover is effective for cones of *Abies* and *Cedrus*, which readily disintegrate under this treatment and which can easily be damaged by heating in the sun or in kilns. It is also used for separating fruit of some hardwoods, such as *Quercus* and *Fagus*, from their involucral coverings (Morandini, 1962). At the same time it is suitable for a modest degree of drying of these species and of others like them which need to be stored at a relatively high moisture content in order to retain viability. *Dipterocarpus*, *Hopea* and *Triplochiton* are tropical genera for which the method is suitable. It can be used for drying the thin fleshy fruit covering of *Vitex*, *Maesopsis* and other species which are then stored or sown as dried fruits.

The drying process is slow under this method and the period of time needed is dependent on the natural air humidity and temperature. But it is the safest method for any "delicate" species which will not stand heating or very rapid drying.

(b) Sun drying

This method is well-suited to drying of cones and fruit of species which will withstand the rather high temperatures involved. It is commonly used in the dry season in tropical, sub-tropical or warm temperate climates where it can be 100% effective in causing fruits to open and can make kilns unnecessary. In moist cool temperate climates it is much less reliable and may need to be supplemented, if not replaced, by kiln drying.

Spreading the fruit in layers on screens, platforms, canvas or other sheeting in the sun is one of the simplest methods of air drying and requires little investment in equipment. In the Mediterranean, pine species such as P.pinea and P.halepensis are handled by this method (Morandini, 1962), as are P.kesiya and P.merkusii in Thailand and the Philippines (Bryndum, 1975, Seeber and Agpaoa, 1976). Fruit can be laid on wire screens with meshes of suitable size to let seeds drop through onto canvas or polythylene sheets. The main requirements are:

(1) Frequent stirring and turning to promote uniform drying and opening of the cones and release of the seed;

(2) Arrangements for immediate covering of fruit in the event of rain, either by moving them indoors or by erecting a temporary shelter over them;

(3) Care to avoid overheating of the fruit while they still have a high moisture content. This may involve preliminary precuring under cover or the avoidance, in the initial stages, of devices such as a base of corrugated iron sheeting or a covering of glass or polythene, which are designed to trap heat and raise temperature. The importance of this varies greatly according to the strength of sunlight locally and to the heat tolerance of individual species;

(4) Frequent removal of any seeds which have separated from the fruit, prevent their being exposed too long to intense direct sunlight; and,

(5) Protection against birds, rodents and insects which may pose a more serious threat in open air drying than in drying inside a building. Ants will carry off a large proportion of eucalypt seed unless they are rigorously excluded from the extraction area while rodents and birds have a taste for the seed of pines.

Eucalypts. Sun-drying is also effective for the capsules of *Eucalyptus* spp. wherever local climatic conditions are favourable. A range of techniques is given by Boland *et al*.,(1980).

Small seed collections usually involve drying individual capsules or clippings of capsule-bearing branches. These can be spread out in a thin layer on canvas, calico or plastic sheeting, in a dry and well-ventilated position either in the sun or in shade. A small seed extractor can be made by placing the capsules on wire mesh a few centimetres from the bottom of a box and placing a sheet of clear plastic or glass over the top. The capsules should be shaken daily and the seeds removed, so that they are not exposed for longer than necessary to high temperature.

Bulk seed collections are often spread on tarpaulins on the ground, placed in special concrete enclosures, or raised up above the ground in frames on wires. Spreading the capsule-bearing branches on the ground requires little equipment but is expensive because of the frequent turning required to permit the lower layer to dry out.

A more practical method of drying large quantities of capsules is to spread them over a frame covered with wire netting. The wire mesh permits a greater air circulation around the capsules than can be obtained if they are placed on the ground. A canvas sheet underneath the frame catches the seed as it is shed. Such structures may be large or small, permanent or temporary. Small, temporary frames are suitable for use by the migratory seed collector and the large, permanent structures are placed in central seed extraction areas.

The rate of seed release during natural drying varies with the capsule characteristics of each species, capsule maturity, and most importantly, on the drying conditions. Very mature capsules of some species can release their seed within a few hours under optimum drying conditions but under average conditions most species will dry sufficiently in 3-4 days. Some eucalypts characteristically retain unopened capsules on the tree for several years; these capsules may become very woody and are often difficult to open.

Although drying in full sun leads to rapid opening, there is an inherent danger that, if the temperature becomes too high, any primary dormancy in the seed may be strengthened. The capsules should not be placed directly on metal which is exposed to the sun, since this may result in high temperatures which damage the seed.

During natural drying, ants and birds can cause considerable seed losses. Ants will carry away viable seeds and leave the chaff behind. Spraying an aerosol insect repellant or spreading an insecticide dust around the seed-bearing material will usually discourage pilfering. Seed-eating birds such as the domestic sparrow can also be responsible for seed losses during extraction.

Other species which may be sun-dried include dry zone legumes such as *Acacia* and *Prosopis* spp. and various species of *Toona*, *Lagerstroemia*, *Leucaena*, *Casuarina*, *Albizia falcataria* and *Pithecellobium dulce* (Seeber and Agpaoa, 1976). In India the "cones" of *Casuarina equisetifolia* are placed in trays in the sun and a thin cloth is secured to the top of the trays to prevent the "seeds" from being blown away in the wind. The "cones" are treated with BHC 10% powder or other insect repellant to prevent ants from removing the "seeds". In three days the "seeds" separate from the "cones", if left longer other "cone" fractions get mixed with the "seeds" (Kondas, 1981). In general, hardwood fruits and seeds are more easily damaged by overheating than those of conifers, so care must be taken to avoid prolonged exposure of the seeds to intense direct sunlight. Intermittent shade may be necessary.

KILN DRYING

Kiln drying is often very important in cooler areas where sun drying is not sufficient to release seeds from fruit. In eucalypt forests in Australia, a wide range of kilns have been developed to aid in the quick release of seeds from fruit so that large quantities of seeds can be collected for aerial sowing programs (see Boland *et al.*, 1980).

EXTRACTING SEED FROM LEGUMES USING MECHANICAL THRASHING DEVICES

This is particularly important for extracting seed from the legumes (or pods) of many species of Australian acacia. In many species, the pods are thinly woody and even after sun or kiln drying are most reluctant to release seeds from the arils and pods.

In Sabah, seeds of Acacia mangium (an Australian acacia) are separated from the pods, after drying, by rotating them for 10-15 minutes in a cement mixer together with blocks of hard timber 10 x 10 x 15cm (Bowen and Eusebio, 1981). Several types of mechanical thrasher suitable for Acacia pods are described by Doran et al., (1983).

SEED CLEANING

This is a necessary part of any seed collection operation and Australian techniques for eucalypts are given in "Eucalyptus Seed" by Boland et al., (1980) and for acacias in Doran et al., (1983). Mechanical cleaning usually depends on sieving, sorting according to length, winnowing (blowing), flotation, specific gravity or a combination of these.

(a) Sieving

A sequential sieving through a graduation of mesh sizes can produce a high level of cleanliness with many forest tree seedlots. This process has been mechanized by the vibrating screens of machines like the 'Vac-A-Way Gravity Screen'.

Problems arise when there are large proportions of impurities similar in size to the viable seed. In this case a combination of methods may be required to achieve acceptable results.

(b) Sorting according to length

Cleaning with sieves relies on the separation of seeds, with diameter the critical factor. Fractioning according to length cannot be done with sieves, but this is possible with an indented cylinder. In addition to its use for separating good seed from the impurities, the equipment is used in agriculture for separating seed mixtures and can also be used for grading seeds.

This equipment consists of a slightly inclined horizontal rotating cylinder and a movable separating trough. The inside surface has small closely spaced hemispherical indentations. Small material is pressed into the indents by centrifugal force and can be removed. The larger material flows in the centre of the cylinder and is discharged by gravity. Depending on the type of impurities, the seed may be separated via the indentations or by passing down the cylinder.

(c) Winnowing

Winnowing is widely used for cleaning grain and other seeds in many parts of the world. Wind or an air stream is used to separate light material (chaff) from the heavier remainder (i.e. full seed). In its crudest form, the uncleaned seed may simply be thrown into the air on a windy day. Various fractions of the seedlot separate out, and the desired ones are retained. This principle has been refined in seed cleaning machines commonly referred to as blowers. Many seed cleaning machines use a combination of winnowing and screening. The screens are used to remove the largest and finest fractions and the intermediate fractions containing the seed are winnowed.

Kurt Pelz Saatmeister Mark 2

For cleaning leguminous seed, Division of Forest Research has successfully made use of a blower of Australian manufacture called 'Kurt Pelz Saatmeister Mark 2'. The machine comprises three comparments(see Doran *et al.*,1983).An automatically agitated hopper feeds material to be cleaned vertically down into the first compartment. Heavy material and seed normally fall straight down into the bucket. Controllable suction vents are located in the second and third compartments, which extract the light material as the uncleaned seed is fed into the first compartment. By adjusting the vents, it is possible to control the fraction of light material which is separated out.

South Dakota Blower

The South Dakota Blower is useful for cleaning small lots of seed. The machine provides an updraught within a transparent tube. The updraught carries off the lighter particles which are trapped by the baffles near the top of the tube. By careful adjustment of the updraught, only the desired heaviest fraction is retained.

(d)Flotation

Flotation in water is an effective final treatment to remove small impurities. The method relies on differences in density, with the sound seed sinking to the bottom of the water bath and the lighter material, including empty seeds, floating on the surface. After removal of the impurities, the water is drained off and the seed thoroughly dried before storage.

(e) Specific gravity separation

The SG separator employs a flotation principle. A mixture of seed is fed onto the lower end of a sloping perforated table. Air, forced up through the porous deck surface and the bed of seeds by fan, stratifies the seed in layers according to density, with the lightest seed and particles of inert matter at the top and the heaviest at the bottom. An oscillating movement of the table causes the seed to move at different rates across the decks, the lightest seeds float down under gravity and are discharged at the lower end, whilst the heaviest ones are kicked up the slope by contact with the oscillating deck and are discharged at the upper end.

ACKNOWLEDGEMENT

In preparing these notes I have relied heavily on information compiled by DANIDA (a draft manuscript titled 'A Guide to Forest Seed Handling', CSIRO (Eucalyptus Seed) and J.W. Turnbull (FAO/DANIDA Training Course on 'Forest Seed Collections and Handling', Chiang Mai, Thailand 1975), and Mr J.C. Doran for notes prepared for the Sri Lanka Tree Seed Centre. The permission of DANIDA to use some of their unpublished material is gratefully acknowledged.

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Appendix 1. Eucalist printout for Eucalyptus grandis in Australia

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IDENT SPECIE         HERBARIUM   HYBRID COLLECTOR    COLNO    DATE  ASS SP BFFSJPBWPM TYPE      LAT   LON  ALT LOCATION
29155 GRANDIS        BRISBANE           M.I.H.BROOKE  3394 28011972                            1722 14525  885
29156 GRANDIS        BRISBANE           A.K.IRVINE     567 10071973                            1715 14525    0
29157 GRANDIS        BRISBANE           A.K.IRVINE     603 09081973                            1720 14530    0
29158 GRANDIS        BRISBANE           COLLECTOR UN 14105                 * *                 1700 14500    0 ATHERTON TABLD
29159 GRANDIS        BRISBANE           R.DREGHORN     310                 *                   1700 14500    0 GADGARRA
29160 GRANDIS        BRISBANE           COLLECTOR UN       03071899          *                 1720 14520    0 WILD R
29161 GRANDIS        BRISBANE           H.S.CURTIS         25111949          *                 1840 14550    0 MT FOX
29162 GRANDIS        BRISBANE           C.T.WHITE     3508 21061927                            2540 15230    0 GUNDIAH
29163 GRANDIS        BRISBANE           L.J.WEBB               1956          *                 2840 15310    0 WHIAN WHIAN S/F
29164 GRANDIS        BRISBANE           J.G.O.TEPPER           1956          *                 2840 15310    0 WHIAN WHIAN S/F
29165 GRANDIS        BRISBANE           C.T.WHITE    12773 02061945          *                 2840 15310    0 WHIAN WHIAN S/F
29166 GRANDIS        BRISBANE           R.COVENY      4477 05091972                            2834 15316  600
29167 GRANDIS        BRISBANE           R.H.B.SIEBEL   125 11061970          *                 1849 14551    0 MT FOX
29168 GRANDIS        BRISBANE           C.T.WHITE    10465 25081936          *                 2830 15310    0 COOPERS CKVIAMULLIM
29169 GRANDIS        BRISBANE           C.T.WHITE          00091912          *                 2800 15320    0 CURRUMBIN
29170 GRANDIS        BRISBANE           C.T.WHITE     1780 00121921          *                 2750 15310    0 TAMBOURINE MT
29171 GRANDIS        BRISBANE           J.SHIRLEY                            *                 2720 15250    0 ENOGGERA
29172 GRANDIS        BRISBANE           W.D.FRANCIS          111920                            2800 15300    0 NR EMU VALE
29173 GRANDIS        BRISBANE           R.J.HENDERSO   135 17081966          *                 2700 15230    0 SOMERSET DAM
29174 GRANDIS        BRISBANE           C.T.WHITE          00081917          *                 2740 15250    0 WOOGAROO CK
29175 GRANDIS        BRISBANE           C.T.WHITE          10111924          *                 2720 15250    0 FERNY GROVE NR BRIS
29176 GRANDIS        BRISBANE           C.T.WHITE          00041909        * *                 2800 15300    0 SPRINGBROOK
29177 GRANDIS        BRISBANE           D.A.GOY        313 00000313        **                  2810 15250    0 CHRISTMAS CK
29178 GRANDIS        BRISBANE           C.T.WHITE          00011916        * *                 2750 15310    0 TAMBORINE MT
29179 GRANDIS        BRISBANE           C.E.HUBBARD   2463 05051930        **                  2750 15310  510 TAMBORINE MT
29180 GRANDIS        BRISBANE           C.T.WHITE          13091915          *                 2730 15250    0 GOODNA
29181 GRANDIS        BRISBANE           S.T.BLAKE    15820 05051945        **                  2750 15310    0 TAMBORINE MT
29182 GRANDIS        BRISBANE           W.D.FRANCIS        00031916          *                 2610 15250    0 KIN KIN
29183 GRANDIS        BRISBANE           J.KEYS                             *                   2610 15300    0 LAKE COOTHARABA
29184 GRANDIS        BRISBANE           W.E.MOORE          00061917          *                 2600 15230    0 TAMAREE
29185 GRANDIS        BRISBANE           COLLECTOR UN       00071950          *                 2610 15240    0 NR GYMPIE
29186 GRANDIS        BRISBANE           C.T.WHITE          00111916                            2630 15250    0 BLACKALL RGE
29187 GRANDIS        BRISBANE           C.T.WHITE     3347 27121926          *                 2750 15310    0 TAMBORINE MT
29188 GRANDIS        BRISBANE           C.T.WHITE     8702 90111932          *                 2710 15250    0 NORTH PINE R
29189 GRANDIS        BRISBANE           C.T.WHITE     7524     1930        ***                 3020 15242  750 DORRIGO S/F
29190 GRANDIS        BRISBANE           R.PARKINSON   2636 20051961                            3120 15250    0
29191 GRANDIS        BRISBANE           R.COVENY      6024 16021975                            3202 15212  120
29192 GRANDIS        BRISBANE           W.F.RIDLEY     232 27061962         *                  3110 15250    0 13 MS KEMPSEY
29193 GRANDIS        BRISBANE           C.E.LANE-POO  1441 00011930                            3030 15250    0
29194 GRANDIS        MELBOURNE          C.T.WHITE     3347 27121926          *                 2758 15311    0 MT TAMBOURINE
29195 GRANDIS        CSIRO DIV.         D.J.BOLAND    1414  4111972          *                 2607 15242  115 NEGYMPIEVETERANLOGG
29196 GRANDIS        CSIRO DIV.         C.E.LANE-POO          21930        * *                 2627 15241    0 IMBIL
29197 GRANDIS        CSIRO DIV.         C.T.WHITE           1111924          *                 2725 15258    0 FERNYGROVENRBRISBAN
29198 GRANDIS        CSIRO DIV.         COLLECTOR UN           1930            *               3127 15244    0 WAUCHOPE
29199 GRANDIS        CSIRO DIV.         F.M.BAILEY            11930        * *                 3121 15246    0 CAIRNCROSSSF
29200 GRANDIS        CSIRO DIV.         W.A.W. DE BE       20081931          * *               3018 15308    0 COFFS HBR
29201 GRANDIS        CSIRO DIV.         D.J.BOLAND      94  1101969          *                 3148 15232    0 5MW COOPERNOOK
29202 GRANDIS        CSIRO DIV.         W.A.W. DE BE       29091931          *                 3008 15301    0 NANA GLEN
29203 GRANDIS        CSIRO DIV.         M.I.H.BROOKE       27071972        * * *               3000 15300    0 COFFS HBR- URUNGA
29204 GRANDIS        CSIRO DIV.         C.E.LANE-POO          11930        * *                 3034 15254    0 NEWRY SF
29205 GRANDIS        CSIRO DIV.         J.C.DORAN          28031974        ***                 2827 15312  100 MEBBIN SF MURWILLUM
29206 GRANDIS        CSIRO DIV.         G.M.CHIPPEND   477 30051968        * ***               3224 15221    0 7.4MEBULAHDELAH
29207 GRANDIS        CSIRO DIV.         D.I.NICHOLSO       24081947          *                 3027 15301    0 REPTON
29208 GRANDIS        CSIRO DIV.         M.R.O.MILLET          51938            *               3150 15237    0 COOPERNOOK
29209 GRANDIS        CSIRO DIV.         W.A.W. DE BE   264 17081931        ***                 3011 15308    0 BUCCA VIA COFFS HBR
29210 GRANDIS        CSIRO DIV.         M.I.H.BROOKE  3734 24071973        ***                 3028 15256    0 24.3MDORRIGO-C R
29211 GRANDIS        CSIRO DIV.         J.C.DORAN       34 28031974        ***                 2827 15312  100 MEBBINSF
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Appendix 1. Eucalist printout for Eucalyptus grandis in Australia

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IDENT SPECIE         HERBARIUM   HYBRID COLLECTOR    COLNO    DATE  ASS SP BFFSJPBWPM TYPE       LAT   LON ALT LOCATION
29155 GRANDIS        BRISBANE           M.I.H.BROOKE  3394 28011972                             1722 14525 885
29156 GRANDIS        BRISBANE           A.K.IRVINE     567 10071973                             1715 14525   0
29157 GRANDIS        BRISBANE           A.K.IRVINE     603 09081973                             1720 14530   0
29158 GRANDIS        BRISBANE           COLLECTOR UN 14105                 * *                  1700 14500   0 ATHERTON TABLD
29159 GRANDIS        BRISBANE           R.DREGHORN     310                 *                    1700 14500   0 GADGARRA
29160 GRANDIS        BRISBANE           COLLECTOR UN       03071899          *                  1720 14520   0 WILD R
29161 GRANDIS        BRISBANE           H.S.CURTIS         25111949          *                  1840 14550   0 MT FOX
29162 GRANDIS        BRISBANE           C.T.WHITE     3508 21061927                             2540 15230   0 GUNDIAH
29163 GRANDIS        BRISBANE           L.J.WEBB               1956          *                  2840 15310   0 WHIAN WHIAN S/E
29164 GRANDIS        BRISBANE           J.G.O.TEPPER           1956          *                  2840 15310   0 WHIAN WHIAN S/E
29165 GRANDIS        BRISBANE           C.T.WHITE    12773 02061945          *                  2840 15310   0 WHIAN WHIAN S/E
29166 GRANDIS        BRISBANE           R.COVENY      4477 05091972                             2834 15316 600
29167 GRANDIS        BRISBANE           R.H.B.SIEBEL   125 11061970          *                  1849 14551   0 MT FOX
29168 GRANDIS        BRISBANE           C.T.WHITE    10465 25081936          *                  2830 15310   0 COOPERS CKVIAMULLIM
29169 GRANDIS        BRISBANE           C.T.WHITE          00091912          *                  2800 15320   0 CURRUMBIN
29170 GRANDIS        BRISBANE           C.T.WHITE     1780 00121921          *                  2750 15310   0 TAMBOURINE MT
29171 GRANDIS        BRISBANE           J.SHIRLEY                            *                  2720 15250   0 ENOGGERA
29172 GRANDIS        BRISBANE           W.D.FRANCIS          111920                             2800 15300   0 NR EMU VALE
29173 GRANDIS        BRISBANE           R.J.HENDERSO   135 17081966          *                  2700 15230   0 SOMERSET DAM
29174 GRANDIS        BRISBANE           C.T.WHITE          00081917          *                  2740 15250   0 WOOGAROO CK
29175 GRANDIS        BRISBANE           C.T.WHITE          10111924          *                  2720 15250   0 FERNY GROVE NR BRIS
29176 GRANDIS        BRISBANE           C.T.WHITE          00041909        * *                  2800 15300   0 SPRINGBROOK
29177 GRANDIS        BRISBANE           D.A.GOY        313 00000313        **                   2810 15250   0 CHRISTMAS CK
29178 GRANDIS        BRISBANE           C.T.WHITE          00011916        * *                  2750 15310   0 TAMBORINE MT
29179 GRANDIS        BRISBANE           C.E.HUBBARD   2463 05051930        **                   2750 15310 510 TAMBORINE MT
29180 GRANDIS        BRISBANE           C.T.WHITE          13091915          *                  2730 15250   0 GOODNA
29181 GRANDIS        BRISBANE           S.T.BLAKE    15820 05051945        **                   2750 15310   0 TAMBORINE MT
29182 GRANDIS        BRISBANE           W.D.FRANCIS        00031916          *                  2610 15250   0 KIN KIN
29183 GRANDIS        BRISBANE           J.KEYS                             *                    2610 15300   0 LAKE COOTHARABA
29184 GRANDIS        BRISBANE           W.E.MOORE          00061917          *                  2600 15230   0 TAMAREE
29185 GRANDIS        BRISBANE           COLLECTOR UN       00071950          *                  2610 15240   0 NR GYMPIE
29186 GRANDIS        BRISBANE           C.T.WHITE          00111916                             2630 15250   0 BLACKALL RGE
29187 GRANDIS        BRISBANE           C.T.WHITE     3347 27121926          *                  2750 15310   0 TAMBORINE MT
29188 GRANDIS        BRISBANE           C.T.WHITE     8702 90111932          *                  2710 15250   0 NORTH PINE R
29189 GRANDIS        BRISBANE           C.T.WHITE     7524     1930        ***                  3020 15242 750 DORRIGO S/E
29190 GRANDIS        BRISBANE           R.PARKINSON   2636 20051961                             3120 15250   0
29191 GRANDIS        BRISBANE           R.COVENY      6024 16021975                             3202 15212 120
29192 GRANDIS        BRISBANE           W.F.RIDLEY     232 27061962         *                   3110 15250   0 13 MS KEMPSEY
29193 GRANDIS        BRISBANE           C.E.LANE-POO  1441 00011930                             3030 15250   0
29194 GRANDIS        MELBOURNE          C.T.WHITE     3347 27121926          *                  2758 15311   0 MT TAMBOURINE
29195 GRANDIS        CSIRO DIV.         D.J.BOLAND    1414  4111972          *                  2607 15242 115 NEGYMPIEVETERANLOGG
29196 GRANDIS        CSIRO DIV.         C.E.LANE-POO          21930        * *                  2627 15241   0 IMBIL
29197 GRANDIS        CSIRO DIV.         C.T.WHITE           1111924          *                  2725 15258   0 FERNYGROVENRBRISBAN
29198 GRANDIS        CSIRO DIV.         COLLECTOR UN           1930            *                3127 15244   0 WAUCHOPE
29199 GRANDIS        CSIRO DIV.         F.M.BAILEY            11930        * *                  3121 15246   0 CAIRNCROSSSE
29200 GRANDIS        CSIRO DIV.         W.A.W. DE BE       20081931          * *                3018 15308   0 COFFS HBR
29201 GRANDIS        CSIRO DIV.         D.J.BOLAND      94  1101969          *                  3148 15232   0 5MW COOPERNOOK
29202 GRANDIS        CSIRO DIV.         W.A.W. DE BE       29091931          *                  3008 15301   0 NANA GLEN
29203 GRANDIS        CSIRO DIV.         M.I.H.BROOKE       27071972        * * *                3000 15300   0 COFFS HBR- URUNGA
29204 GRANDIS        CSIRO DIV.         C.E.LANE-POO          11930        * *                  3034 15254   0 NEWRY SE
29205 GRANDIS        CSIRO DIV.         J.C.DORAN          28031974        ***                  2827 15312 100 MEBBIN SF MURWILLUM
29206 GRANDIS        CSIRO DIV.         G.M.CHIPPEND   477 30051968        * ***                3224 15221   0 7.4MEBULAHDELAH
29207 GRANDIS        CSIRO DIV.         D.I.NICHOLSO       24081947          *                  3027 15301   0 REPTON
29208 GRANDIS        CSIRO DIV.         M.R.O.MILLET          51938            *                3150 15237   0 COOPERNOOK
29209 GRANDIS        CSIRO DIV.         W.A.W. DE BE   264 17081931        ***                  3011 15308   0 BUCCA VIA COFFS HBR
29210 GRANDIS        CSIRO DIV.         M.I.H.BROOKE  3734 24071973        ***                  3028 15256   0 24.3MDORRIGO-C R
29211 GRANDIS        CSIRO DIV.         J.C.DORAN       34 28031974        ***                  2827 15312 100 MEBBINSE
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Appendix 2. Seed Data Sheet used by Collectors, Tree Seed Centre, CSIRO

CSIRO Division of Forest Research
PO Box 4008
Canberra ACT 2600

SEED DATA SHEET

Species: Seedlot No.

Collection locality:

Latitude: ° 'S Longitude: ° 'E Altitude:(m) Aspect Slope

Climatic zone: Met. Station:

Association includes:

Geology and Soil: pH:

Collection no.	Bot. spec.	Photo. no.	Ht (m)	dbh (cm)	Tree description	Seed wt (g)	No. of viable seed /10 g

Work supervised by: Date:

SEED COLLECTION TECHNIQUES USED IN ZIMBABWE

by B.R.T.Seward

Introduction.

Other papers to be presented at this workshop will cover collection techniques of indigenous species and wild populations. This paper briefly sets out some considerations given to, and methods used in, seed production and collection from plantation species confined to pines and eucalypts. Because most seed users are well aware of the gains to be made by using improved or genetically superior seed, and therefore its increasing importance in the future, emphasis is given to collections in seed orchards. Although seed can be and is collected in varying quantities from commercial plantations, site selection and management for seed production purposes is seldom a consideration when commercial/industrial plantations are established. Seed orchards and seed stands, however, should be designed, sited and managed for maximum yields at economic prices and an essential prerequisite for attaining these objectives is a sound understanding of flowering phenology and productivity.

Wherever possible, flowering and seed productivity studies should be conducted over a range of sites, linked to climatic data, age, tending methods and parent material. It follows that, if a range of full sib or half sib families is used across sites in any such studies, results will be more meaningful and less subject to extraneous effects.

A.1. Flowering and Fruiting in Eucalypts.

Flowering studies in eucalypts have been an on-going exercise in Zimbabwe and, although less advanced than those carried out in conifers, valuable information is being assembled for a number of species at one locality (Appendix 1). This particular locality was chosen because of the range of sites and species, access to climatic data and the availability of staff to carry out the studies. Much work remains to be done, especially at other sites, to investigate the individual and collective roles that the many factors - including that of insect pollination, for example - may have on seed productivity. Limited experience to date suggests that, providing those species that can be grown successfully in this country are not planted widely "off-site", seed is produced in acceptable quantities, although it must be emphasised that proper site selection and management techniques are essential for maximising seed yields. It is believed, in fact strongly recommended, that the successful production of eucalypt seed requires a good working knowledge of eucalypt taxonomy and of the affinities between different groups of species within each of the important subgenera. Not only is this necessary for identification purposes, but it is also important to know or to recognise related species that may cross pollinate freely with each other and give rise to unwanted hybrid situations.

It is interesting to note that flowering patterns in some eucalypts grown in exotic environments can vary appreciably from those of the same species growing in their natural habitats - notwithstanding localised variations resulting from seasonal effects. It is not advisable therefore to use information emanating from other countries, but rather to build up your own. Other characteristics such as seed productivity, maturation and shed also appear to be affected by environment - at least that is the Zimbabwean experience. Some eucalypt seed crops in Australia, for instance, appear to be less productive in their early years, are more prone to predation of one sort or another and tend to shed their seed more rapidly on maturation than has been found under local conditions.

A.2. Eucalypt Seed Collection.

Before commencing collections, checks on seed maturity should be made which, in the case of most smaller seeded eucalypts, can be done very easily by cutting open capsules with a sharp knife or secateurs to expose the seeds. As a general rule, light and dark coloured seed indicate immaturity and maturity respectively. In carrying out checks for maturity, it is important to recognise that, in some environments at any rate, branches may carry a range of capsules at different stages of maturity as a result of more than one year's flowering and the fact that the capsules of many species can remain unopened on live branches for long periods after the seed has ripened. Collecting quantities of immature seed can, at best, lower overall viability of a seedlot, and at worst deny the collector that season's crop at maturity.

The size and shape of a tree or trees from which collections are to be made will largely determine the methods and equipment to be used (see Appendix II). Collections from plus trees and seed orchards are normally carried out using various types of extension ladders or a tree bicycle to provide access up, or into, the crown from where small capsule-bearing branches can be cut off using long handled secateurs. Manipulating long ladders generally requires two men, so that while one man is operating up in the tree the other remains on the ground collecting the fruiting material being harvested from the crown. The same modus operandi applies to collections using a tree bicycle as, although these can be operated by one man, the practice is not recommended because of the possibility of accidents. Safety and safety equipment cannot be over-emphasised where any form of climbing is involved. Other advantages of using teams of two or more men for collection are the time factor; where this is limiting, economies of scale and the fact that operators can alternate between the more arduous and less tedious tasks effectively increasing productivity.

In Zimbabwe, seed extraction from freshly picked capsules is usually conducted near collection sites, thereby reducing the time factor between collection and extraction. Thus the need to use the more expensive calico sheeting or bags to avoid damaging the seed does not arise, and plastic bags have been found suitable providing they are kept reasonably cool under shade in the field to minimise sweating and condensation. Should the need ever arise to store or transport fresh capsules for any length of time before extracting seed, then obviously other methods more applicable to collections from natural populations in Australia could be used.

A.3. Eucalypt Seed Extraction.

For most species, collections can be timed to take place during the dry months of the year, in which case extraction can be carried out very effectively under open-air conditions. Should collections need to be made during the wet months, some form of shed or shelter, preferably with artificial heating, is desirable. As these can take many forms, they are not discussed in detail except to mention that polythene, hothouse-type structures making use of solar energy have been used successfully in this country.

Any base on which capsules can be spread out in a thin layer to afford rapid drying and avoid a build up of moisture will suffice for extraction. Plasticized tarpaulins have been found most effective, being portable, robust and easy to clean. Seed extraction, particularly in those species with small fruit such as E. camaldulensis, presents few problems because moisture loss is generally rapid and the capsule valves open readily. Larger-capsuled species take longer, and it is interesting to note that seed recoveries in terms of fresh capsule mass tend to decrease with increasing capsule size. Maximum seed recoveries will only be obtained when all the capsules are fully opened and some form of agitation is applied to recover the high proportion of seed located in the base of capsules. The removal of impurities, such as small pieces of leaves, twigs, peduncles and capsules, from extracted seed is best carried out by sieving, using various gauges of screening most appropriate for different seed sizes.

B.1. Pine Seed Collection.

While collections cannot be viewed in isolation from flowering phenology and productivity, earlier studies of these factors in this country have already been published. Discussion is, therefore, centred on collection methods in seed orchards, and it is necessary to start with the assumptions that the optimum sites for seed production have already been established and that management techniques have been taken into consideration.

B.2. Advantages of Collecting by Clones.

The collection of orchard seed by individual clones has been the standard practice in Zimbabwe for a number of years and individual clonal identities have been maintained throughout the extraction, testing and storage processes. It is felt that the extra effort and costs involved are more than justified by the substantial gains and advantages over bulked orchard collections, some of which are listed hereunder:

a. It enables one to act immediately on information, be it the susceptibility of certain clones to pests and diseases or to results emanating from progeny tests, and any undesirable clones can be isolated straight away;

b. It affords the means whereby individual clonal seedlots can still be bulked, if required, but mixed in direct proportion to their test results to give an equal clonal representation in the planting stock raised from this seed. Bulked orchard collections nearly always contain unequal amounts of seed from the different clones represented in the orchard because some clones are more prolific producers than others;

c. It allows management and decision makers more flexibility in how they want to raise and plant their seedlings. They can either order and use seed of mixed clones, as in b. above, or order their seed and raise their seedlings as individual clonal lots. Both mixed or individual clonal seedlots can be selected from those clones identified by progeny tests (assuming these cover a wide range of sites) to be best suited for a particular site where, for example, certain elevations or drought resistant characteristics may be important considerations;

d. If individual clonal seedlots are used, this opens up another option in that plantation establishment can be carried out using "blocks" of individual clones. Although the merits of this system are open to debate, there are strong arguments in its favour because, if some clones succumb to a disaster of one sort or another, management could be made easier by clear felling "blocks" rather than have a percentage mortality distributed over a wide area. Identifying clones that do succumb to disasters is also made easier if individual clonal identities have been maintained through "block" plantings within plantations.

B.3. Collection Methods.

Records built up over a number of years have established the order in which cones of most clones ripen and, although there is obviously a lot of overlapping at the height of ripening, there is nonetheless a set order which remains constant, regardless of seasonal effects. Appendix III shows the design, layout and number of ramets of each clone established in a P. elliottii seed orchard, No.53, at Gungunyana Forest Research Station. Appendix IV is a control form used for the planting and survival of grafts, where a separate page is used for each clone. Every ramet in the orchard is labelled by clone and grid number, and collecting individual clones therefore becomes a comparatively straightforward operation by the supervisor giving the collectors a list of clones and their grid number (see Appendix V compiled from Appendix III), thus enabling them to locate the trees without wasting time. Collectors usually work in pairs using similar methods and equipment to those used in eucalypts, except a long handled crook is used to sever cones from branches in place of long handled secateurs.

Cones are picked up from the ground and put into jute bags which are labelled with all the relevant details before being moved from the orchard to sheds or racks near extraction points. As an additional precaution, in case exterior labels become detached, a second label is placed inside the bag before it is sewn up or tied in the field.

Extracting and processing pine seeds is outside the scope of this paper, but no real problems are encountered, maintaining clonal identities at each stage until, finally, the seed is tested and stored by individual clones.

Appendix 1

EUCALYPTUS FLOWERING STUDIES — J.M.F.R.S.

SUMMARY FOR YEAR: 1983

Number of trees in flower on one observation day during the week.

CODE	SPECIES	DSN JM	TOTAL Nº TREES	MONTH																																																				
				JANUARY				FEBRUARY				MARCH					APRIL				MAY					JUNE				JULY				AUGUST					SEPTEMBER				OCTOBER					NOVEMBER				DECEMBER				
				WEEK NUMBER AND DATE																																																				
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53
BAA:A	E. tessellaris	621	6																										1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	4	4	3	2	2	1	
CAFOA	E. ficifolia	1073	1																																																					
CAFUA	E. calophylla	1083	35	32	33	34	32	27	21	17	12	7	6	10	10	6	6	3	2	1	2	2	1	1	1	1	1										1	1	1	1	2	2	1	1				2	2	3	4	15	18	24	32	
CAFUF	E. gummifera	1067	41						6	11	13	28	34	30	27	19	14	11	20	17	12	10	7	6	3	3	1	2	2	1	1																									
CAFULA	E. nesophila	415	1																																																					
CCB:A	E. torelliana	356	5	2	1	1	1		1	2	2	2	2	1	2	2	3	4	4	1	1	1	1	1	1	1	1																			2	5	5	5	3	3	3	2	1	1	
CCB:A	E. torelliana	411	18	3	1	1	1	1	1	2	2	2	1	1	1	2	3	3	3	3	2	1	1	1	1	1	1														1	1	1	2	6	7	8	8	5	2	3	5	4	1	1	
CCC:A	E. citriodora	414	15	1																	1	3	6	7	8	8	10	11	11	11	11	10	10	9	9	8	5	5	2	2	1	1														
CCC:A	E. citriodora	882	11	1	1	1															3	3	3	6	7	11	11	11	11	11	11	10	10	10	10	10	9	8	6	2	2	2	4	4	7	6	6	6	5	5	5	4	3	3	5	
CCC:B	E. maculata	407	23	1	2	2	3	6	9	18	21	21	23	23	20	12	8	3	7	8	5	4	2	3	3	3	2	1	1	1	1	1	1	2	2	3	3	3	3	4	4	4	4	5	5	5	5	4	4	3	3	2	3	3	2	
EAC:A	E. tetrodonta	1081	8	2	2	3	3	3	2	2	4	3	3	2	2	3	4	3	3	2	4	5	4	4	4	4	4	4	4	4	4	4	4	4	4	3	4	4	4	5	5	5	6	6	6	6	6	6	6	6	6	6	6	6	6	
EFC:A	E. miniata	1074	1																				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1															
IAA:A	E. cloeziana	364	23	23	18	7	3	1																																		1	1	1	1	1	1	1	2	4	7	9	13	17	23	
IAA:A	E. cloeziana	405	17	17	12	7	3	1																																							1	1	4	7	10	16	16	11	9	
IAA:A	E. cloeziana	616	4	1	3	4	4	4	3	2	2	1	1	1	1	1	1		1	1	1						1	1	1	1																								1	
IAA:A	E. cloeziana	631	30	9	4	1																																									2	5	8	15	16	19	14	11	5	
IAA:A	E. cloeziana	632	26	20	13	5	1																																											1	5	11	13	12	7	
IAA:A	E. cloeziana	640	38	9	7	4	2	1																																										1	1	4	4	7	5	
IAA:A	E. cloeziana	641	36	15	6	3	1																																					2	2	3	4	7	10	14	27	24	20	13	
IAA:A	E. cloeziana	880	31	13	4	2	1																																								1	1	4	6	22	28	22	19	
MAHAA	E. muellerana	1078	39	3	2	2	2	2	2	6	7	12	9	11	11	12	9	6	6	8	9	10	11	7	8	9	7	9	9	6	5	5	6	5	5	6	7	4	6	5	7	5	7	6	5	5	8	11	11	6	5	6	3	3	9	
MAHAB	E. laevopinea	637	28	2	2	2	3	7	7	9	11	18	18	28	28	28	28	28	28	28	28	28	28	28	28	25	25	19	16	12	7	8	9	20	24	24	24	27	28	28	28	28	28	28	25	21	21	16	7	4	3	1	1	1	1	
MAHAB	E. laevopinea	638	15	10	10	15	8	5	7	8	9	9	8	11	9	9	5	5	5	3	3	3	1	1	1	1			1	1	1				1	2	4	7	7	7	6	2	4	4	7	7	7	3	4	5	6	9	10	10	13	
MAHEC	E. phaeotricha	636	32								1	1	1	1	4	4	7	5	14	14	24	24	32	29	21	15	9	3	3	1	1						1	1	1	1	1	1	1	1	1	1	1									
MAIAAA	E. pilularis	633	11																									1	1	2	5	8	10	10	10	10	10	9	6	3	6	9	8	8	8	8	7	4	2	1	1	1				
MAIAAA	E. pilularis	879	25												1	1	1	1	1	1	1	2	4	4	4	7	7	9	11	10	27	29	28	28	28	25	18	9	6	5	5	4	3	2	9	13	13	7	3	3	2	1	1			

EUCALYPTUS FLOWERING STUDIES — J.M.F.R.S.

SUMMARY FOR YEAR: 1983

Number of trees in flower on one observation day during the week.

CODE	SPECIES	DSN JM	TOTAL NO TREES	MONTH																																																				
						JANUARY				FEBRUARY				MARCH				APRIL					MAY				JUNE					JULY				AUGUST					SEPTEMBER				OCTOBER					NOVEMBER				DECEMBER		
				WEEK NUMBER AND DATE																																																				
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53
MAKAA	E. sp. ? obliqua	615	31	5	7	7	4	2	2	2	2	3	3	2	1	1	1											1	1	1	1	1	2	2	1	1	1	3	3	2	2	2	1	1	3	3	4	5	5	5	4	3	3	2	5	
MAKAA	E. obliqua	890	13	1	1	5	5	12	7	5	3	2	2	2	3	3	3	4	4	4	4	3	3	3	3	4	4	4	4	3	3	3	3	3	2	2	3	3	4	4	4	4	4	2	1	1	1	1	1	1	1	2	2	1	1	
MAKCA	E. regnans	630	1																																																			
MAKCA	E. regnans	691	245						1	3	3	2	1	4	4	4	6	5	5	4	3	2	5	9	13	11	11	14	14	14	9	5	3	2	6	6	5	2	1	1	1	1	2	2	1					1	1	1	1			
MAKCA	E. regnans	728	10	2	2	3	3	3	2	2	2	2	1	1	2	2	1	1	1	1	1		1	1	1	1																												
MAKCA	E. regnans	799	64																																																		
MAKCA	E. regnans	802	212				1	3	3	3	3	3	2	2	4	4	3	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1					2	2	2	2	1	1	1	1								1	1	1	1	
MAKCA	E. regnans	804	244												5	5	3	7	13	6	4	3	2	1	1	1	1	1		1	1	1	1	1	1	1	1	1	3	5	6	4	1	1	1							1	1	1	1	
MAKCA	E. regnans	891	12																																		1	1	1	1	1	1	1	1	1	1	1									
MAKCA	E. regnans	892	5																																											1	1	1	1	1	1					
MAKCB	E. fastigata	624	18																															2	3	3	3	3	5	5	5	5	6	6	9	10	10	10	6	3	2	1	1	1	3	
MAKCB	E. fastigata	693	33	9	5	2	1																																													3	23	
MAKDA	E. oreades	628	4																																																		
MAKDA	E. oreades	696	29	13	14	22	13	5	2																																					2	2	2	4	3	3	3	12	
MAKED	E. sieberi	626	20																											1	1	3	7	10	13	13	14	11	7	5	5	6	6	9	13	10	7	4	3	2	2	2	2			
MAKED	E. sieberi	698	31																													1	2	4	5	7	5	5	6	9	12	15	19	31	31	26	19	5	2							
MATELA	E. radiata	619	19	4	4	2	1	1							1	1	1	1	1	1	1	1	1.	1	1	1	1	1	2	2	2	2	1	1	1	1	2	2	2	3	4	4	5	5	5	5	5	9	9	14	13	15	15	15	9	
MATELA	E. radiata	697	28	1	1																																											2	4	4	7	3	2	
MATEL	E. ? radiata	1087	44											1	3	3	4	4	4	5	5	14	18	27	34	42	42	42	41	41	39	37	35	35	31	34	34	36	33	30	30	28	19	19	15	12	7	2	1							
MATHDA	E. andrewsii	623	19	5	3	2	1	1																					1	1	1	1	1	1	1	1	1	1	1	2	3	2	5	6	8	11	14	14	14	17	16	17	15	14	11	
MATKF	E. rossii	620	18	2	1	2	3	3	3	3	3	3	3	3	2	2	2	2	1	1	1	1	1	2	2	2	2	1	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	3	2	2	2	
MATKF	E. rossii	639	5																										1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			1	1	1	1	1				
SBA:A	E. deglupta	746	29	4	4	4	5	4	3	3	3	2	2	2	2	1						1	1																				2	3	5	6	6	6	6	6	6	7	7	7	5	
SBA:A	E. deglupta	761	40	2	2	2	2	2	2	2	1	1	1	1																													1	1	1	1	1	2	1	1	1	1	2	2	2	
SBA:A	E. deglupta	878	31				1	2	5	5	7	6	5	6	6	5	5	1	1	1	1																																		1	
SECAA	E. deanei	599	31	2	1	1																										1	1	1	1	1	2	2	6	8	5	9	12	9	10	6	7	4	8	5	6	6	6	4	

EUCALYPTUS FLOWERING STUDIES — J.M.F.R.S.

SUMMARY FOR YEAR: 1983

Number of trees in flower on one observation day during the week.

CODE	SPECIES	OSN JM	TOTAL Nº TREES	MONTH																																																
				JANUARY					FEBRUARY				MARCH					APRIL				MAY					JUNE				JULY				AUGUST				SEPTEMBER					OCTOBER				NOVEMBER				DECEMBER				
				WEEK NUMBER AND DATE																																																
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53
SECAA	E. deanei	600	33	1	1	1																							1	1	1	2	2	4	4	3	3	5	5	6	6	6	6	7	9	9	7	7	5	5	5	3	2	2	1	
SECAA	E. deanei	601	25			4	9	13	19	18	13	7	7	4	3	3	2	1																																					1	
SECAA	E. deanei	635	24	1	1	1																																		1	1	2	2	3	5	5	6	9	8	5	5	4	3	3	6	
SECAA	E. deanei	699	32	1	1	2	7	8	6	2	1	1	1																																									1	1	
SECAA	E. deanei	700	32	1	1	6	12	11	7	3	1	1	1	1																																		1	1	1	1	1	1	1	1	
SECAA	E. deanei ?	894	98																							1	1	1	3	4	5	6	6	6	6	6	6	6	5	5	5	5	2	2	1	1	1									
SECAA	E. deanei ?	1076	42											1	1	1	1	1	1	1	1	1	1																																	
SECAB	E. grandis	589	21								1	5	7	13	13	20	20	20	15	9	8	7	7	4	3	3	2	1	1													1	1	2	3	3	3	3	3	2	1	1	2	2	2	
SECAB	E. grandis	596	7										1	2	2	7	7	7	7	7	6	3	3	2	1	1	1																													
SECAB	E. grandis	603	32					1	2	5	5	14	23	23	23	22	21	12	7	3	2	1	1																																	
SECAB	E. grandis	605	31								2	7	14	14	14	17	26	24	21	14	8	8	4	2	2	1																														
SECAB	E. grandis	606	32							1	5	12	16	24	25	29	32	31	29	25	15	9	6	3	1	1'	1																													
SECAB	E. grandis	607	31								1	4	11	27	27	30	30	30	30	27	19	13	8	3	2	1	1																													
SECAB	E. grandis	608	36								1	8	11	21	23	31	31	31	31	28	16	11	8	4	4	3	2	1																												
SECAB	E. grandis	609	34								3	3	9	20	22	28	32	32	27	27	27	24	17	9	5	2	2	1																												
SECAB	E. grandis	610	32								1	2	8	23	23	29	29	29	26	24	20	20	15	11	6	5	4	1	1																1	1	1	1	2	2	2	2	2	2	1	
SECAB	E. grandis	611	34											2	5	16	26	28	28	25	23	20	16	7	4	1	1																													
SECAB	E. grandis	886	23							1	1	1	3	4	5	8	8	8	23	23	23	23	19	13	13	10	10	10	7	7	5	6	6	5	4	3	4	3	3	3	2	1	1	1	1											
SECAC	E. saligna	588	31	5	8	12	21	10	4	1																																										2	2	10	
SECAC	E. saligna	602	14	1	1	1																							1	1	1	1	1	1	1	1	2	2	3	3	3	3	2	2	2	2	3	1	2	2	1	1	1	8	
SECAC	E. saligna	604	25	6	3	3	2	2	1																																					1	2	3	6	6	12	13	13	15	
SECAC	E. saligna	612	34	15	8	4	2	1																												1	1	1	1	1	1	1	1	1	1	1	3	3	4	7	7	11	11	30	
SECAC	E. saligna	613	30	3	10	23	24	24	17	11	8	7	2																																									
SECAO	E. botryoides	597	16	1	1	1																																										1	1	2	2	4	
SECAO	E. botryoides	598	34	5	3	5	2	1	1																																					1	4	6	11	16	13	21	24	27	
SECAO	E. botryoides	617	7	3	4	5	3	2	1	1																																						2	3	2	3	5	7	

EUCALYPTUS FLOWERING STUDIES — J.M.F.R.S.

SUMMARY FOR YEAR: 1983

Number of trees in flower on one observation day during the week.

CODE	SPECIES	DSN JM	TOTAL Nº TREES	MONTH																																																			
				JANUARY				FEBRUARY				MARCH					APRIL				MAY					JUNE				JULY				AUGUST					SEPTEMBER				OCTOBER				NOVEMBER					DECEMBER				
				WEEK NUMBER AND DATE																																																			
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53
																																				•																			
SECAD	E. botryoides	885	28							1	1	9	23	26	26	26	26	23	16	11	5	5	5	6	6	5	3	1	1	1	1																							
SECAF	E. robusta	1079	36	2	2	4	4	5	7	9	9	15	19	20	20	21	26	25	25	21	18	18	12	9	8	6	5	2	1	1	1																								
SECCC	E. resinifera	359	22	17	9	4	2	1	1																																					2	2	7	7	13	21	22	20	20	
SECCC	E. resinifera	745	29	3	1	1																									1	1	1	2	2	2	3	2	2	1	1	1	7	9	10	11	13	8	6	9	8	12	9	9	4	
SECEA	E. propinqua	1066	43	23	17	11	7	6	3	1	1	1																									1	1	1	2	2	2	2	1	1	3	3	3	5	6	7	9	12	17	
SECED	E. punctata	1080	42	36	33	35	30	22	12	5	1																																	1	1	1	2	4	7	10	18	24	33	42	
SICAA	E. gomphocephala	362	10																																																				
SIDAA	E. occidentalis	409	0																																																				
SIS:A	E. cladocalyx	366	10	2	1	1	1			1	1	3	3	6	6	6	6	6	6	6	6	6	5	5	5	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	7	7	7	7	6	7	8	8	8	8	7	7	6	
SNAAA	E. urophylla	706	8	1	1	1	5	6	8	8	8	8	8	8	7	7	4	2	1	1																																			
SNAAA	E. urophylla	707	15																	3	4	4	4	4	4	4	4	3	2	1	1	1	1	1	1	1	1	1	1	1	1													
SNAAA	E. urophylla	708	9																																1	1	1	1	1	1	1	1			1	1	1							
SNAAA	E. urophylla	710	6				1	1	1	2	5	5	5	5	3	2																																							
SNABA	E. alba	412	0																																																				
SNABA	E. alba	413	10																						1	2	2	2	2	2	3	4	5	5	5	5	5	5	5	4	4	2	1	1										
SNABA	E. alba	705	36	1	1	1	1																																																
SNABGA	E. brevifolia	1086	18	1	1	1	1	1	1	1	1	1	1	1	2	2	1	1				1	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1								
SNEEB	E. tereticornis	357	20	11	8	8	5	4	5	3	2	1	1				3	3	2	2	1	1	1	1					1	1	1	2	2	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	6	9	12	15	18	17	17	
SNEEB	E. tereticornis	361	22															1	1	1	1	1	1	3	4	6	7	9	8	8	8	8	9	11	13	13	14	12	12	19	17	17	17	17	14	6	3	4	2	1	1			
SNEEB	E. tereticornis	368	23	4	2	2	2	2	1			1	1	1	1	2	2	1	1	1	2	2	1	1													1	1	1	1	1	2	3	3	7	7	9	16	21	17	14	11	8	12	
SNEEB	E. tereticornis	591	32	4	4	5	5	3	3	3	3	5	5	6	6	3	3	1	1	5	5	4	2	3	4	6	6	5	4	3	2	3	4	6	7	9	12	12	12	13	12	16	19	24	25	30	30	25	13	5	5	3	1	1	1	
SNEEB	E. tereticornis	592	33						1	1																						3	4	6	7	8	14	17	24	31	32	30	19	8	5	3	2	1	1	1	1	1	2	
SNEEB	E. tereticornis	593	35	4	5	7	4	4	3	3	2	3	3	3	1	3	3	3	4	5	5	7	12	14	14	17	29	32	32	32	28	25	24	16	11	7	5	5	11	11	11	13	15	15	15	11	5	2	1	1	1	1	1	1	3	
SNEEB	E. tereticornis	594	33	12	12	8	8	5	7	8	8	8	9	7	5	5	7	7	9	8	13	15	24	30	31	32	33	33	33	31	31	31	29	29	18	14	11	10	10	7	5	3	3	3	2	3	3	3	5	5	3	4	4	4	6	
SNEEB	E. tereticornis	595	15																																	1	2	2	2	4	5	7	15	15	15	15	6	2	1					
SNEEB	E. tereticornis	748	38	27	19	12	3	3	1	1																																					3	5	12	17	19	18	15	13	

EUCALYPTUS FLOWERING STUDIES — J.M.F.R.S.

SUMMARY FOR YEAR: 1983

Number of trees in flower on one observation day during the week.

CODE	SPECIES	DSN JM	TOTAL Nº TREES	MONTH																																																		
				JANUARY				FEBRUARY					MARCH				APRIL				MAY					JUNE				JULY					AUGUST				SEPTEMBER				OCTOBER					NOVEMBER				DECEMBER			
				WEEK NUMBER AND DATE																																																		
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53
SNEEB	E. tereticornis	1077	43							1	1	1	1	2	1	3	5	5	8	8	15	22	33	37	41	41	41	40	40	38	29	29	29	28	21	16	11	9	6	4	1	1	1	1	1	2	3	3	1							
SNEEF	E. blakelyi	618	16																									1	1	1	1	1	1	1	1	1	1	1	1	1	3	3	3	3	2	1	1		1	1	1					
SNEEP	E. camaldulensis	371	28					1	1	2	2	9	12	15	18	17	18	15	17	17	10	9	9	8	10	9	7	5	7	7	5	4	4	4	2	4	4	3	3	2	2	2	2	2	3	2	2	2	2	1	1					
SNEEP	E. camaldulensis	372	33																																							2	2	4	7	13	13	15	22	19	16	7	2			
SNEEP	E. camaldulensis	373	47	2	1		1	1	1							1	1	1	3	4	4	5	5	7	7	7	7	8	14	15	15	16	16	19	18	24	24	34	34	34	34	35	36	35	34	34	35	35	34	27	25	16	9	3	1	
SNEEP	E. camaldulensis	374	8	1	1	1	1	1	1																1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
SNEEP	E. camaldulensis	375	52	18	18	20	14	8	8	3	1	4	2	1	1	1	1	1			1	1	1	1	1	1	1	1	1		1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	5	6	9	23	
SNEEP	E. camaldulensis	376	53																															2	2	2	2	2	2	2	2	2	2	3	4	4	4	4	3	2	2	3	1	1	1	
SNEEP	E. camaldulensis	377	23													1	1	1	1	2	3	3	4	4	7	8	8	8	8	8	10	12	12	12	12	12	12	12	12	12	12	9	5	2	2	1	4	5	6	6	5	2	1	1		
SNEEP	E. camaldulensis	378	56	3	3	2	2	1	1																							1	1	1	1											1	1	1	1	1	1	2	5	5	5	
SNEEP	E. camaldulensis	379	56													1	1	2	2	4	4	5	7	7	9	9	12	7	8	6	10	13	10	10	10	14	14	14	10	9	12	8	8	6	8	5	6	6	6	4	3	1				
SNEEP	E. camaldulensis	380	57										1	1	1	1	2	2	4	5	7	8	5	4	7	6	8	5	8	8	9	16	11	12	7	10	9	9	9	7	5	5	6	3	3	3	8	7	3	1	1	1				
SNEEP	E. camaldulensis	381	57	14	10	6	4	2	1	1		1	1	1	1	1	1	1	1													1	1	1	1						1	1	1	1	4	7	12	14	17	39	39	35	27	21	17	
SNEEP	E. camaldulensis	382	49	2	3	3	3	3	2	2	1	1	1	2	2	1	1	1																													1	1	1	1	2	2	3	4	
SNEEP	E. camaldulensis	383	59	5	6	6	6	3	4	2	2	3	3	1	1	1	1	1	3	5	6	2	3	4	9	11	11	13	18	18	24	21	18	14	14	13	11	21	24	24	28	37	37	40	40	40	40	31	23	20	11	5	1	1	1	
SNEEP	E. camaldulensis	384	59	3	6	6	5	3	1																																									1	4	5	11	
SNEEP	E. camaldulensis	385	40	1	1		1	1	1																							1	1	1	1	2	3	3	3	3	4	7	9	9	9	9	9	9	8	6	4	3	2	1	2	
SNEEP	E. camaldulensis	386	61									1	1	1	1	1	1	1	1	2	2	2	1	1	2	2	2	3	3	2	4	7	6	4	2	3	4	7	6	5	4	3	1	1	1	1	1	2	2	2	3	3	1	1	1	
SNEEP	E. camaldulensis	387	63	4	9	9	14	9	12	7	4	4	3	1	1																																				2	5	8	
SNEEP	E. camaldulensis	388	54	1																											1	1	1	2	2	2	3	3	4	4	6	7	9	7	12	20	20	25	25	25	18	13	5	3	1	
SNEEP	E. camaldulensis	389	54	2	2	1	1	1																																					1	2	5	14	34	34	29	27	16	
SNEEP	E. camaldulensis	390	59	26	17	13	6	6	7	4	3	3	2	2	1	1	2	6	6	7	9	9	3	3	8	6	6	6	9	5	4	9	6	11	13	8	9	6	8	11	16	16	21	36	40	40	41	45	44	44	37	19	11	7	8	
SNEEP	E. camaldulensis	391	63	5	4	4	3	2	1	1																																				1	1	1	1	1	2	4	5	10	
SNEEP	E. camaldulensis	392	59	1																														1	1	1									1	1	2	4	4	4	4	3	3	
SNEEP	E. camaldulensis	393	52	1																																										1	1	2	2	4	4	2	1	
SNEEP	E. camaldulensis	394	51																													1	1						1	1	2	2	2	2	2	3	3	3	3	1	1	1	1	

EUCALYPTUS FLOWERING STUDIES — J.M.F.R.S.

SUMMARY FOR YEAR: 1983

Number of trees in flower on one observation day during the week.

CODE	SPECIES	DSN . JM	TOTAL Nº TREES	MONTH																																																		
				JANUARY					FEBRUARY				MARCH				APRIL					MAY				JUNE				JULY					AUGUST				SEPTEMBER				OCTOBER					NOVEMBER				DECEMBER				
				WEEK NUMBER AND DATE																																																					
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53
SNEEP	E. camaldulensis	395	48	7	4	3	8	4	10	6	3	3	2	1	1	1	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3	3	4	3	3	3	2	5	
SNEEP	E. camaldulensis	396	60	1	2	2	1	1	—	—	—	—	1	1	1	1	1	3	4	4	5	5	2	6	14	17	19	21	21	16	17	17	14	11	10	11	8	6	11	11	11	11	14	15	11	9	8	5	4	3	3	2	1	1	1	
SNEEP	E. camaldulensis	397	55	2	1	1	1	1	—	—	—	1	1	1	2	2	2	2	2	2	2	1	4	5	5	5	5	3	3	4	7	4	5	9	7	6	4	6	9	9	10	10	10	6	3	2	8	8	7	7	5	6	6	3	5	
SNEEP	E. camaldulensis	398	57	—	—	—	—	—	—	—	—	—	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	3	3	7	7	8	8	7	7	7	8	10	9	9	7	7	6	4	4	8	8	8	6	2	1	1	1	
SNEEP	E. camaldulensis	399	36	5	5	5	7	7	10	5	5	4	6	2	4	7	5	2	1	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	1	1	1	1	2	2	1	2	3	3	6	4	3	2	1	6	
SNEEP	E. camaldulensis	400	58	1	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	1	1	1	1	1	3	3	4	5	6	9	9	10	11	14	14	14	15	14	14	18	16	15	18	18	15	11	8	5	5	3	3	
SNEEP	E. camaldulensis	401	58	13	6	2	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	1	1	1	1	1	1	2	5	9	9	10	11	12	
SNEEP	E. camaldulensis	402	42	1	—	—	—	—	1	2	2	2	3	3	4	4	3	4	4	4	4	5	7	5	5	5	5	5	5	5	7	4	6	5	4	6	6	7	6	6	8	8	5	5	3	3	3	1	2	2	2	1	1	—	—	
SNEEP	E. camaldulensis	403	40	1	—	—	1	1	1	—	—	—	—	—	—	—	1	1	1	1	1	1	1	3	3	2	1	1	1	—	1	1	1	1	1	—	1	1	1	1	1	1	1	3	4	3	9	9	9	9	8	5	3	3	4	
SNEEP	E. camaldulensis	404	55	2	2	1	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	1	1	—	—	—	3	
SNEEP	E. camaldulensis	584	36	—	—	1	1	1	1	—	—	1	1	2	1	1	1	1	1	1	2	1	1	—	1	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	1	1	1	2	
SNEEP	E. camaldulensis	585	30	—	—	—	—	—	—	2	2	4	5	3	2	1	1	1	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
SNEEP	E. camaldulensis	586	20	—	—	—	—	—	2	2	2	3	1	1	1	1	1	1	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
SPEAR	E. ovata	408	23	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	3	3	3	3	1	1	1	1	—	—	1	2	2	3	4	5	9	9	11	13	14	19	20	20	22	22	16	16	16	16	16	11	8	8	5	9	
SPIDA	E. dunnii	614	30	—	—	—	—	—	1	3	4	5	3	3	3	2	1	1	1	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	
SPIDA	E. dunnii	709	11	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
SPIFE	E. cypellocarpa	629	23	1	1	1	2	1	3	5	3	3	2	2	1	1	1	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	1	2	2	1	1	
SPIFE	E. cypellocarpa	692	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
SPIFG	E. nitens	247	16	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	2	2	5	7	8	8	8	10	12	12	12	12	7	4	4	2	2	2	2	2	2	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
SPIFG	E. nitens	358	14	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	1	1	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
SPIFG	E. nitens	701	25	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	1	1	1	1	1	1	3	7	7	8	8	8	8	7	5	3	3	2	1	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
SPIFG	E. nitens	702	12	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	2	5	7	8	9	9	9	9	9	9	6	6	4	1	1	1	1	1	1	1	—	—	—	—	—	—	—	—	—	—	—	—	
SPIFG	E. nitens	703	6	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	1	1	1	1	1	2	3	3	3	4	4	4	5	5	5	5	5	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	—	—	—	—	
SPIFG	E. nitens	704	17	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	3	5	6	7	7	7	10	10	12	12	12	13	6	5	12	12	12	12	7	10	10	10	9	7	4	4	2	1	1	1	—	
SPIFG	E. nitens	794	18	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	1	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	—	—	—	—	—	—	—	—	—	—	—	
SPIFG	E. nitens	795	60	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	1	1	1	1	1	1	—	—	—	—	—	—	—	

EUCALYPTUS FLOWERING STUDIES — J.M.F.R.S.

SUMMARY FOR YEAR: 1982

Number of trees in flower on one observation day during the week.

CODE	SPECIES	DSN JM	TOTAL Nº TREES	MONTH																																																	
				JANUARY					FEBRUARY				MARCH				APRIL				MAY				JUNE					JULY				AUGUST					SEPTEMBER				OCTOBER					NOVEMBER				DECEMBER				
				WEEK NUMBER AND DATE																																																	
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53
SPIFG	E. nitens	796	227																													1	1	1	1	1	2	3	3	2	2	2	2	1	1	1										
SPIFG	E. nitens	798	85																						3	6	9	12	17	20	20	20	20	18	15	15	9	4	3	1	1	1	1	1												
SPIFG	E. nitens	800	91																																													1	1	1	1	1	1			
SPIFG	E. nitens	801	150																			1	2	3	6	18	27	29	61	61	61	94	97	101	100	100	97	94	89	81	81	77	54	38	27	15	7	3	1	1	1	1	1			
SPIFG	E. nitens	803	204																					1	3	4	4	4	4	7	15	17	23	23	19	17	15	11	24	23	23	21	11	11	11	6	3	3	2	1	1					
SPIFG	E. nitens	893	107																		1	1	1	1	2	6	7	7	24	25	25	25	34	34	41	46	41	37	31	27	21	17	8	5	2	1	1	1	1	1	1					
SPIFI	E. maidenii	627	23																																						2	4	8	16	20	20	17	13	8	5	5	5	4	3	1	
SPIFI	E. maidenii	695	30																																																			
SPIFL	E. globulus	747	32												1	1	1	3	3	4	12	15	14	14	9	5	2	2	2	1																										
SPIFL	E. globulus	797	116																					2	7	7	10	8	5	9	6	8	13	17	17	17	17	17	14	14	15	15	14	14	11	8	3	2	2	2	1	2	2	1		
SPICK	E. macarthuri	1070	7																			1	1	1	1	1	1	2	2	2	2	1	1	1	1	1	1	1	1	1	1															
SPIKE	E. smithii	1075	38																			1	1	3	7	10	12	12	12	12	11	7	4	3	1	1	1											1	1	1	1	1	1	1	1	
SPINL	E. urnigera	1085	3																																																			
SPINN	E. perriniana	1071	0																																																			
SUAAA	E. rummeryi	881	35										3	5	12	15	16	19	28	33	33	33	34	29	24	21	20	17	18	16	16	13	13	13	6	7	3	4	2	3	1															
SUAAA	E. rummeryi ?	883	28						2	2	3	3	4	4	3	2	2	1	1	1								1	1	1	2	3	4	4	4	4	4	4	4	6	7	7	10	9	5	7	6	4	3	2	2	1	1	1	1	
SUABB	E. leptophleba	406	4											1	2	2	3	3	3	3	3	2	2	1	1	1	1	1	1	1			1	1	1																				1	
SUJ:B	E. ochrophloia	367	2																				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					1	
SUL:B	E. moluccana	410	31	5	5	5	9	9	6	3	2	3	1																									1	1	1	1	1	2	2	2	2	3	3	4	3	2	2	2	2	8	
SUP:E	E. drepanophylla	622	25	2	1																										1	1	1	1	1	1	2	2	2	4	6	6	10	10	12	18	20	23	22	15	8	6	2	2	2	
SUP:I	E. siderophloia	416	17	5	5	6	5	3	3	4	3	2	3	3	2	2	2	1	2	2	2	2	2	2	2	1	1	1	1							1	1	3	3	4	5	7	9	10	12	13	14	12	11	10	5	6	4	3	3	
SUP:S	E. crebra	365	26	1	1	1										1	1	3	4	8	9	15	19	20	22	22	22	22	22	22	22	22	22	21	20	17	17	16	15	17	12	10	6	6	7	5	5	4	4	2	1					
SUV:D	E. paniculata	360	19	2	1									1	2	2	4	5	8	12	12	13	16	17	19	19	19	18	18	15	11	13	13	13	10	12	10	11	13	11	11	11	10	9	10	9	8	4	1	1	1	1				
SUX:A	E. melliodora	1082	42													2	3	4	12	17	21	30	31	36	36	38	38	39	40	40	39	37	40	38	32	31	31	26	21	17	15	12	7	4	2	3	3	2	1	1	1	1	1	1		
SUX:C	E. leucoxylon	1084	9												3	3	3	3	2	3	3	3	4	4	4	4	4	4	3	3	3	2	2	2	2	2	2	1	1	1																
SWA:A	E. microcorys	634	36																		1	2	2	2	3	3	4	9	15	20	27	31	31	31	31	31	31	31	31	31	32	32	32	27	16	9	4	5	1	1	1	1				

EUCALYPTUS FLOWERING STUDIES — J.M.F.R.S.

SUMMARY FOR YEAR: 1983

Number of trees in flower on one observation day during the week.

CODE	SPECIES	DSN JM	TOTAL Nº TREES	MONTH																																																		
				JANUARY				FEBRUARY					MARCH				APRIL					MAY				JUNE					JULY				AUGUST				SEPTEMBER					OCTOBER				NOVEMBER				DECEMBER				
				WEEK NUMBER AND DATE																																																				
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53
SWA:A	E. microcorys	884	25																																	2	6	7	10	10	14	15	13	11	5	3	3	3	2	2	1					
SWA:A	E. microcorys	895	96	6	6	6	6	6	3	3	1	1																																		3	5	14	18	30	34	45	47	44	44	37	25	
—	E. huberana	625	21																													1	1	2	2	5	7	7	8	8	8	7	4	4	3	2	1	1	1							
—	E. huberana	694	31	1	1	1	1																																											1	1	1	1	
—	E. mtaoensis	363	18					1	1	1	1	2	4	4	5	6	7	8	12	12	13	10	12	12	11	12	12	9	9	9	8	7	7	6	7	7	9	9	5	5	7	7	6	4	4	4	3	3	2	1	1	1	1	1	1	
—	Syncarpia glomulifera	587	30																																						5	8	11	8	5	5	1									
—	Tristania conferta	590	33	5	2	1	1																																							1	4	9	24	28	28	28	28	24	13	
SIT:N	E. gillii	1068	0																																																					
SIDCA	E. nutans	1069	0																																																					
SLOBC	E. tetraptera	1072	0																																																					
—	E. grandis	1140	51	2	1			4	7	19	24	36	39	39	39	35	30	19	13	5	5	2	3	3	3	2	2	1			1	1	1	1	1	2	2	2	1	1			1	1	4	4	3	1			1	1	1	1	3	
—	E. botryoides	1141	52	1	1	6	7	4	4	1	1	3	3	3	7	8	8	8	11	9	7	11	8	6	7	4	5	3	4	3	2	2	1	1	1	1	3	3	2	1	1	1	2	2	3	3	3	2	1	1	1	1	3	3	7	

Appendix II

SEED COLLECTION EQUIPMENT

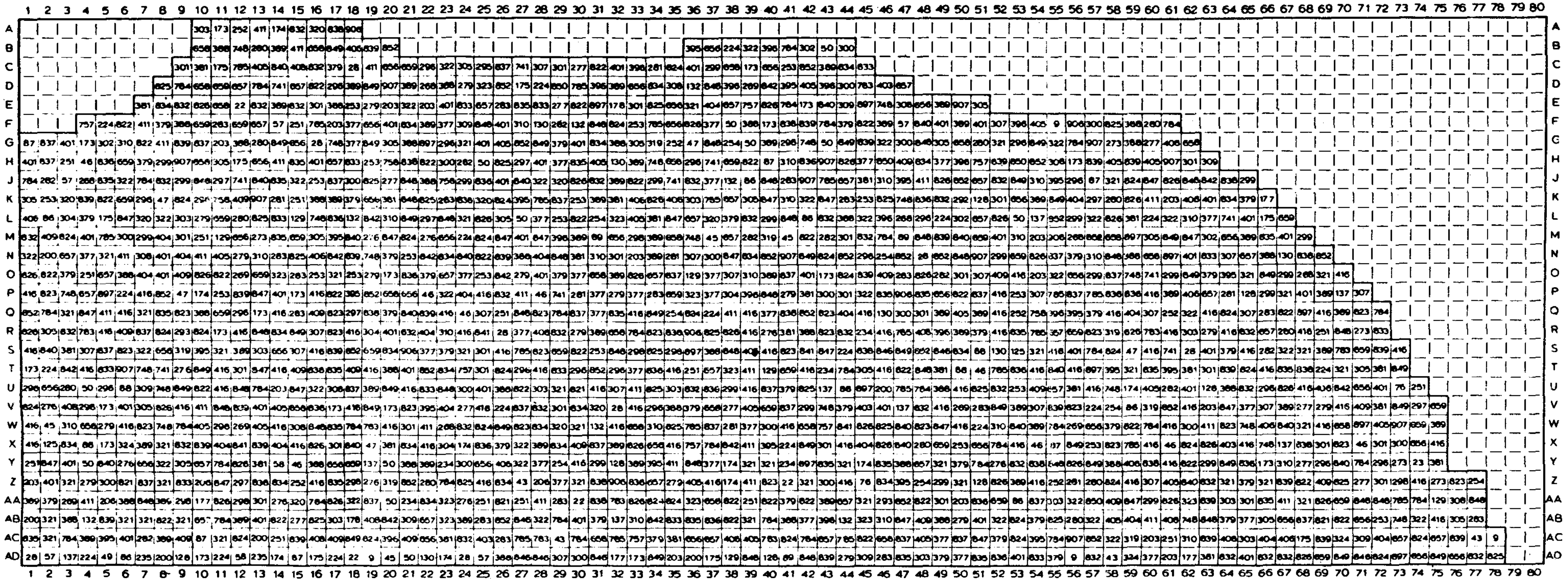
Equipment	Supplier	Price US($)
Tree Bicycle	H.Schneebeli and Co., Schaffhauserstrasse 307, Zürich 50, Schweiz. Forstgerätestelle Waldemar Grube KG D-304, Hützel über Soltau, West Germany. Forest Suppliers Inc., Box 8397, 205 W.Rankin Street, Jackson, Mississippi, 39204 - 397, U.S.A.	1100,00
Ladders	Booth Cubitt Engineering Limited, P.O.Box 3534, Harare, Zimbabwe. AB Wibe, Mora, Sweden Henning Jepson, Formervangen 19, DK - 2600 Glostrup, Denmark.	(Combination ladders) 50-80 (Aluminium extension ladders) 50-160 (Fibreglass extension ladders) 250-500
Commando saw (High limb chainsaw)	Forest Suppliers Inc., Box 8397, 205 W.Rankin Street, Jackson, Mississippi, 39204-397, U.S.A.	20,00
Soil pH meter	Forest Suppliers Inc., Box 8397, 205 W.Rankin Street, Jackson, Mississippi 39204 - 397, U.S.A.	150,00
Secateurs (Hand pruners)	Forest Suppliers Inc., Box 8397, 205 W.Rankin Street, Jackson, Mississippi 39204 - 397, U.S.A.	8,00 - 30,00
Heavy duty pruners	Forest Suppliers Inc., Box 8397, 205 W.Rankin Street, Jackson, Mississippi 39204 - 397, U.S.A.	65,00

For further information please contact:-

Danida Forest Seed Centre,
Krogerupvej 3A,
DIC-3050 Humlebaek, Denmark.

CSIRO, Forest Research Division (Seed Section)
P.O.Box 4008,
Queen Victoria Terrace,
A.C.T. 2600,
Australia.

Appendix III



SEED ORCHARD 53

PINUS ELLIOTTII

GUNYANA FOREST RESEARCH STATION
COMPARTMENT A9
ALTITUDE: 1060m
PLANTED: FEBRUARY 1976
SPACING: 5m x 5m

CLONE NUMBER	NO. OF RAMETS	CLONE NUMBER	NO. OF RAMETS	CLONE NUMBER	NO. OF RAMETS	CLONE NUMBER	NO. OF RAMETS	CLONE NUMBER	NO. OF RAMETS	CLONE NUMBER	NO. OF RAMETS
9	4	308	7	132	7	408	6	277	10	832	35
22	4	309	7	137	8	409	19	279	16	833	13
23	1	310	21	173	8	411	25	280	12	834	22
28	8	319	7	174	9	416	89	281	7	835	24
43	4	320	9	175	8	656	37	282	9	836	18
45	4	321	42	177	4	657	34	283	17	837	27
46	9	322	31	178	3	658	23	292	1	838	18
47	5	323	10	200	6	659	28	293	2	839	29
49	1	324	3	203	15	741	10	295	1	840	19
50	12	377	32	206	3	748	20	296	20	841	4
57	5	379	36	224	18	757	7	297	7	842	11
58	2	381	22	234	5	758	4	298	10	846	7
76	2	388	34	235	2	783	8	299	21	847	22
86	6	389	49	251	15	784	37	300	18	848	36
87	6	395	18	252	6	785	21	301	26	849	33
88	5	396	14	253	20	821	4	302	4	850	4
89	3	401	45	254	8	822	34	303	12	852	26
125	2	403	3	268	6	823	23	304	4	897	13
128	7	404	17	269	6	824	30	305	18	906	7
129	6	405	23	273	5	825	21	307	19	907	13
130	6	406	16	276	10	826	36		TOTALS	124	1861

Appendix IV

Form 4 (Revised 1973)

PLANTING AND SURVIVAL OF GRAFTS

SEED ORCHARD NO.______ SPECIES ______________________________

CLONE NO. ______ NO. GRAFTS PLANTED ____________

Grid No.	Batch No.	Date Planted	Date Removed, Reasons and Remarks

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Appendix V

CLONE	GRID REFERENCE
130	F x 28 H x 32 Q x 46 AD x 22 N x 67 S x 52
9	F x 55 AC x 78 AD x 56 AD x 19

TESTING AND STORAGE OF EUCALYPTUS AND ACACIA SEED

By D.J.Boland

Seed testing is a necessary operation so that eventually the nurseryman will have some idea as to how many germinants to expect from a given quantity of seed or even if the seed is indeed viable. The essence of good seed testing is the application of reliable standard methods of examination to ensure that uniform and reproducible results are obtained. These determinations can best be made by following where possible the International Rules for Seed Testing (Anon, 1976) or preparing local standards for testing if necessary.

Several tests can be made on seeds such as determining the capacity of the seeds to germinate and to grow into normal seedlings, purity tests, vigor, moisture content, seed weight, genuineness and seed health. The aim of this article is to concentrate on germination tests for eucalypts and acacias. Similarly, because seed storage is important to maintain viability, this aspect will be covered for the same two genera. For all other aspects of testing it is recommended that seed researchers consult "A Guide to Forest Seed Handling" (DANIDA) where a large range of issues are discussed. Much of the information given in this article is derived from "Eucalyptus Seed" (Boland *et al.*, 1980) and "Handbook on Seeds of dry-zone Acacias" (Doran *et al.*, 1983).

GERMINATION TESTS FOR EUCALYPTS

The seed of most eucalypts can be easily germinated, although some species require special conditions such as pre-treatment by cold or moist stratification and seed of other species have particular temperature or light requirements.

1. Direct viability tests

The easiest way to determine the viability of eucalypt seed is by the direct method of observing germination under controlled conditions of light, temperature and moisture.

ISTA recommends that germination tests should be made on only the pure seed fraction obtained in the purity analysis, but because of the problem of separating the seed and chaff of eucalypts it has approved germination tests based on samples of equal weight rather than equal number of seed, as in the case of other small-seeded tree species such as birch, poplars and willows (Anon.,1976).

Viability tests for eucalypts have been described by Grose and Zimmer (1958), Floyd (1964) and Scott (1972). Prescriptions for testing 47 of the commercially more important eucalypt species have been published by ISTA (Anon.,1976).

1.1 DEFINITIONS

(a) Germination

Germination in a laboratory test is defined as the emergence from the seed of the embryo with healthy structures essential for development into a normal plant under favourable conditions in soil. In eucalypts a seed is considered to have germinated when the radicle has developed normally and the cotyledons have emerged from the seedcoat and have unfolded or spread.

(b) Normal seedlings

In testing for viability it is necessary to distinguish between normal and abnormal seedlings as the latter are excluded from viability figures. A normal seedling is defined as one that can develop into a healthy plant under favourable conditions (e.g. suitable soil, water supply, temperature and light). A normal eucalypt seedling at assessment should have a healthy radicle, hypocotyl, cotyledons and terminal shoot.

(c) Seed dormancy

This refers to the resting or quiescent condition of the seed. Seed are said to be dormant when they fail to germinate even after being given seemingly favourable conditions for germination. Such seed usually remain firm and apparently viable but ungerminated at the end of the chosen germination period. If the number of such seed exceeds 20% of the germinants, the tests should be repeated, taking steps as outlined later to break dormancy. Dormancy is common in a few species of eucalypts.

(d) Dead seed

These are seed that at the end of the test period are not fresh, ungerminated seed (i.e. not dormant) and have not produced seedlings.

1.2 MATERIALS AND EQUIPMENT

Germination tests on eucalypts are usually conducted at a constant temperature in a germination cabinet which has facilities for illumination. Replicates of a given weight of seed plus chaff are placed on moist filter paper, sand or vermiculite in a petri dish. Glass petri dishes rather than plastic dishes are used because their heavier lids prevent the germinating seedlings from raising the lid and causing the substrate to dry out. Seed lots and replications are identified by marking the lid of the petri dish with a felt pen or wax pencil.

We use a simple cabinet that is 50 x 50cm in cross section and 92cm high. The cabinet has an opaque door and the interior is artificially lit by two 40-watt cool-white fluorescent tubes located vertically at the rear of the cabinet. The cabinet temperature can be regulated to provide different levels in the day and night. The higher temperature is controlled by one thermostat having an adjustable temperature range of 10-54°C and the lower temperature is controlled by another thermostat having an adjustable temperature range of 3-37°C (tolerance ± 1°C). Time clocks are used to switch from one thermostat to the other and to turn the lights on or off. The air temperature within the chamber is monitored by a thermograph.

The petri dishes are placed on a series of removable wire trays held on shelf supports at verticle intervals of 5cm. Care must be taken not to overload the cabinet with dishes as shading will occur. Dishes at the front of the cabinet receive less light than those closest to the light source.

1.3 PROCEDURE FOR TESTING VIABILITY

(a) Sampling

A seed sample should be limited to 50 viable seeds when 9cm petri dishes are used, to avoid crowding of seedlings after germination. Appendix 1 lists recommended sample size (weight) for some species based on average viability data. At least four replicate samples are used for each seed lot. This number is considered necessary because of the variation in results that occur from replicate to replicate.

When the seed lot consists of a mixture of seed and chaff, the sample should be as representative of the seed lot as possible. Mixing by hand and sampling by repeated halving with a spatula is described by Grose and Zimmer (1958). Sampling with 'mixer-dividers' such as the Boerner and the Gamet dividers will yield reliable samples with less effort. Sleeve-type seed samples (triers) are not normally used as eucalypt seed lots are mostly small and difficult to handle with this type of instrument.

The upper portion of the Boerner divider consists of an inverted-conical overhead seed hopper that has a small circular outlet hole and an associated sliding cut-off valve at its base. This valve is operated manually to control the flow of seed out of the hopper. Below the hopper is an upright conical structure with a smooth external surface. Regulated quantities of seed are allowed to fall onto the surface and the seed are randomly distributed into a series of chambers around the base of the cone. Outlets from alternate chambers lead to one or other of the two receiving vessels, thus dividing the seed lot into two parts.

The Gamet divider consists of an overhead seed hopper and is operated electrically. The dividing mechanism is a fast rotating spindle to which is attached a hard rubber cross-arm. This tosses the seed centrifugally into two chambers set at an angle of 180^{o} to each other and thus divides the seed lot into two portions. The Gamet divider can divide small seed lots of eucalypts more accurately than the Boerner divider: the latter divider is more appropriate for dividing large seed lots.

(b) Test conditions

Substrate. Seed of most species of eucalypts germinate satisfactorily on moist filter paper. Filter paper resting on an inverted watchglass, with a gauze filter paper forms an effective substrate (Grose and Zimmer, 1958). In the Seed Section we lay filter paper over fine vermiculite. For a 9cm diameter glass petri dish, 9g of vermiculite and a Whatman No.1, (9cm diameter) filter paper are used. Between-paper tests, where seed are placed between two layers of moist paper, have been used occasionally for eucalypts (Magini, 1962; Vivekanandan, 1971).

An advantage of using filter paper as a substrate is that the very small eucalypt seed are easy to see. In some species, however, leachates from the seed and/or chaff become concentrated on the paper and cause the radicle to become deformed. We have found inhibitory leachates in some seed lots of E.calycogona, E.citriodora, E.cloezania, E.deglupta, E.diversicolor, E.grandifolia, E.haemastoma, E.intertexta, E.kruseana, E.maculata, E.melliodora, E.microtheca, E.patellaris, E.resinifera, E.sphaerocarpa and E.striaticalyx. It may be preferable to place the seed of such species directly on top of sand or vermiculite, thus allowing the leachates to drain away. This arrangement may also be preferred if the seed have been dusted with a fungicide or insecticide (so that excessive concentrations of these chemicals near the germinating seed are avoided), and for species with large seed (so that better contact between the substrate and the seed is provided).

Moisture. High humidity, which is essential for seed germination, can be maintained if the substrate is kept moist and the lid of the petri dish fits tightly. When seed are being tested at high temperatures, such as 30-35°C, the substrate may dry out quickly and therefore require periodic wetting.

We commence tests by applying a predetermined quantity of distilled water from a syringe to the filter paper and substrate in a petri dish. For 7g of vermiculite, 24 ml of distilled water is used. The sample of seed to be tested is then sprinkled over the moistened filter paper. Tests are examined regularly and the filter paper and vermiculite kept moist by the addition of water when required, generally two to three times a week.

Temperature. Grose (1962) determined the optimum temperatures for the germination of seed from 70 eucalypt species over a wide range of constant and alternating temperatures. He found little change in germinative capacity between constant and alternating temperatures, but the rate of germination was slower under alternating regimes. In addition there was some interaction between temperature and light. Seed incubated in darkness at a temperature above 15°C germinated better if the temperature regime was alternated with another in the 5-15°C range. It is therefore considered preferable to test with adequate illumination so that constant temperatures may be used.

Scott (1972) found that seed from most species of eucalypts germinated satisfactorily at constant temperatures close to 25°C. Seed of tropical species tended to have higher optimum temperatures for germination and seed of some temperate species germinated best below 25°C. (see Appendix 1).

The temperature optima cited in Appendix 1 are mostly based on tests with more than one seed source per species.

Light. Clifford (1953) showed that light is required for the satisfactory germination of some species of Eucalyptus, particularly if the seed is not fully mature. Grose (1962) found that as the temperature for germination departed from the optimum, light became a more important factor. For some species light is required even at the optimum temperature, but others appear to be insensitive to light. Floyd (1964) illustrated with E.grandis, which at 26°C (near optimum) had a germination capacity of 45% after 16 days in continuous darkness; on exposure to light the remaining seed germinated within 3 days. He also found that E.pilularis germinated almost completely in continuous darkness at 26°C.

In studies on various provenances of E.camaldulensis, Awe (1973) found no distinct differences between provenances in their light requirements for germination. He found that 98% of viable seed germinated in continuous light and that for satisfactory germination at least a short period of light is required in the early period of germination. The red light region of the spectrum (600-700 nm) promoted and stimulated germination, and the infrared region (720 nm)inhibited germination.

During germination tests the seed should be exposed to a period of light each day. If they cannot receive light from sources within the incubator or light through the glass door of the incubator, they should be removed daily and illuminated for at least 10 min.

(c) Special treatments for breaking dormancy

Viable mature seed of most eucalypt species germinate under favourable conditions without preconditioning. A few species, particularly alpine species in Monocalyptus(such as E.delegatensis and E.pauciflora) and Symphyomyrtus (such as E.glaucescens), require cold, moist pre-treatment to break dormancy. Cold-moist stratification can generally overcome dormancy in seed of all eucalypts that grow naturally in the alpine forests of Australia.

Various methods of overcoming dormancy have been tested. Working with E.pauciflora, Boden (1957) tested physical methods such as cutting or abrading the testa, cold-moist stratification, wet and dry heating, and the application of a range of chemicals including potassium nitrate, thiourea, calcium hypochlorite and sulphuric acid. The most effective treatments were alternating temperature of 3-25°C, cold-moist stratification, cutting the testa, soaking the seed in water for 48 h, and the application of potassium nitrate solution. Bachelard (1967) found that the germination of dormant seed of E.delegatensis, E.fastigata and E.regnans could be improved by treatment with gibberellic acid.

When dormancy is known or suspected, we stratify seed by first setting up the petri dish as for a normal test. Then the filter paper and vermiculite are moistened and the seed are placed on top. The lid is put on and the dish is placed in a cool-room at 3-5°C for the period specified for the particular species (see Appendix 1).

(d) Duration of test

The duration of the test period for eucalypts was examined by Scott (1972). She recommended that a test should last until 90% of the seed had germinated. For the majority of species this is 10-21 days. A different standard was applied by Floyd (1964), namely that the germination test should be regarded as complete when the daily germination falls below 1% of the total for small seed and to zero for large seed. We follow Scott's procedure and the usual number of days that elapse between setting up tests and the first and last day of counting for each eucalypt species is given in Appendix 1.

(e) Evaluation

Normal seedlings. A seedling should be evaluated when it has developed sufficiently to permit the normality of its structures to be assessed. Initially the seed imbibes water and swells, and after a number of days the elongating hypocotyl forces the radicle through the seedcoat. At this stage the end of the hypocotyl has a conspicuous root collar (referred to as a clinging disc by Gauba and Pryor, 1958, 1959) which is large relative to the radicle. The root collar is folded down and slightly over the radicle.

Abnormal seedlings. During germination tests with eucalypt seed it is not uncommon to observe a small fraction of abnormal seedlings. We keep a record of the types and numbers of abnormal seedlings in a seed lot. Most of these seedlings die, although some with abnormal numbers of cotyledons can develop into normal healthy plants. Abnormal plants have been excluded from the viability figures given in Appendix 1.

Abnormal eucalypt seedlings can be divided into three groups, viz. those having abnormalities of the radicle, the hypocotyl, and the cotyledons. Typical abnormalities are poor elongation and a lack or paucity of root hairs. An abnormal hypocotyl may be colourless and watery in appearance or may be quite dry and flaky.

Counting. Each time the seedlot is examined we remove fully developed germinants with forceps and record the number removed. These examinations are repeated at intervals of a few days and most tests are completed in 3-4 weeks.

When the test is terminated, the remaining seed are squashed with a pair of forceps. Any seed found to have a sound, firm, white embryo are considered to be potentially germinable. If the number of sound, ungerminated seed exceeds 20% of the germinants, dormancy is suspected and the test is repeated using other conditions, such as cold, moist stratification.

1.4 CALCULATING RESULTS

The number of normal seedlings produced and the number of sound ungerminated seed are combined (a record is kept of the number of dead seed and abnormal seedlings but these are not included in viability calculations). The viability of the seed lot is expressed as so many viable seed per unit dry weight of the seed and chaff mixture.

The viability figure derived for the seed lot under test can be compared with the average figure for the species given in Appendix 1. This appendix can be used as a guide to determine whether the seed lot under test has high or low viability.

2. Indirect viability tests

Indirect tests for viability entail an assessment of the number of seed per sample potentially capable of germination. A simple test is to allow the seed to imbibe water and then to squash them with a pair of forceps to reveal the condition of the embryo. The number of fresh seed per unit weight of seed plus chaff will provide a rough estimate of viability.

Tetrazolium and excised-embryo tests for viability (see ISTA rules for procedure, Anon., 1976) are impracticable for routine testing of eucalypts because of the very small size of the seed. X-ray testing is potentially useful for the rapid assessment of viability, but more investigation is needed before it can be used routinely; the small size of most eucalypt seed makes evaluation of the X-ray plates difficult. Some preliminary studies on four species have been made by Kamra (1974). Because most germination tests can be made fairly quickly, X-ray testing would be of most benefit for those species which require 4-6 weeks of stratification before germination.

3. Laboratory hygiene

At the Division of Forest Research, the following procedures are used to maintain hygienic conditions. Before tests are set up, petri dishes are washed in detergent and rinsed in a solution of sodium hypochlorite and water. The germination cabinets are also washed regularly with this solution.

Fungi may grow on the seed and across the surface of the filter paper during testing. The fungi seem to originate from spores attached to the surface of the seedcoat. Common fungi genera present on E.delegatensis seed are Alternaria, Aspergillus and Penicillium. Fungal growth can be controlled by spraying with Karathane at a concentration of 0.8g in 1 litre of distilled water. The spray does not affect seed germination.

4. Fumigation

Eucalypt seed should be fumigated before storage to kill insect pests. Carbon disulphide is frequently used for this purpose and is usually applied in a fume cupboard to protect personnel. The chemical is used at a rate of 240g m^{-3} space in the fume cupboard. The length of exposure required depends on temperature and lies within the range of 2.5h at 10°C to 0.7h at 30°C. The seed should be spread out and well aerated (e.g. for about 3h) to remove the gas before they are placed in storage. As an alternative, Craig (1959) placed crystals of paradichlorbenzene in sealed jars with eucalypt seed to protect the seed in storage from insects; he found no loss of germination capacity after 3 years.

Our most common technique now is to place the seed in a plastic bag and replace the air with carbon dioxide gas followed by a heat sealing of the plastic (see full details under acacia seed storage).

5. Storage

5.1 LONGEVITY

Pioneering work on the longevity of eucalypt seed was carried out by Ewart (1908). In tests of 81 seed lots, of ages ranging from a few weeks to 57 years, representing 38 species and varieties, he found that most of the eucalypts tested retained some viability for 20 years. Similar studies by Hall (1914), Maiden (1903-33) and Grose and Zimmer (1958) confirmed that seed of most eucalypt species stored dry in uncontrolled conditions will retain much of their germination capacity for at least 10 years.

At the Division of Forest Research, mature seed of all eucalypts can be kept viable for 5-20 years if stored at a low moisture content in sealed containers at 3-5°C. The majority of species can be stored for 10 years at room temperature with some loss of viability; complete loss of seed viability occurs in some species by 15 years, but in most not until 20 or more years. Of the more important commercial species, E.obliqua and E.diversicolor seed seem to lose their viability sooner than average. The seed of E.deglupta can deteriorate rapidly if stored at room temperature and must be kept in air-tight containers at 3-5°C. E.microtheca seed have shown a significant decline in viability within 2-3 years and storage at low temperatures is recommended.

5.2 PREPARATION FOR STORAGE

(a) Moisture control

Although it is widely accepted that the moisture content of seed is a critical factor in determining their longevity in storage, the relationship has received little investigation in Eucalyptus.

In the United States, Jones (1967) found significant differences in the germination capacity of seed of a red gum (a hybrid involving one or both of E.camaldulensis and E.tereticornis)stored for 2 years at moisture contents of 2.5, 5.5, and 8.5%, and he recommended storage at 2.5% moisture content. Limited tests in Australia have indicated that an adequate storage life for most species can be achieved if the moisture content is in the range 4-8%. Suiter and Lisbao (1973) observed rapid increases in seed moisture when the humidity of the air surrounding the seed was higher than 60%. If seed are extracted in humid conditions the moisture content of the seed may have to be reduced by further drying if extended storage is required.

When seed are not stored in moisture-proof containers it is advisable to maintain a relative humidity in the storage room of between 20 and 40% (Suiter and Lisbao, 1973).

(b) Containers for storage

For long-term storage, eucalypt seed should be kept in airtight containers. Glass or plastic bottles with screw tops and tin-plate containers with tight-fitting lids are suitable. They should be as full as possible to reduce the amount of included air. The seed may also be placed in sealed plastic bags within the containers. A desiccant, such as silica gel, placed in the container may be a useful precaution in humid conditions.

GERMINATION TESTING FOR ACACIAS

The major problem in germination testing of acacias is breaking seed dormancy. The seedcoat is usually hard and impervious to water. A secondary problem is the determination of replicate sample sizes for testing. Factors such as light effects and temperatures to promote optimal germination have not been thoroughly studied. For this reason this section will concentrate on techniques to break dormancy in acacias.

The cause and nature of seedcoat impermeability are not fully understood, but it has been found that under natural conditions and after most artificial treatments the first site at which water penetration occurs is the strophiole. This is the weakest and least reinforced area of the seedcoat and is seen as a small raised area close to the hilum but in the side opposite the micropyle (Cavanagh, 1980).

Numerous techniques have been used to render Acacia seeds permeable. In Australia treatment of the seeds with boiling or hot water was practised last century and elsewhere sulphuric acid was commonly used (Ford-Robertson, 1948). Germination usually proceeds rapidly once the seedcoat is made permeable. In all techniques used there is danger of injury to the embryo if the treatment becomes too severe. The most successful treatments fall essentially into two major classes (Cavanagh, 1980):

Wet: use of boiling or hot water, acids, organic solvents and alcohols.

Dry: use of dry heat, microwave energy, impaction, percussion and manual or mechanical scarification.

1. WATER TREATMENTS

1.1 Cold or warm water

Soaking Acacia seed in water below about 40°C is effective in promoting germination only in those seeds which already have a permeable seedcoat (soft seeds). It is common to find a small fraction (10%) of soft seeds in acacia seed lots but some species have a high proportion of soft seeds if they are harvested before the pods have dried out. However, most seeds will develop impermeability as they mature on the tree or in subsequent storage (e.g. A.senegal, Kaul and Manohar, 1966).

1.2 Boiling water

A frequently-used technique is to immerse the seed in 4-10 times their volume of boiling water (100°C), remove the heat source, and allow the seeds to soak in the gradually cooling water for 12-24h. This method is widely applied but can give erratic results. The volume or weight ratio of seeds to water is critical, and optimum soaking time may vary between species. The rate of cooling is greatly influenced by the scale of the operation and the nature of the container used, so precise control is difficult to achieve. The method appears to give better results for Australian acacias than for the majority of African species (Delwaulle, 1979). Pretreatment with concentrated sulphuric acid is frequently more effective for African acacias.

Boiling acacia seeds in water removes the cuticle and sometimes part of the pallisade layers of the seedcoat and can effectively break dormancy. The range of response to boiling is illustrated by the following examples: A.sieberiana (an African acacia) gives 60% germination after boiling for 1h (Larson, 1964). A.acuminata and A.pycantha will withstand 100°C for a maximum of 5 seconds (Harding, 1940) and A.terminalis for a maximum of 30 seconds (Clemens et al., 1977). For many acacias immersion in boiling water for more than 30 seconds is detrimental.

1.3 Hot water

Boiling usually promotes germination to a critical point beyond which there is a decline in the final germination percentage. Soaking in water within the range 60-90°C is often as effective as soaking at 100°C but there is less chance of damage at the lower temperatures. For several Australian acacias soaking the seed at 80°C for 1-10 minutes is effective (Clemens et al., 1977).

1.4 Discussion

Advantages: When suitable prescriptions have been determined, hot and boiling water methods are reasonably effective for many species, little or no special equipment or chemicals are required, the cost is negligible and with minor precautions the technique is safe for the operator.

Disadvantages: The technique may be unsatisfactory because wet, swollen seeds are difficult to handle and cause problems in mechanical seeders or in pelleting.

2. ACID SCARIFICATION

Soaking in concentrated sulphuric acid is the most common method of treating acacia seeds. The effect on the seedcoat is similar to that of prolonged boiling and the seedcoat is left dull and shallowly pitted. It is a more effective method than boiling water for many African acacias. This scarification technique requires a supply of commercial grade sulphuric acid (95%, 36N), acid resistant containers, wire containers and screens, and an abundant supply of water for rinsing the seeds after treatment.

Safety precautions require strict attention as concentrated sulphuric acid is dangerous to people and materials. It should be handled at all times with great care. When mixed with water it produces an exothermic reaction. Water should never be added to the acid or it may boil explosively. If a dilute mixture is required the acid must be allowed to trickle slowly into stirred water. All operators whould wear acid resistant protective clothing, gloves and eye protection.

A procedure for acid scarification, based on Bonner *et al.*, (1974) is as follows:

(a) Allow seeds to come to air temperature and make sure the seed surface is dry.

(b) Completely immerse the seeds in undiluted acid (1200ml per kg of seed) for the required period. The treatment is best carried out at 20-27°C; lower temperatures require longer soaking times.

(c) Remove the seeds from the acid, immediately wash them thoroughly in cool running water for 5-10 minutes to remove all traces of acid. Use a large amount of water at the start of the washing and stir carefully.

(d) Spread the seeds in a thin layer for surface drying, unless wet sowing is preferred.

The optimum soaking period will depend on the species. It is usually in the range 20-60 minutes but soaking for 120 minutes has given very good results for *A.caven*, *A.farnesiana*, *A.nilotica* and *A.tortilis* in tests at the CSIRO Seed Centre, Australia. A less severe acid treatment can be applied by pouring acid over a pile of seeds (approx. 1 litre of acid per 35kg of seed), distributing the acid throughout the seeds by turning with a shovel, and then washing the seeds thoroughly (Bonner *et al.*, 1974).

2.1 Discussion

Advantages: Acid treatment is effective for many species and can be carried out with simple equipment and at a low cost for materials as the acid is reusable. The treated seeds are dry and unswollen and suitable for mechanical sowing or short-term storage.

Disadvantages: The prescription for the treatment must be carefully defined and a pilot test is desirable. The temperature of the acid during the treatment must be carefully controlled. The greatest disadvantage is the risk to personnel in using the acid and the need to rigidly enforce safety precautions.

3. MANUAL SCARIFICATION

Piercing, chipping, nicking or filing the testa of individual seeds with a mounted needle, knife, handfile or abrasive paper is a technique especially suitable for small quantities of seed. Scarification on the shoulder of the seed one quarter of the way round the circumference from the micropyle (ISTA 1981) or the removal of one square millimetre of seedcoat at the cotyledon end (Magini 1962) is sufficient. This is usually considered to be the most reliable method of pretreatment and the percentage germination following this operation probably approximates closely to the germination capacity (Moffett 1952). Hand scarification is recommended as a method for pre-treating acacia seeds before germination tests (ISTA 1981). However, instances have been recorded when chipping the seedcoat has proved detrimental to germination (Clemens *et al.*, 1977).

4. MECHANICAL SCARIFICATION

A number of commercial machines are available which operate on the principle of tumbling or blowing the seeds against an abrasive surface in a drum or mixer. The machines may be portable hand-operated models or larger, less mobile machines driven by an electric motor. Various models, e.g. the Forsberg scarifier are advertised by seed equipment companies.

4.1 Discussion

Advantages: Mechanical scarification requires no temperature control- it is safe for the operator, the seeds remain dry and so are suitable for machine sowing, and with appropriate machines large quantities of seed can be processed.

Disadvantages: The larger machines are expensive; machine-scarified seeds frequently sustain considerable damage and their storage life is reduced.

5. VARIATION IN RESPONSE TO TREATMENT

Within any acacia seedlot not all the seeds are equally "hard". The proportion of hard seed in a sample depends on the environmental conditions during the growth of the plant, the degree of maturation of the seeds when collected and the length of the storage period. Mature seeds and those that have been stored for several months or years usually have less than 10% of seeds that will germinate rapidly without pretreatment. A study of *A.aneura* seed of several provenances and ages found the percentage of "soft" seeds to be within the range 0.7-4% (Preece 1971). The degree of seed polymorphism may influence the relative success of pretreatment techniques. Interaction between the treatment and seedcoat sensitivity results in differential germination, the degree of which depends on the severity of the treatment. Different responses may be obtained when the seeds are divided into different size classes (Moffett, 1952). Variation in hardseededness will occur within a sample, between samples of the same species and between species. This makes it impossible to prescribe a standard technique which will be optimum for all seeds. When treating large or valuable seed lots with the more severe treatments such as mechanical and sulphuric acid scarification, or boiling water it is recommended that a preliminary test be made to determine the optimum prescription. This can be done by subjecting small samples to a range of conditions, e.g. different periods of immersion in acid, and then germinating the seeds.

6. CALCULATION OF GERMINATION RESULTS

No guidelines have been published to show the range of variation in viability of Australian acacia species. In testing these species we normally count and weigh 50 seeds for a species and use those seeds as the replicate sample for testing. On the basis of these tests we can calculate the number of viable seeds per 10g and the average percentage germination. Table I gives results for three species of *Acacia*.

TABLE I

	No. of viable seeds per 10gms ± S.D.	No. of Tests	Average germination percentage	Temperature °C
Acacia aneura	660 ± 330	125	76	25
A.cyclops	175 ± 101	7	57	25
A.mearnsii	730 ± 200	43	88	25

7. STORAGE

7.1 Longevity

In general, acacias, by virtue of their hard seedcoat which minimises moisture exchange and the loss of stored reserves through respiration, retain their viability well for many years and present few storage problems. Seeds of some species can remain viable in relatively uncontrolled laboratory storage for at least 57 years (Holmes and Buszewicz, 1958) and 68 years (Ewart, 1908), and even more remarkable, for at least 50 years in the field (Moffett, 1952).

While a general recommendation for acacia seeds is to store them dry, in moisture-proof containers in a cool secure location, some species require special treatment. A.harpophylla (brigalow) is a good example of the latter. Given routine treatment, brigalow loses all viability within one year of harvest (Johnson, 1964), while seeds held at -20°C retain viability and remain soft for up to five years (Coaldrake, 1971).

7.2 Storage of treated seeds

Seeds dried after boiling water treatment can be safely stored for at least short periods (e.g. 1 year) with no loss in viability (Moffett, 1952). This also applies to acid-scarified seeds (Cheema and Qadir, 1973), microwave treatment (Cavanagh, 1980) and to mechanically scarified seeds providing they remain undamaged by the pretreatment.

7.3 Insect control before storage

Before storage, acacia seed should be fumigated or dusted with insecticidal powder to kill insect pests. This is extremely important in bruchid infested seedlots, the viability of which may be quickly lost through ongoing attacks by successive generations of the weevil.

Carbon disulphide is frequently used as a fumigant for this purpose, and must be applied in a sealed container with provision for safe injection and release of the gas so as to protect personnel. The chemical is used at a rate of 240g per cubic metre of air space. The length of exposure required depends on temperature: 3.5h at 10°C to 0.7h at 30°C. Afterwards, the seed should be spread out and well aerated (e.g. for about 3h) to remove the gas before storage. Larvae living within the hard seedcoat of acacias may survive the initial treatment, so careful observation of the seedlots and repeat fumigation may be required.

The 'skin-packaging' of tree seed and their preservation by the carbon dioxide exchange method (CEM) is under evaluation by the Division of Forest Research, CSIRO, Canberra and is showing encouraging early results (J.W.Turnbull, ubpublished). In this technique, seed with an appropriate volume of CO_2 gas is sealed in a bag made of plastic laminated film of low gas-permeability. Head space is reduced by the seed absorbing the CO_2 gas which may give a tightly sealed, relatively inflexible package. The seed is thus locked away from damaging agencies. The technique is cheap, easily applied and is in regular use for the safe preservation and transport of grains and foods (Mitsuda *et al*., 1973). It does, however, require more testing before adoption for routine storage of acacia seed.

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Appendix 1. Results of seed viability Tests, and Recommendations for sample weight. Test Temperature and Duration.

Species	Number of viable seed per 10 g		Number of seed lots tested	Recommendations for:				Additional recommendations
	Mean or mean ± S.D.[A]	Highest recorded		Weight of replication (g)	Temperature[B] (°C)	First count (days)	Final count (days)	
1	2	3	4	5	6	7	8	9
fibrosa								
E. fibrosa subsp. *nubila*	3220	4200	3	0·15	(25)	5	14	
E. ficifolia[C]	420 ± 150	700	14	1·20	20	5	14	
E. flocktoniae	1220 ± 660	2275	11	0·40	15;20	10	28 +	Or stratify 4 weeks, then 20°C
E. foecunda	4580 ± 2290	9730	14	0·10	15	10	28	
E. foelscheana	350 ± 180	780	11	1·50	25	5	14	
E. forrestiana	460	700	4	1·00	15	10	21	
E. fraxinoides	1200 ± 380	2080	18	0·40	25	7	28	
E. froggattii	3200		1	0·15	20	5	14	
E. gamophylla	1280	2910	5	0·40	(25)	5	10	
E. gardneri	1410	2070	4	0·40	20	7	21	
E. gilbertensis	100		1	5·00	(25)	3	10	
E. gillii	830	1260	5	0·60	(25)	5	21	
E. glaucescens[C]	1190 ± 560	2880	30	0·40	20	5	10	Stratify 6 weeks
E. globoidea	1620	2800	8	0·30	20;25	7	21	
E. globulus subsp. *bicostata*[C]	980 ± 530	2360	31	0·50	(25)	5	14	
E. globulus subsp. *globulus*[C]	735 ± 380	1400	20	0·70	25	5	14	
E. globulus subsp. *maidenii*[C]	1580 ± 850	3240	21	0·30	(25)	5	21	
E. gomphocephala	680 ± 280	1280	30	0·70	(25)	5	14	
E. gongylocarpa	650	980	5	0·80	(25)	5	21	
E. goniantha subsp. *goniantha*	1060	1370	3	0·50	20;15	7	21	
E. goniocalyx	1130	2520	7	0·50	(25)	5	14	
E. gracilis	5260	12500	7	0·10	15;20	10	21	
E. grandifolia	350	490	3	1·50	30	5	14	Substratum of vermiculite only
E. grandis[C]	6520 ± 3440	21000	157	0·10	25	5	14	

TAXONOMY OF AUSTRALIAN BIPINNATE ACACIAS: SECTION BOTRYCEPHALAE, WITH A KEY TO BIPINNATE ACACIAS

by D.J.Boland

Section Botrycephalae of subgenus Phyllodineae is an important Australian group of some proven and many potentially important evergreen, nitrogen-fixing, bipinnate acacias. Species in the group are important for tannin production (e.g. A.mearnsii in Africa), fuelwood and agroforestry. The aim of this review is to consider some general features of the group and to give details of their taxonomy. A key is provided to the four known species of this group growing currently as exotics in Africa.

Species with bipinnate mature foliage are common amongst African acacias (i.e. species belonging to subgenus acacia - the thorny stipular, often deciduous acacias) but rare amongst the more typically phyllodinous Australian species. Of the approximate 700 described Australian species, only 10% (about 70 species) are known to retain bipinnate foliage at maturity. There are in fact two sections within the Australian subgenus Phyllodineae that have bipinnate foliage, viz. sections Botrycephalae and Pulchellae; the main difference being racemose versus axillary inflorescences for the latter (also occasionally spines consisting of reduced branches as in the case of A.pulchella). Section Botrycephalae consists of about 36 species restricted to temperate and sub-tropical S.E. Australia (occurring in States of Qld, NSW, Vic, SA, and Tas) while section Pulchellae contains 27 species restricted to south-western Western Australia.

The habit and habitat of bipinnate Botrycephalae acacias varies widely. They range from small subalpine shrubs 1-2m tall, e.g. A.nano-dealbata, to tall fringe rain-forest trees over 30m tall, e.g. A.elata. In all species the foliage is delicately displayed in more or less horizontal fronds and the leaflets in at least a few species are believed to display a diurnal rhythm of opening and closing. The most northerly species is probably A.storyi on the Blackdown Tableland and the most southern species, A.mearnsii and A.dealbata. The bipinnates are typically understory shrubs in eucalypt forests, regenerating from seed after fire. Some have the capacity to form root suckers, e.g. A.dealbata. They are not particularly drought resistant.

The uses and potential uses of Australian bipinnates overseas is varied. A.mearnsii is the best known Australian bipinnate species and tannin has been extracted commercially from the bark in Africa, South America, India, China (plus other countries). The wood is used for pulp, fuelwood and poles. Other bipinnate species are little used at present but A.dealbata produces a good quality pulp in Australia and A.decurrens is used for windbreaks among tea plantations in Sri Lanka. Bipinnates are also used in erosion control (Anon 1984) and for shade trees. One disadvantage of bipinnates in Australia is that trees are often seriously attacked by wood borers.

Botrycephalae contains several fast-growing pioneer-type species. The initial growth rate of some, e.g. A.mearnsii, is fast, often faster than many eucalypts, but most are short-lived (about 10-15 years). Some longer-lived species are A.silvestris and A.elata. About 16 of the 36 species of botrycephalae could be considered to have agroforestry potential. These are A.silvestris, A.glaucocarpa, A.parvipinnula, A."blayana", A.mearnsii, A.decurrens, A.trachyphloia, A.irrorata, A.chrysotricha, A.parramattensis, A.leucoclada, A.olsenii, A.fulva, A.filicifolia, A.deanei and **A.storyi.** These species produce robust shrubs and small trees amongst the tallest in Botrycephalae. The distributions of several species is shown in Fig. 1.

The taxonomy within Botrycephalae is still very confused and it requires an expert to precisely delineate between some closely related species within the group. This has been an important reason why they have escaped serious study in the past. In addition seed has been extremely difficult to obtain - the timing of collections is critical as seed can mature and fall within a two week period. An alphabetic list of species in Botrycephalae is given in Table 1 (one species A."blayana", whose trees grow to about 70 ft tall is undescribed (Boland and Midgley 1984).

For scientists involved in species selection, it is important to determine whether the Botrycephalae can be divided into subgroups of closely related species. This can, for instance, eventually shed light on the main tannin producing species and the groups that contain the fastest growing species. After examining the chemical composition of the gums of several species in Botrycephalae, Anderson (1978) and Anderson et al (1971, 1984) suggested that the Botrycephalae could be divided into two groups. They proposed that Botrycephalae be grouped into those species having a gum chemistry not too dissimilar from Section Phyllodineae, e.g. A.filicifolia, A.leucoclada, A.terminalis and A.silvestris, and that a second group had a more unique gum chemistry, e.g. A.deanei, A.irrorata, A.parramattensis, A.parvipinnula and

A.trachyphloia.

A full revision and classification of Botrycephalae is currently being undertaken by Miss M. Tindale and it is possible that the group may be separated into four new groups tentatively based on the following species (Tindale pers. comm.). The precise characters separating the groups are not established here.

Group 1	Group 2	Group 3	Group 4
mearnsii	shinoides	decurrens	dealbata
parramattensis	pruinosa		leucoclada
deanei	"blayana"		silvestris
loroloba	debilis		
constablei			
olsenii			
parvipinnula			

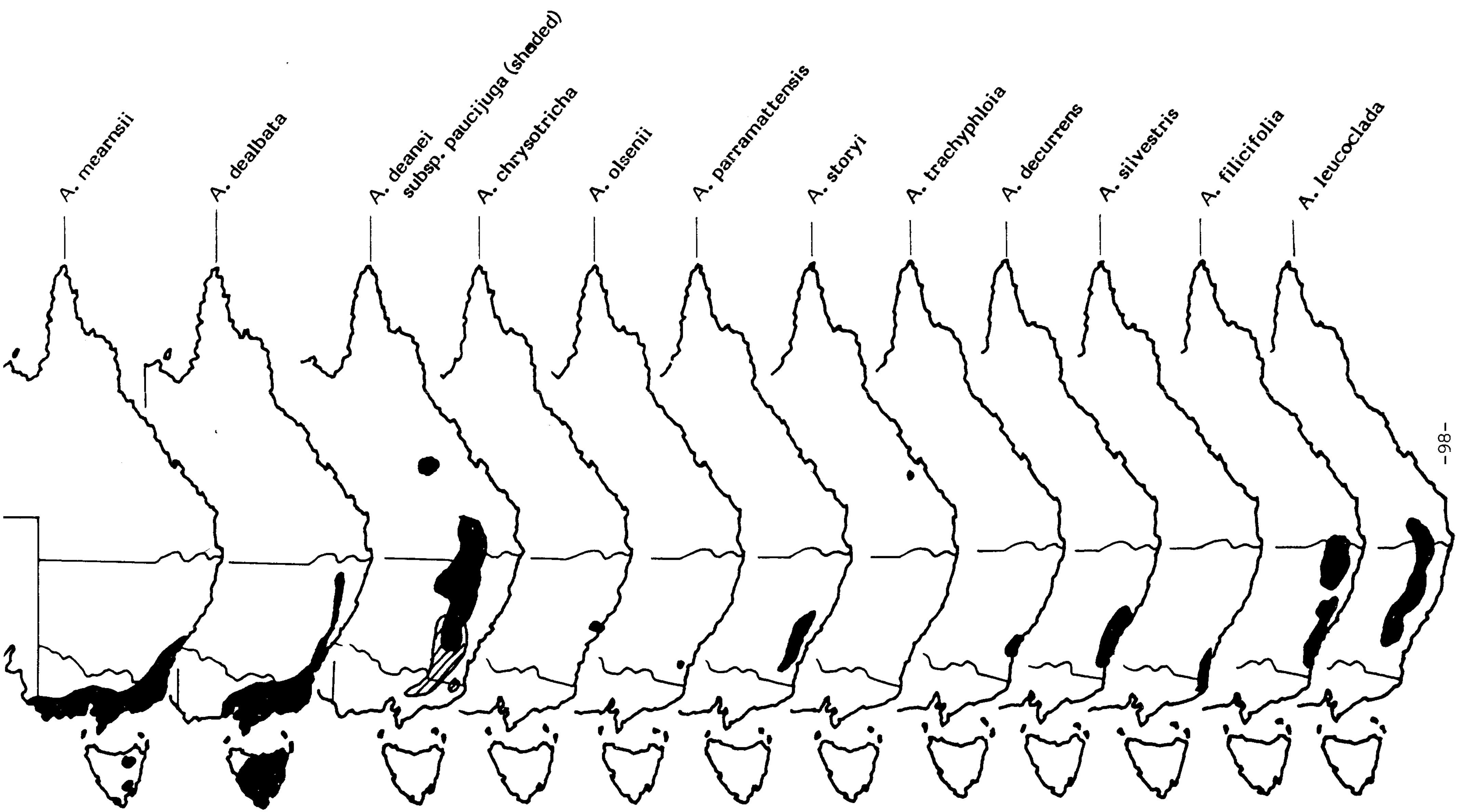

Figure 1.

Distributions of 12 bipinnate acacias (section Botrycephalae)

TABLE 1. Alphabetic list of Species in Subgenus Phyllodineae, Section Botrycephalae.

sect. Botrycephalae

- baileyana
- "blayana"
- cardiophylla
- chinchillensis
- chrysotricha
- constablei
- dealbata
- deanei
- debilis
- decurrens
- elata
- filicifolia
- fulva
- glaucocarpa
- irrorata
- jonesii
- latisepala
- leucoclada
- loroloba
- mearnsii
- mitchellii
- mollifolia
- muellerana
- nanodealbata
- olsenii
- oshanesii
- parramattensis
- parvipinnula
- polybotrya
- pruinosa
- pubescens
- schinoides
- silvestris
- spectabilis
- storyi
- terminalis
- trachyphloia

TABLE 2. Length of time to ripen legumes of some bipinnate *Acacias*.
(Information - M. Tindale pers.comm.)

A.filicifolia (5-6 months)
A.silvestris (6 months)
A.elata (12 months)
A.decurrens (5-6 months)
A.dealbata (5-6 months)
A.leucoclada subsp. leucoclada (5 months)
    subsp. argentifolia (4-5 months)
A.loroloba (probably 9-11 months)
A.mollifolia (c. 6 months)
A.baileyana (6 months)
A.parvipinnula (not known but they flower
A.deanei (twice in the one year

BOTANY

Flowers

The inflorescences are usually in racemes (one exception is A.mitchellii - where floral heads are solitary or rarely in pairs) of globular flower heads. The calyx is tubular, with 4-5 lobes, petals 4-5 and valvate. The filaments are free and numerous. The ovary is superior and 1-locular and the fruit is a legume.

In A.mearnsii, it takes about 12 months between floral initiation and flowering and a further 12-14 months before the legumes mature. This period of maturation is variable amongst bipinnates as some take as little as 6 months to mature. Some typical examples are given in Table 2.

Fruits

The pods or legumes are flattish, variably coloured, occasionally hairy and sometimes slightly constricted between the seeds. Legumes range in size from about 5-12cm long and up to 1cm wide.

Leaves

Both seedlings and adult leaves are bipinnate and consist of a central stem (the rhachis) with several pair of side rhachi (the pinnae), each with several pair of pinnulae (the ultimate leaf units). The rhachis may be terete, quadrangular or angular and between each pair of pinnae there may be one or several extra floral nectaries on the upper side of the rhachis. The precise function of these nectaries has not been determined but they can exude sugary substances in small globules. The anatomical structure of them has been examined by Broughton (1985).

BOTANICAL KEYS

There is no complete key to all species of Botrycephalae at present. The best regional keys to bipinnates in Australia are "A Handbook to Plants in Victoria" (Willis 1972), "Flora of the Sydney Region" (Beadle et al, 1972), and "Native Trees and Shrubs of South Eastern Australia" (Costermans 1981). These keys cover most of the areas where bipinnates occur.

Features of diagnostic value in regional keys for Botrycephalae are mainly vegetative and floral features are not important. Important characters are the number of pairs of pinnae and pinnulae, sizes and shapes of pinnulae, whether flower heads are solitary, the number and position of interjugary glands (the extrafloral nectaries), the presence and character of leaflet hairs, branchlets winged angular or terete. The pods maybe coloured, glabrous or hairy and some are slightly constricted between the seeds (e.g. A.mearnsii). The seed aril doesn't seem to be important diagnostic character within the group.

A key to the four Botrycephalae species commonly found in Africa is given in Table 3.

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TABLE 3. A Key to Bipinnate Acacias (from: Flora of the Sydney region, 1982)

by Mary D. Tindale D.Sc.

A. Pinnules more than 2mm broad, usually 4-12mm broad. Prominent gland 1-4mm long between the lowest pair of pinnae and the base of the petiole.

B. Leaves 30-40cm long. Mature pinnules 2.5-5cm long, much paler beneath, the apex acuminate, 11-17 pairs. Legume straight or slightly constricted, 12-14cm long, about 12mm broad. Tree up to 20m high. Widespread. WSF or RF (especially the margins), in deep shady gullies and along watercourses. Coast, Cumb. Pl., Woronora Plateau and Blue Mts. Ss. Fl. mainly late Dec to March. Mountain Cedar Wattle.
69 A.elata A. Cunn. ex Benth.

*B. Leaves 3.5-20cm long. Mature pinnules 7-20mm long, not paler or much paler beneath, the apex acute or obtuse.

C. Flowers 27-40 in each head. Pinnules not paler on the lower surface, 11-20 pairs. Pinnae 4-5 pairs. Legume constricted, 7.5-16cm long, 5-10mm broad. Tree up to 16m high. Cumb. Pl., Coast, Hornsby Plateau and Hunter River Valley. WSF, in deep shady gullies, usually near creeks. Ss and shales. Fl. late Nov-Feb. 70 A.schinoides Benth.

*C. Flowers 6-15 in each head. Pinnules much paler on the lower surface, 8-16 pairs. Pinnae 1-6 pairs. Legume not constricted, 3-11cm long, 8-17mm broad. Shrub up to 2m high or a tree rarely up to 6m high. Widespread. DSF, woodland or scrub, usually on rocky hillsides. Ss. Fl. mostly March-Nov. Sunshine Wattle. 71 A.terminalis (Salisb) Macbride.

*A. Pinnules 0.5-1.5mm broad. One to several glands each 0.5-1mm long often present between the lowest pair of pinnae and the base of the petiole.

D. Interjugary glands never present on the rhachis.

E. Pinnules clothed with hairs.

F. Foliage silvery. Ridges of the stem smooth, densely pubescent. Legume blue, glabrous. Shrub or tree up to 30m high. Blue Mts.,usually a garden escape. Fl. Aug-Oct. Silver Wattle. 72 A.dealbata Link

*F. Foliage green. Ridges of the stem scabrous, with tubercles each bearing a tuft of minute hairs. Legume black, scabrous, clothed at first with short, pale yellow or white, appressed hairs. Shapely tree 5-12 (rarely up to 30) metres high. Widespread. DSF and RF margins, usually near watercourses.

Mainly Ss. Fl. Nov-early Jan.

73 A.irrorata Sieber ex Spreng
ssp. irrorata

*E. Pinnules glabrous or with several marginal cilia, without an apical tuft of hairs.

G. Branchlets glabrous or clothed with hairs about 0.1-0.2mm long. Pods brown or black, pubescent or glabrous.

H. Flowers 8-12 in a head. Stems with insignificant ridges (0.1-0.2mm high) which are densely pubescent with grey hairs or rarely almost glabrous. Straggly shrub 0.3-3m high. Southern Blue Mts. DSF, often on dry stony ridges. Ss. Fl. Sept-Oct, rarely Jan.

7 A.jonesii F.Muell. et Maiden.

*H Flowers 20-30 in a head.

I. Stems with small insignificant ridges usually 0.1-0.2mm high. Pinnae 6-14 (usually 8-12) pairs. Pinnules 20-33 (rarely up to 40) pairs, 2.5-7 (mainly 3-5)mm long. Legume black or brown, 6-11cm long, 3.5-7.5mm broad. Shrub or tree 2-7 (rarely up to 12) metres high. Widespread. DSF. Ss and Shales. Fl. late Nov-late Jan., rarely until April.

75 A.parramattensis Tindale

*I Stems with broad, wing-like ridges usually 0.6-2mm high. Pinnae 4-12 pairs. Pinnules 15-35 pairs, 5-14mm long. Legume brown or dark brown, 4.5-10.5cm long, 4-7mm broad. Tree 4-14m high. DSF or in open undulating country. Widespread. Shales. Fl. July-early Sept.

Green Wattle. 76 A.decurrens (Wendl.) Willd.

*G. Branchlets pilose or hispid, the hairs 0.8-2mm long. Legume blue and glabrous.

J. Pinnae bluish, glaucous. Legume 8-14mm broad, straight or almost so. Tree usually 5-10m high. Garden escape. Fl. Aug-Sept at low altitudes, Oct-Jan at high altitudes. Cootamundra Wattle.

*77 A.baileyana F. Muell.

J. Pinnae green, non-glaucous. Legume 4-5mm broad, more or less constricted between the seeds. Bushy shrub 0.9-2.4m high. DSF, on gravelly clay ridges and in Melaleuca scrub. Shales.

Fl. Aug-Oct. 78 A.pubescens (Vent) R. Br.

*D. Interjugary glands present on the rhachis between 1 or more pairs of pinnae.

K. Pinnules narrowly lanceolate to ovate or narrowly lanceolate-oblong, the lower surface villous with silvery hairs, the apices markedly acute to sub-acuminate. Legume submoniliform, almost straight-sided, densely lanate with grey or chestnut-coloured hairs. Tree 1.5-10m high. HP. DSF. Ss. and basalt. Fl. April-June. 79 A.fulva Tindale

*K. Pinnules linear to oblong, the apices obtuse or subacute. Legume straight or submoniliform, glabrous, pubescent or tomentose, never lanate.

L. Stem blue-glaucous, blue-brown or blue-black. 2-5 interjugary glands between the insertion of each pair of pinnae. Young tips of the foliage white, cream-coloured to dark yellow.

M. Flowers usually 22-30 in a head. Corolla 1.5-1.8mm long. Ovary clothed with long, weak, white hairs. Pinnules usually 6-10 (rarely 3-5)mm long, mostly 35-55 (rarely 23-68) pairs. Legume blue or purplish-blue, glaucous, straight-sided, 4-12cm long, 7-18mm broad. Pinnae 5-14 pairs. Tree up to 14m high, the trunk brown, grey or greyish-green in young trees. Hornsby Plateau, Northern Blue Mts., Hunter River Valley and Woronora Plateau. DSF., on rocky hillsides and alluvial flats. Ss, Shales and Alluvium. Fl. Aug-Sept, rarely Oct. Fern-leaf Wattle.

80 A.filicifolia Cheel et Welch

*M Flowers usually 14-18 in a head. Corolla 1-1.2mm long. Ovary glabrous. Pinnules 3-5mm long. Legumes blue-brown or blue-black, 5-11cm long, 5-9mm broad, submoniliform, when mature glabrous or very sparsely clothed with short, white, appressed hairs. Pinnae 14-30 (rarely more) pairs. Shrub or tree 2.5-10m high, the trunk very silvery in young trees. Blue Mts., Hornsby Plateau, Cumb. Pl., Hunter River Valley. DSF. Ss, Shales and laterite. Fl. Sept-early Dec, also sometimes April-July in the more northerly regions.

81 A.parvipinnula Tindale

*L. Stem brown or black, not glaucous. 1-3 interjugary glands present between the insertions of all, a few or the lowest pair of pinnae. Young tips of the foilage yellow or almost greenish-yellow.

N. Flowers 8-12 in each head. Straggly shrub 0.3-3m high. Southern Blue Mts., DSF, often on dry stony ridges. Ss. Fl. Sep-Oct rarely Jan.

82 A.jonesii F.Muell. et Maiden

*N. Flowers 20-38 in each head.

0. Stems glabrous or sparsely clothed with short appressed hairs. Pinnules broadly rounded or subacute, 2.5-7 (mainly 3-5)mm long, glabrous except sparsely ciliate along the margins, 20-33 (rarely up to 40) pairs. Pinnae 6-14 (usually 8-12) pairs. Legume black or brown, submoniliform, 6-11cm long, 3.5-7.5mm broad. Glands of the leaf-rhachises and peduncles of the inflorescences glabrous or slightly pubescent. Shrub or tree 2-7 (rarely up to 14)metres high. Cumb.Pl., lower slopes and valleys of the Blue Mts and Woronora Plateau. DSF. Shales, breccia or more rarely Ss. Fl. late Nov-early Feb, rarely until April.

83 A.parramattensis Tindale

*0 Stems velvety-pubescent. Pinnules broadly rounded, 1.2-3mm long, glabrous above, densely pubescent below, ciliate along the margins, 30-44 pairs. Pinnae 9-20 pairs. Legumes black, sub-moniliform, 4-9cm long, 4.5-8mm broad. Glands of the leaf-rhachises and peduncles of the inflorescences densely tomentose. Tree 5-15m high. Woronora Plateau, also Blue Mts. rarely CP (garden escape). DSF. Ss, Shales and Slates. Fl. Oct-Dec, mostly Nov. Black Wattle.

84 A.mearnsii De Wild.

Recently two other bipinnate species, namely A.spectabilis A.Cunn. ex Benth. and A.farnesiana (L.) Willd. have been recorded from the Sydney region but both are rare. A.spectabilis, which belongs to Group 8 (Botrycephalae),has been found between Rylstone and Glen Alice. This species is a shrub or small tree up to 4m high and would be placed in the section with pinnules 2mm or more wide; it is characterized by only 4-8 pairs of obtuse light green pinnules and by flower heads with 14-20 flowers. A.farnesiana, an introduced species belonging to the subgenus Acacia which is otherwise unrepresented in the Sydney region, has been found at Wondabyne and Broke. It is a shrub up to 4m high and may be distinguished from other bipinnate species in this region by the spiny stipules, by the round golden flower heads in groups of 1-3 in the axils of the leaves and by the indehiscent turgid black legumes.

List of Technical Words Used in Acacia Keys

Acacia	genus of leguminous plants with about 1200 species
aril	tissue partly enclosing the seed at the funicle end
axil	angle between leaf or phyllode and the stem
bipinnate	leaf which is divided twice giving feathery appearance
cotyledons	first pair of leaves produced after germination
cylindrical	shaped like a cylinder as in some Acacia flowers (=spike)
funicle	tissue connecting seed with placenta
gland	structure on upper edge of phyllode, or on rhachis of divided leaves
globular	shaped like a ball as for many Acacia flowers
inflorescence	arrangement of flowers on a plant axis
legume	a pod -- contains seed in leguminous plants
--merous	4--merous, 5--merous with 4 or 5 sepals and petals in the flower
nervation	pattern of minor nerves in a leaf or phyllode
ovule	organ that becomes a seed after fertilisation
paniculate	a branched inflorescence
petals	inner ring of structures protecting a flower
phyllode	a vertically flattened petiole performing the functions of a leaf - a bipinnate leaf may be attached at the end
pinna (ae)	the ultimate division of a once-divided leaf
pinnate	divided once into pinnae (of a leaf)
pinnule	the ultimate division of a bipinnate (twice divided) leaf
placenta	tissue which bears ovules and seeds
pulvinus	the tissue at the attachment of a phyllode with a stem
rachis	a stalk or axis of a divided leaf or of an inflorescence
reticulation	when the leaf or phyllode has many cross veins
scandent	climbing or trailing form of a plant
sepals	outer ring of structures protecting a flower
sessile	without a stalk (of a leaf or flower bud)
simple	undivided (inflorescence)
spike	cylindrical (inflorescence)
stipules	paired structures at the base of a leaf or phyllode
terete	cylindrical, round in cross-section
testa	seed coat
xeromorphic	modified to withstand heat or dryness

PROBLEMS OF IDENTIFICATION OF EUCALYPTUS SPECIES

by M.I.H.Brooker

It may be of some comfort to know that to most Australians, all "gum" trees look the same. This may be an unfair generalisation because to many people the eucalypts of their local area at least do become somewhat familiar to them. But take people to a different place and they are immediately at a loss. They can recognise the single stem of trees compared with multiple-stemmed mallees, and rough barks compared with smooth, tall compared with short, etc., and that is where the layman's taxonomy ends. This is not to belittle the foresters, horticulturalists, nurserymen and botanists because they make every effort to become familiar with the popular or commercially valuable species. But people in these categories make up a very small proportion of the population, and the species in the popular or commercial categories do not add up to a great number.

In Perth, Western Australia where I live, we are lucky to have large numbers of natural trees left standing (Table 1). As a consequence, most people there can recognise the following common eucalypts; jarrah (Eucalyptus marginata), marri (E. calophylla), tuart (E. gomphocephala), and wandoo (E. wandoo). The plain on which Perth stands is about 30km wide. To the east are the low hills of the Darling Range where jarrah, marri and wandoo are again common but tuart is quite absent. However, another species comes in. This is E. accedens which is smooth-barked like wandoo and the tree looks superficially similar. I estimate that most people could not distinguish E. wandoo from E. accedens. Both have smooth, light-coloured bark, and an upright tree habit, similar-coloured leaves, etc., but a closer look at the bark will pay dividends. The bark of E. accedens is always powdery and in one season of the year, pink. Wandoo is never powdery and varies in colour from white to yellowish. In fact the two species are unrelated.

There are lessons to be learnt from this one example:

(1) habit and bark colour are of low reliability in distinguishing species;

(2) powderiness of the bark is of higher reliability (it is not merely seasonal).

Further examination of these two species will result in the recognition of several other characteristics that make the identification easy if the identifier is confronted with only those two species, E. wandoo and E. accedens. The most readily available of these characteristics is the bud shape which can usually be determined by examination of fallen buds on the ground beneath the crowns of the trees. This introduces another lesson. Bud shape is useful in separating these two species, but the long conical bud of wandoo cannot be easily distinguished from the 5 or 6 species that are related to it and which differ on grounds other than bud characteristics.

If the citizen of Perth is in difficulty so close to home, imagine his or her plight in going further east where on the road to Kalgoorlie, 500km away, at least 40 more species of Eucalyptus are encountered just along the route, and there are up to 100 more in the remaining area of the south-west of the State. E. wandoo itself occurs over the whole distance and an interesting change occurs in the eastern part of its distribution as the seedlings are hairy compared to the glabrous seedlings of the form just east of Perth. Hairiness of the seedling is a characteristic of high reliability and has resulted in E. wandoo being divided taxonomically into two subspecies. This is the only discernible and consistent distinction between the two. If further characteristics of equally high reliability were found, E. wandoo would be split into two species rather than two subspecies.

An interesting problem arises in the distinction between two related species, E. rudis, which is endemic to a small area in the south-west of Australia, and E. camaldulensis, which is distributed widely throughout mainland Australia. Both are river gums, i.e. their normal habitats are the banks of fresh-water streams. E. camaldulensis is a mostly smooth-barked tree. E. rudis can be wholly smooth- or wholly rough-barked. They have somewhat similar buds and fruit. In habit they look alike and it is believed that over a narrow zone they grade into each other. With this information only, it would seem that they are difficult to separate. However, they are instantly recognisable by their seeds, black and rough in E.rudis, yellow and smooth in E. camaldulensis. The conclusion here should be clear. Habit and bark characters are not of high reliability, whereas whole seed characters are.

These illustrations include species that you may not be familiar with but they shed some light on the reliability of characters in naturally-growing as well as in plantation eucalypts.

We in Australia are confronted by much greater numbers of species over wide areas compared with the situation in your countries. In Australia, the species tend to become adapted to localised sites which we instinctively take into account. For example, a smooth-barked tree looking like E. camaldulensis but growing naturally away from underground fresh water we immediately dissociate from E. camaldulensis. Similarly, if we see a very rough-barked tree growing away from water, it is unlikely to be E. robusta. Yet this species grows well on well-drained soils in cultivation. An ironbark tree growing in sandy mallee scrub is immediately dissociated from E. paniculata. It is most likely E. sideroxylon. We are never bothered by the possibility that a problem tree may be a cross between E. botryoides and E. brassiana as the two species can in no way come together in natural stands.

In contrast, you are confronted with many fewer species but often all growing together in the one plantation. You do not have the assistance of a specific locality or a characteristic niche, which may narrow the possibilities to 5 or 10 species. In addition, plantation eucalypts may have been grown from seed obtained in your country from plantation trees which can hybridise. This can introduce problems that we do not encounter in Australia. We may be familiar with an F1 of Eucalyptus A x B because we have seen them where they occur in Australia, as in the notorious example of E. saligna x grandis, but we may never have seen an F1 of Eucalyptus C x D which are species that have never had the possibility of crossing in natural stands.

Another problem in identifying plantation eucalypts is that whole areas may have been derived from seed of a particular form that we are not familiar with. For example, E. resinifera grows naturally over a north-south range of 3000km Habit, bark and leaf characteristics are consistent but the buds vary greatly. Original seed may have been taken from a population with an unfamiliar bud shape. Taken further, problems like this may become confused with intergradation of one species to another - in this case E. resinifera to E. pellita.

An aspect of identification that is very difficult for an identifier to come to terms with is the concept that seed from a particular natural stand may produce trees that perform in various ways differently from the normal. A simple example but one of little consequence in identification is the predominance of pendulous branchlets seen sometimes in plantations of E. camaldulensis. This is only a superficial modification. Of greater importance to someone using a key, is the condition sometimes seen in plantation trees of the clustering of buds and fruits (inflorescences) at the ends of branchlets giving a terminal appearance to the inflorescences which are normally axillary and spaced along a leafy shoot.

These examples and others should lead us to the conclusion that we must categorise our tree characteristics according to their reliability. We must not be too carried away by the length of the operculum, the straggly habit of a tree or the fact that the rough bark does not extend to the smallest branches, just to give some simple examples.

Table 1 A case study in the identification of Eucalypts (Around Perth, Western Australia)

The genus *Eucalyptus* has evolved about 600 species among which are the

common name	some characters	example
bloodwoods (Corymbia)	leaf venation closely pinnate bark rough and broken into chunks inflorescences terminal fruit large and woody	marri (*Eucalyptus calophylla*) N.b. leaves discolorous in this species
stringybarks (Monocalyptus)	leaf venation not closely pinnate bark rough and held in long strips inflorescences axillary fruit moderately large	jarrah (*Eucalyptus marginata*) N.b. leaves discolorous in this species
boxes	leaf venation not closely pinnate bark rough and broken without special pattern inflorescences axillary	tuart (*Eucalyptus gomphocephala*) N.b. leaves almost con-colorous in this species
gums (*Symphyomyrtus*)	bark smooth white non-powdery	wandoo (*Eucalyptus wandoo*) N.b. leaves con-colorous
	bark white or pink powdery	powder-bark wandoo (*Eucalyptus accedens*) N.b. leaves con-colorous

DEVELOPMENT OF THE EUCALYPT PLANT AND A CASE STUDY OF EUCALYPTUS CAMALDULENSIS AND E.MICROTHECA

by M.I.H.Brooker

The eucalypt seed requires optimum conditions for germination - a suitable substrate, the right temperature, the right moisture content, and usually light. These factors vary between species and some species are notable for their requirement to be kept cool for long periods before germination can be induced.

Germination proceeds by the absorption by the seed of water which is taken up by the dormant embryo. The root of the embryo elongates and breaks the seedcoat. It turns down into the substrate which it requires for stability and as a source of water and nutrients for the developing seedling. Soon after the root begins to develop, the cotyledons, which to this stage have remained dormant and pressed against each other or folded, begin to enlarge, breaking the seedcoat even more. The stem between the cotyledons and the root starts to develop and pushes the cotyledons upwards as the root goes downwards. At this stage the seedcoat usually remains over the cotyledons but is soon shed as the shoot develops.

After the cotyledons, true leaves begin their development. In the young seedlings the leaves produced in succession are seedling leaves and juvenile leaves. In the young sapling, intermediate leaves are produced and on the mature sapling and young tree, adult leaves are produced.

Species show great variation in the type of leaves developed in the young stages. Related species produce similar leaves in the seedling and unrelated species tend to produce distinctive, contrasting seedlings. As an example, it would not be possible to distinguish the seedlings of the two closely related species Eucalyptus globulus and E. maidenii. But these are easily distinguished from the unrelated E. viminalis or E. gomphocephala or E. decipiens.

The leaves produced in the juvenile phase are often not much different from those of the seedling phase but they are usually bigger. The intermediate leaves show an advance and are clearly a linking phase between the juvenile and the adult, particularly in the development of a petiole which may not be present in the younger phases. The juvenile leaves are often glaucous and the adult leaves are usually green.

The leaves at all stages are produced in opposite pairs, any pair being at right angles to the lower and above pairs. The leaves remain opposite in the seedling but by the intermediate phase they appear to be alternate. This occurs because of unequal elongation of the stem between the bases of a pair of opposite leaves. Finally, the adult leaves alternate on the branchlets. The leaves are petiolate (many juvenile leaves are sessile), green, the same colour both sides, and they are pendulous.

Most species produce lignotubers. These are large woody swellings on the stem at ground level or buried. They begin by a proliferation of plant tissue in the axils of the cotyledons and the first few pairs of leaves. The increasing tissue so-formed at each node becomes enlarged and all unite to make up one mass of woody tissue - the lignotuber. The lignotuber contains many vegetative buds which remain dormant until the tree is cut or burnt. The loss of above-ground stem, trunk and leaves stimulates the development of the buds in the lignotuber. They grow and produce new stems. In species that are predominantly of tree form, one shoot becomes dominant and outgrows the others which wither and die. The vigorous surviving shoot becomes the single stem and trunk of the regenerated tree. In species that are predominantly of mallee-form, several shoots survive and finally produce a multi-stemmed plant - the mallee. Eucalyptus saligna is a species that produces a lignotuber; E. grandis, a close relative, does not.

As the eucalypt plant grows, it develops new tissue both internally (the wood) and externally (the bark), thereby increasing the diameter of the stem or trunk. Each year the outermost part of the bark dies. This dead bark is shed yearly in some species, e.g. E.citriodora, and a permanent smooth bark is maintained - the gums. In many species, the dead bark is held and develops characteristic textures and colours which are an important aid in their identification. These species are the boxes, stringybarks, peppermints, ironbarks, bloodwoods, etc.

After a few years of healthy growth, the eucalypt tree or mallee is reproductively mature. The basic unit of reproduction in Eucalyptus, i.e. the structure or organ that eventually produces the fruit and seed, is a single stalk (peduncle) and the one or more flower buds which develop on it. The peduncle and buds collectively are the inflorescence units. They may occur singly in the axils of leaves or they may be aggregated into a compound inflorescence. The compound inflorescence is either in the axils of the leaves or at the ends of branchlets.

The individual bud on an inflorescence unit consists of a stalk (pedicel), although in some species the stalk is absent and the bud appears to sit squat on the top of the peduncle. The base of the bud is an enlarged receptacle (hypanthium). On the rim of the hollowed hypanthium, the operculum sits. Inside the operculum the stamens are borne on a ring of tissue. Before the operculum is shed, the stamens may be erect, completely inflexed,or irregularly flexed. At flowering, the stamens unfold or spread and push the operculum off - its ring of attachment to the rim of the hypanthium having become dead tissue. The stamens consist of a stalk and a terminal anther.

The ovary, which may contain 2 to about 10 chambers, is seated within the hypanthium and is attached to it by the sides and base. The ovary chambers are surmounted by the style and stigma and these emerge above the hypanthium and the stamens.

As soon as the flower opens, the anthers are mature and viable pollen is shed. It takes a few days for the ovary to be receptive to the pollen. This means that pollen does not usually fertilise an ovule of its own flower. This delaying mechanism is effective in increasing the chances of out-crossing.

The ovules are borne on the placenta and occur in 2,4,6,8 or 10 vertical rows. Only the lowermost ovules can be successfully fertilised.

After fertilisation, the stamens fall and the remaining part of the flower bud enlarges and becomes woody. The fruit is actually a thin-walled capsule enclosed within the woody hypanthium. During this time the fertilised ovules develop into seed. The fruit is held on the branchlets during seed maturation. In some species the fruit dries within days or weeks and sheds the seed. In others, the fruit is held in the crown of the tree for months or years. The drying and shedding may be stimulated by fire.

The fruit open when the roof of the capsule breaks into valves which become erect and allow the contents to fall. First comes the chaff - the unfertilisable and unfertilised ovules, then the seed which are formed at the base of the capsule. The seed fall to the ground and remain dormant until conditions are right for the whole cycle to begin again.

While all eucalypts follow this general pattern of development, species differ in the size, colour, texture, shape, number, etc. of each organ.

A Case Study:

When comparing E. camaldulensis with E.microtheca, it must be remembered that there is variation within both species in many characters, but a few characters in one species are unchanging and contrast with those of the other.

Bark is not always helpful in distinguishing the species. E. camaldulensis is basically smooth-barked although in some individual trees the dead bark may be imperfectly shed, giving a rough effect. Some forms of E.microtheca are rough-barked all over, some are rough only on the trunk with smooth white branches, and western forms are completely smooth-barked. In other words, bark is not a definitive character in these two species.

E. microtheca produces lignotubers. E. camaldulensis is variable. Northern forms produce lignotubers while southern forms do not. The lignotuber may not be easy to see in the field e.g. it may be buried. It can most reliably be seen in seedlings but seedling trials take time.

Contrasting features in the species are the leaves and the reproductory structures. In E. camaldulensis from the southern half of Australia, the leaves are moderately reticulate and contain many oil glands. These characters can be seen readily by holding a fresh leaf obliquely towards the sun and viewing with transmitted light. E. microtheca leaves are quite different. The reticulation is much denser and oil glands are not visible. This is an infallible test which is very useful if the trees are not in bud and fruit.

Confirmatory tests can be made if the trees are producing buds and fruit. In E. camaldulensis, the inflorescence units are normally borne singly in the axils of the leaves. In E. microtheca, they are compound and terminal. Unfortunately, modification by environment can cause the clustering of inflorescences at the ends of the shoots in E. camaldulensis. Many branchlets should be examined.

If dissection of the mature flower buds is made, several features will instantly provide distinctions between the two species. In southern *E. camaldulensis*, the stamens are held completely inflexed within a beaked (rostrate) operculum. In northern *E. camaldulensis*, the outer stamens at least are erect within a conical operculum. This form is also known as *E. camaldulensis* var. *obtusa* because of the obtusely conical operculum which contrasts with the southern beaked forms. In *E. microtheca*, the stamens are variously flexed and form no distinct pattern.

The anthers of *E. camaldulensis* are held on the narrowed tip of the filament of the stamens such that they can swivel (versatile anther). They open by vertical slits. In *E. microtheca*, the anthers are held more or less rigidly on the broad tips of the filaments such that they cannot swivel (adnate anther). They open by pores.

If the outer wall of the ovary is dissected away, the ovules in *E. camaldulensis* will be seen to be in 6 vertical rows. In *E. microtheca* they are in 4 rows.

The fruit of *E. camaldulensis* is always larger and more robust than that of *E. microtheca*. In the *E. camaldulensis* fruit there is always a conspicuous ring of tissue between the rim and the valves. This is the disc. In *E. microtheca*, the disc is so small as to be virtually non-existent.

Seed distinctions provide the final clue to the differences between the species. The seed of *E. camaldulensis* are cuboid, yellow, smooth. In *E. microtheca*, the seed are flattened-elliptical or pointed at one end, brown, reticulate.

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AN INTRODUCTION TO THE STUDY OF CHARACTERS IN EUCALYPTUS

by M.I.H.Brooker

There is very little fossil evidence to enlighten us on the form of the precursors of the eucalypts. Genera of the largely tropical plant family Myrtaceae were probably numerous in the Tertiary flora of Australia. These genera would have been "seen" as unremarkable members of the rainforest flora that once dominated the Australian continent. In the normal process of generation succeeding generation, some natural variants among the plants would have appeared but been unsuccessful in competition with the suitably adapted flora of the prevailing forests. With the onset of change in climate, soils, topography, etc. however, some of these variants which were unsuitable for the old conditions may have had the modifications necessary to survive in new environmental regimes. This is to simplify the situation, as the changes which look to us today to have been catastrophic may have taken place slowly over millions of years.

Some of the new environments in Australia were the result of vast topographic upheavals which produced mountain ranges, particularly the Great Dividing Range along the eastern seaboard of the continent. Climatic change was just as significant as Australia went through periods of high aridity. The land mass also developed different climatic regions, notably the current tropical, summer-rainfall dominant north, and the temperate, winter-rainfall dominant south. Soil changes were just as effective in modifying the environment for plant life. These were loss of fertility, laterisation, lime accumulation, sand-dune formation, accumulation of river sediments, etc.

Thus, over a long period, great modifications to environment forced the selection of a new breed of forest species. Of all the genera and species available for colonisation of modified sites, the ancestral eucalypt must have had the reserves of adaptability that enabled it in modified form to radiate from the retreating rainforests and reach every corner of the continent.

The ancestral eucalypt (Proto-eucalyptus) may have been an erect tree, with smooth bark, relatively homophyllous, with thin, discolorous, opposite leaves which were highly reticulate and with large-angled side veins, conspicuous terminal or pseudo-terminal branched inflorescences, distinct sepals, white or pale-coloured flowers with non-robust petals, detectable but not excessive amounts of volatile oils, without lignotubers and without prominent external waxes. These are but a few characters of *Proto-eucalyptus*. Each of these and the innumerable other characters of the ancestral forms were prone to change. Populations with unique combinations of characters, some ancestral, some derived, must have had selective advantages over others. They became successfully adapted to new conditions.

Over time, whole new groups of species evolved because of their peculiar and successful adaptations. We see evidence of this in the large group of mountain gums (e.g *E.viminalis)* which adapted to the colder, more elevated parts of south-eastern Australia, also the large group of river gums (e.g. *E.camaldulensis*), boxes (e.g. *E.microtheca*) and ironbarks (e.g. *E.paniculata*), and the highly adapted bloodwoods (e.g. *E.polycarpa*) which, while retaining few species or descendants of species in the very wet zones, have produced many hardy species that grow vigorously in the deserts of Australia.

Where, we may ask, do we see evidence of *Proto-eucalyptus* today? It has not survived in the present day rainforest but one species (*Eucalyptus torelliana*), considerably modified, occurs in the rainforest fringes. It is also interesting to note that this species is not the only member of the *Myrtaceae* to make the partial adaptation to the rainforest fringe. Another genus of the family occupies this vegetation zone and appears to have evolved in parallel fashion when some characters are considered, but without the enormous success of *Eucalyptus*. This is the genus *Tristania*, a small group that includes giant trees similar in outward appearance to *Eucalyptus*. *Tristania* flowers have soft sepals which dry and are usually deciduous as a single unit by their attachment at the base. (United over their whole length, they would make an operculum.) The petals of *Tristania* are fleshy with no suggestion of operculum formation and the flower as a whole is nothing like that of a eucalypt. It is in the fruit, however, that parallel evolution seems to have proceeded at its most obvious. The fruit of *Tristania* strongly resembles that of a eucalypt. It is woody, of similar size, and without sepaline remnants.

Perhaps most evidence of *Proto-eucalyptus* can be seen in the adjacent forests of the current high-rainfall zones, if, for example, we look at species like *E.intermedia*, ?close to the ancestors of the bloodwoods, or *E.paniculata*, ?close to the ancestors of the ironbarks, or *E.rummeryi*, ?close to the ancestors of the boxes, or E.tereticornis, ?close to the ancestors of the red gums. These groups are highly successful in numbers of species that have adapted to the environmental regions vastly different from the near rainforest conditions of their ancestors. Or do we look for evidence in the almost "non-eucalypt", Eucalyptus curtisii, a rare endemic of south-eastern Queensland which has a somewhat petaline operculum?

All these considerations are speculative but they are useful when we begin to think of character modifications in eucalypts. It is not immediately evident that the recognition of primitiveness or otherwise of characters is important in identifying a eucalypt. However, modifications in an ancient theoretical population that resulted in the divergence of part of the population in one "direction" to become stringybarks and peppermints,and in another to become ultimately river gums and boxes are vastly more basic and reliable morphological characters than the change that might have resulted in another theoretical ancestral population of river gums diverging in one direction to become E.camaldulensis and in another to become E.tereticornis.

In the group of species resulting from the first example of divergence, there is a vastly greater number of modifications than in the second. More importantly, there are several changes of "principle" included in the assemblage of modifications in the first example compared with that of the second example in which the changes are largely ones of "degree".

The first example has seen the genus Eucalyptus split into subgenera. Definite and immutable morphological change has occurred. In the second example, a theoretical ancestral population has split into two species and the characters that identify both species are not "hard and fast". For example, between E.camaldulensis and E.tereticornis we look for degrees of difference in the length of the operculum and in the habit of the mature tree, also in the degrees of difference in the width of the juvenile leaves. One of the really strong characters in their distinction is the nature of the seedcoat. This is definitive in 99% of the samples examined. In some areas, however, intermediate seed forms occur. Distinction at the species level between sister species is never absolutely clearcut.

In contrast, distinctions between subgenera are absolute in one or more characters. In the example of the stringybarks and the gums, the buds of the former have a single operculum, those of the latter two opercula. There can be no intermediate condition between the two.

Therefore we give different values of reliability to each character. The single or double operculum character is absolute. The seedcoat character is of medium reliability as a general rule, although in the case of E.camaldulensis versus E.tereticornis it is of quite high reliability but never absolute. Further down the reliability scale are the characters of the bark. The presence or absence of some rough bark is of medium reliability. Only in ironbarks is the texture of the rough bark of relatively high reliability. Compared with the mere presence of rough bark, the amount of the rough bark present, i.e. height up the trunk (butt only, or 1/3, or 1/2, or 3/4-barked, or whole trunk, and also limbs) is of low reliability and may be strongly affected by local conditions. Colour of smooth bark is also of low reliability and may be influenced by season. The bark of the famous salmon gum (E.salmonophloia) is grey in spring and intense coppery late summer.

Size, shape and colour are of fairly low reliability in eucalypts. These characters may be initiated genetically but their final form or appearance is often greatly affected by environmental factors. It follows, therefore that characters of size, shape and colour which have the longest and most intimate exposure to the elements are those most prone to modification; those concerned with internal form or structure are the least prone, e.g. anther attachment, leaf venation, inflorescence type. The presence in the developing bud of one or two opercula cannot be changed by contact with the environment, although the time of shedding of the outer of two opercula in bi-operculate species is closely associated with age of the flower bud.

It must be emphasized that in their natural environment Eucalyptus species have maintained their distinctions by many factors which include geographical isolation, ecological isolation, different flowering times and pollen-stigma incompatability. The balance thus preserved,which prevents species from crossing and hence merging, is often fragile.

However, many pairs of species are interfertile as shown by manipulated crosses. In natural conditions their species identity is usually maintained, but natural hybrids between adjoining species can occur. Occasionally they are particularly suited to an area and lead to the establishment of a hybrid swarm.

In contrast, a drastic breakdown of barriers may be provided in exotic plantations when compatible species are brought together for the first time. Flowering periods may be extended in the new conditions, and the possibility of crossing is greatly increased.

Therefore, the purity of plants grown from seed obtained from exotically grown eucalypts must always be suspect, unless it is certain that the mother tree is not growing within the distance of pollen travel of other compatible species. Few studies have been made on the pollen path in *Eucalyptus*, but in one study it was found that the effect of *E.fastigata* pollen on *E.robertsonii* mother trees was almost nil beyond 60m. The subsequent generations from trees of one species growing near a compatible pollen source may reproduce the parental type by selfing or crossing with a tree of the same species, but equally may throw a multitude of recombinant forms of varying similarity to the two distinct parent species.

Notes on characters used in the identification of Eucalyptus

(1) Seed (Figure 1)

Seedlots in *Eucalyptus* when taken untreated from a drying collection of fruit always consist of a mixture of seed and chaff. The seed are usually the larger, less numerous particles in a seedlot. They are usually of a differnnt colour to the chaff. To check for the fertility of presumed seed, a check can be made by crushing or slicing open a "seed". If it is viable, the contents will be a soft, fleshy, white embryo. Small or empty particles are the chaff.

The size, shape, colour and surface markings of the seed vary greatly between species. For example, seed of *Eucalyptus tessellaris* is saucer-shaped, red-brown, thin and smooth. The embryo within has the cotyledons pressed unfolded against each other, hence the seed is thin. The seed of most bloodwoods e.g. *E.ficifolia*, *E.polycarpa* is large, yellow-brown, bulbous at the base (where the embryo is enclosed) and with a transparent wing emerging at the top. The "top" refers to its actual situation when held within an intact fruit before being shed.

The seed of *E.maculata* and *E.citriodora* is oval-shaped, shiny red-brown, smooth, with minute surface cracking.

The seed of E.calophylla is the largest of the genus. Although a bloodwood, the seed are unlike that in the majority of bloodwood species. It is "boat-shaped", black and wingless. E.gummifera seed is similar but smaller and red-brown.

The seed of E.cladocalyx is oval-shaped, grey, fairly smooth except for some shallow longitudinal furrowing. That of E.salmonophloia is similar but smaller and red-brown.

The seed of the many box species, e.g. E.largiflorens and E.microtheca, are mostly oval-shaped, often pointed at one end, grey-brown, with a shallow network pattern on the rounded side. E.populnea seed are amongst the smallest in the genus. That of E.ovata, E.bridgesiana, E.nitens, E.viminalis, and many others are similar to the boxes but are sometimes larger and more angular with rounded depressions on the seedcoat.

All seed so far referred to show a scar (hilum) on the broader, flatter side which is formed when the seed breaks away from its place of formation within the capsule, i.e. on the placenta.

A larger group of species in the genus, the monocalypts plus E.cloeziana have rather large seed of various shapes, red-brown or black, and with the hilum situated on a small face or at the summit of a ribbed area on the ventral side i.e. they were attached to the placenta along their long axis. Often there is little distinction between seed and chaff in this group.

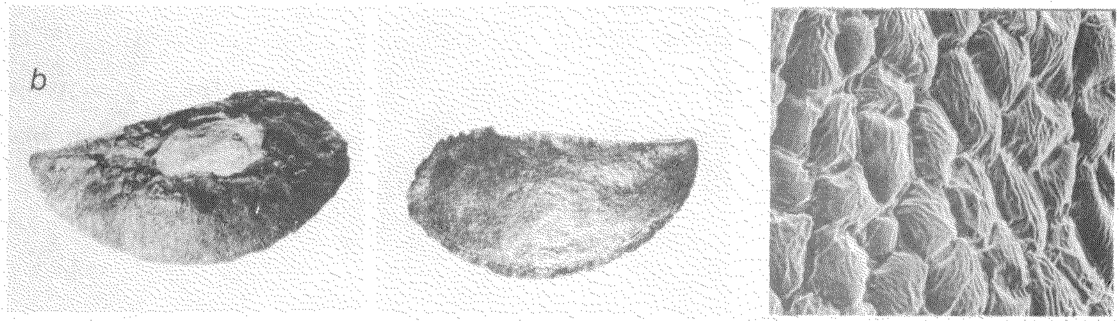
(2) Cotyledons (Figure 2)

The primitive cotyledon in eucalypts is probably reniform (kidney-shaped) and relatively large. These may be seen in E.erythrocorys.

Various modifications have emerged throughout the evolutionary process and the most extreme change has been the great emargination of the lamina resulting in a deeply bifid structure. These are the "bisected" cotyledons (e.g. E.oleosa).

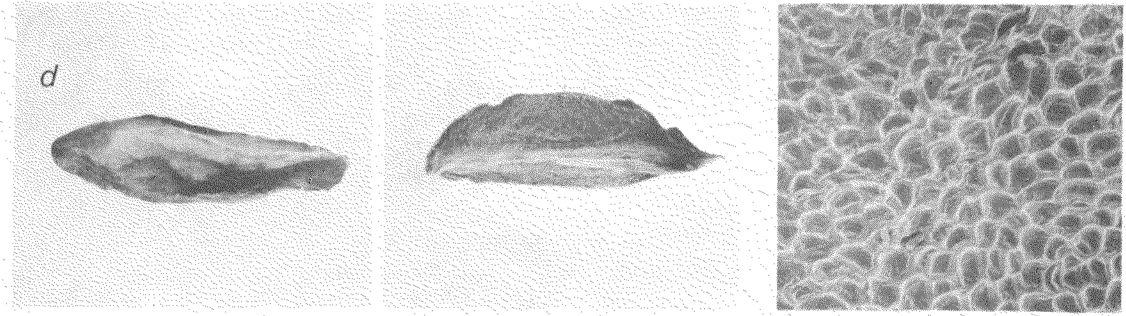
Less emargination than in the bisected group has resulted in a bilobed cotyledon (e.g. E.globulus). E.cladocalyx appears to occupy an anomalous position somewhere in between "bisected" and "bilobed".

E. ficifolia x 1.7

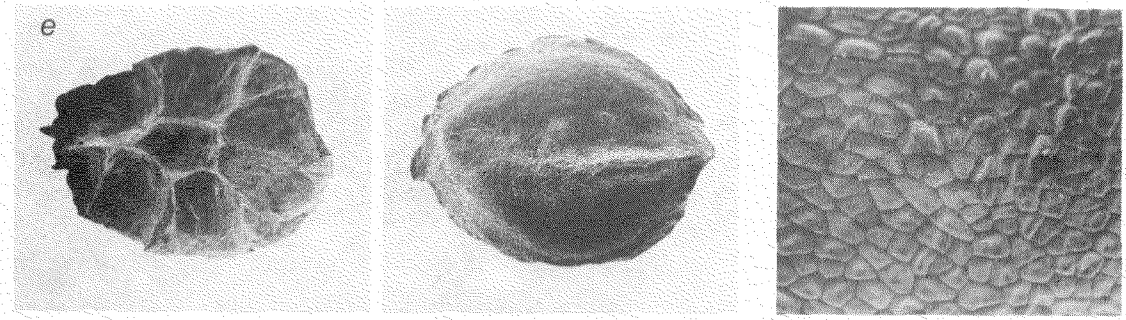


E. calophylla x 1.7

E. haemotoxylon x 1.7



E. gummifero x 5



E. trachyphloia x 9

Figure 1.

An extreme modification is seen in E.marginata where the large cotyledons are subtended by long petioles which are attached to the seedling axis from below ground level.

(3) Juvenile leaves

Many eucalypts are notable for their spectacular juvenile leaves which differ greatly from those in an adult crown, e.g. E.globulus. This is an extreme example in which two highly contrasting leaf forms are clearly demonstrated. Because there is no sudden change from one form to the other, botanists recognise that there is a linking phase which precedes the formation of the final leaves in a mature crown, i.e. an intermediate phase links the juvenile with the adult. The word "mature" is best used for any leaf, juvenile or adult etc., that is fully formed.

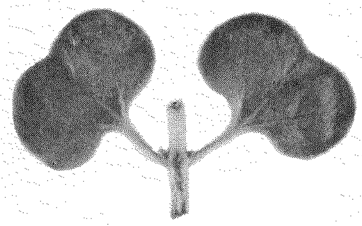
In all species, seedling leaves are formed immediately above the cotyledons. They are often inconspicuous and small. Then follows the juvenile leaves which are always bigger and more conspicuous. Often they are glaucos. In many species they are sessile. Stem, butt or branch coppice approximates the juvenile leaves. The number of pairs of juvenile leaves produced depends on the species. Closely-related species usually have similar juvenile leaves e.g. E.bicostata, E.globulus.

In some species the juvenile leaves and stems are hairy e.g. E.citriodora, E.macrorhyncha. In a few species the juvenile leaves are peltate, i.e. the attachment of the petiole is on the underside of the lamina and inside the margin. This feature is exclusive to bloodwoods, e.g. E.calophylla.

Intermediate leaves are usually similar to the adult but are longer and broader.

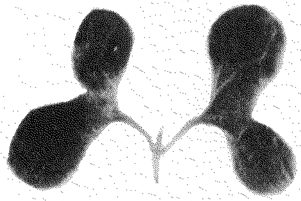
(4) Adult leaves

While there is great variety in the juvenile leaves, the adult leaves are far more uniform. Most are green. Very few are glaucous, e.g. E.sideroxylon. Important distinctions include discolouredness, shininess, dullness, variations of shape, size and venation, and of oil content, e.g. E.citriodora is instantly recognisable by the lemon scent. Among the 20-30 most commonly

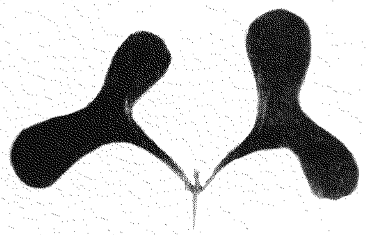


E. erythrocorys x 1.4

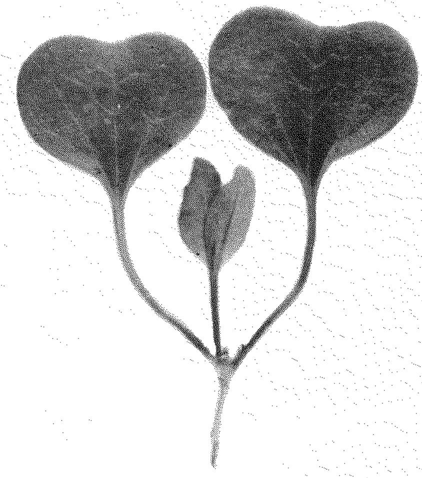
E. oleosa x 3.7



E. globulus x 2.3



E. cladocalyx x 2.3



E. marginata x 0.9

Figure 2.

planted eucalypts, the presence of lemon-scented oils could be regarded as an absolute character for identification. However, among all eucalypts it can only belong in the high reliability group because one other species E.staigeriana has lemon-scented oil. It is easy to distinguish from E.citriodora as it is an ironbark.

Many eucalypys have prominently discolorous adult leaves. These include E.saligna, E.grandis, E.cladocalyx, E.botryoides, E.robusta, E.gummifera. Other species have less prominent discolorous leaves e.g. E.acmenoides, E.rummeryi, E.punctata, E.muelleriana. Slightly discolorous leaves occur in E.gomphocephala and E.maculata, i.e. the distinctiveness of the character is one of degree and should be used with reserve in the latter two groups particularly.

The evolutionary trend in leaf venation has been from the strongly pinnate venation and highly reticulate pattern of, for example, E.gummifera to the reduced venation seen in E.dives and E.delegatensis. Parallel with this trend is the increase in oil gland size, density, and oil content as seen in E.dives.

(5) Bark

Eucalypts are usually referred to as being smooth-barked e.g. E.maculata, rough-barked, e.g. E.amygdalina or partly rough-barked, E.cambageana.

A few smooth-barked species never have evidence of rough bark e.g. E.salmonophloia. Some species which are generally recognised as smooth-barked often have a butt of non-decorticated rough bark, e.g. E.camaldulensis. A related species E.rudis, can be completely rough or completely smooth-barked, the distinction upon which these two species are recognised being bud and seed characters which have a higher degree of reliability than bark.

There are many categories of rough bark. Most notable are the stringybark species in which bark is rough over the whole trunk and is held in coarse, thick, soft, long fibres; the ironbark species in which the rough bark is deeply furrowed and very hard; and the species with tessellated bark in which the rough bark breaks up in small squares which often become blackened and whose outer surfaces flake off with time, e.g. E.tessellaris, E.cambageana, E.cloeziana. In box species the rough bark is held in either fibres or flakes.

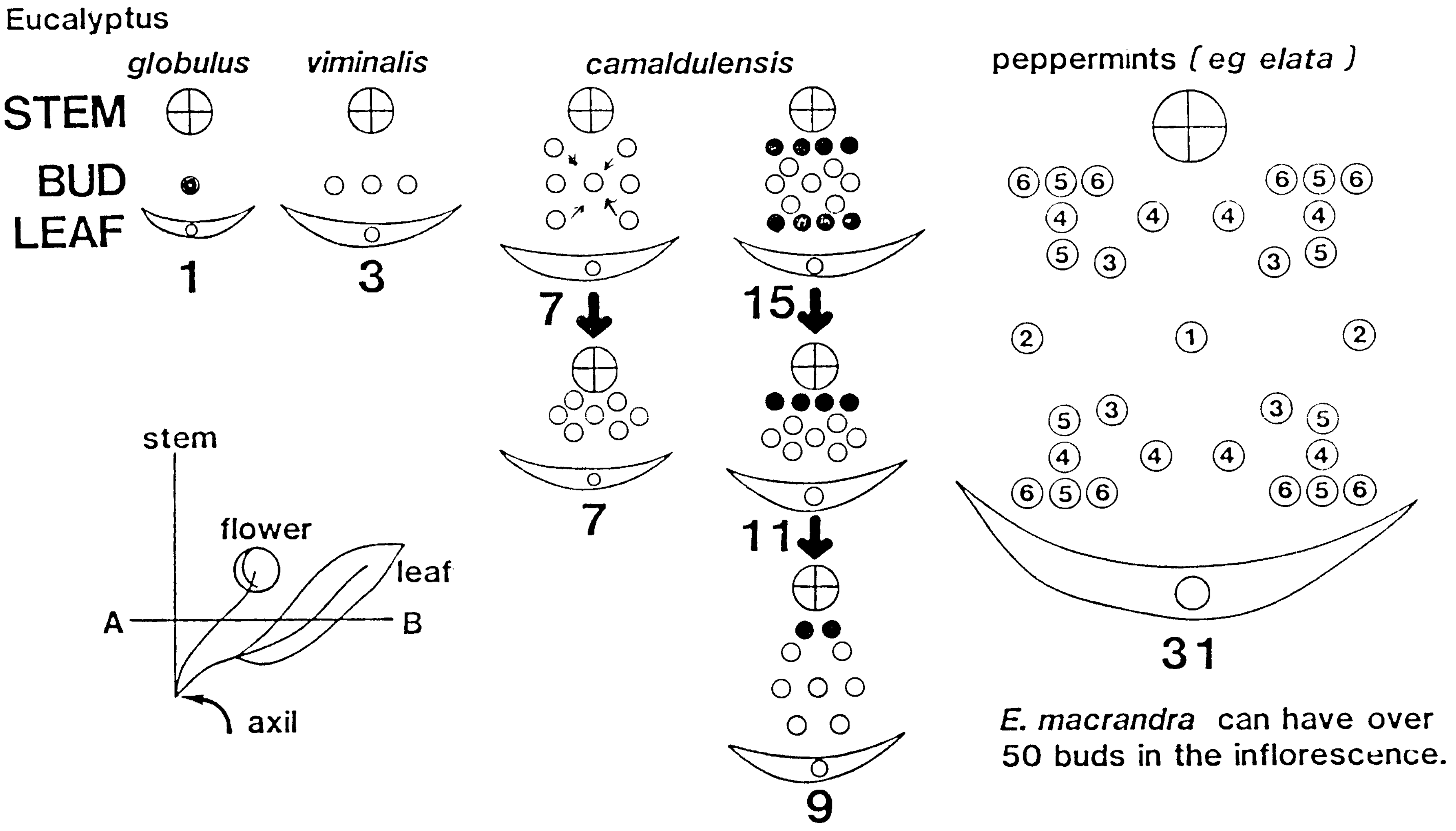
The smooth-barked species lose their outer bark every year but the manner of decortication differs between species. Some lose their bark in long ribbons, e.g. E.viminalis, E.pileata. Others lose it in large slabs, e.g. E.citriodora. Some lose the bark at various times of the year. The oldest, usually grey bark, peels off in irregular slabs and exposes bright cream bark which weathers to orange and finally to grey. In these species, three stages of bark weathering can be seen from the newly exposed cream or orange to the partly weathered light grey to the long-weathered darker grey, which is the next to peel off. This is seen in E.punctata and to a lesser extent in E.camaldulensis.

(6) Inflorescences and reproductory structures (Figure 3)

The unit of an inflorescence in eucalypts is a peduncle bearing buds at the top. There may be a single bud (E.globulus) or the buds occur in 3's (E.viminalis), 7's (E.nitens), 9's, 11's or more (E.amygdalina). The number is odd. The tree buds of a 3-budded inflorescence always occur in a straight line tangential to the axis. Buds often abort as the inflorescence matures resulting in unusual bud numbers but scars of the aborted buds can usually be seen on the expanded summit of the peduncle. For example, a 2-budded infloreccence is almost certainly the result of abortion of a single bud from an original three and the scar is usually evident. A mature 6-budded inflorescence is very likely a seven less one through abortion etc. In only 2 species are the buds united, e.g. E.lehmannii. This unusual inflorescence resulted in its originally being made a separate genus, Symphyomyrtus. The united bud character was later recognised as a superficial modification and the species was placed in Eucalyptus.

The peduncle is usually prominent and slender but may be reduced and stout as in E.globulus. The pedunclate inflorescences may occur singly in the axils of leaves (most species) or be aggregated into a compound structure bare of leaves. The compound inflorescences may terminate a branchlet, e.g. E.gummifera or occur in the axils of leaves, e.g. E.tessellaris. E.cladocalyx is unique in that the single pedunclate inflorescences occur on a leafless portion of the branchlets below the current crop of leaves, i.e. on the second year wood and not in the axils of leaves.

Considering now the structure of individual flower buds, the precursor of Eucalyptus had sepals and petals. The evolutionary modification has seen



E. macrandra can have over 50 buds in the inflorescence.

Figure 3.

the union of the sepals into a single structure, the outer operculum and the petals into a similar, single structure, the inner, usually prominent operculum referred to in keys. In some species the inner operculum can be seen to consist of four joined structures (petals) e.g. *E.microcorys* and *E.tetragona*.

Two opercula can be clearly seen in a mature bud of *E.gummifera*. If a longitudinal slit is made through the bud, the two-layered unfused opercula can be seen.

Most species initiate two opercula. The actual process of flowering requires the loss of both opercula and the unfolding or spreading of the stamens. In many species the outer operculum sheds early in bud development and the bud enlarges and matures with only the inner operculum to protect the flowering parts. The loss of the outer operculum leaves a ring scar around the bud which persists throughout bud development and is a permanent reminder that an outer structure has been shed. Occasionally the minute outer operculum detaches completely at the base but remains tightly held on the finally much enlarged inner operculum, e.g. *E.camaldulensis*. In some species both opercula are held till maturity and shed at the same time, i.e. at flowering. Examples are *E.gummifera*, *E.maculata*, *E.sideroxylon*. There is therefore no operculum scar on the side of the bud during its development. The bud tissue is uninterrupted from the base to the top of the bud.

In many other species only one operculum develops. This is evident by the lack of a scar on the side of the bud and by the single operculum as seen by taking a longitudinal section. The species include, *E.amygdalina*, *E.delegatensis*, *E.muelleriana*.

In several species the primitive sepaline condition is retained while the petals alone are fused into an operculum. In *E.tetragona* the sepals are not shed and can be seen throughout bud development and on the rim of the fruit. In a few species the sepals are shed when the bud is minute e.g. *E.cleoziana* and *E.microcorys*. In two or three species the outer operculum may break into four sepals which are shed as the bud enlarges, e.g. *E.spathulata*.

Within the unopened bud the stamens are situated in various ways. In a large group of species, all the stamens are completely erect with the anther held uppermost, e.g. *E.occidentalis*. In another large group the stamens are completely inflexed with the anthers held downwards at the base of the bud cavity, e.g. E.diversicolor, E.melliodora. In many species the stamens do not conform to either of these easily recognised patterns. They are variously flexed with the anthers held against the style.

In a few species the stamens are clustered at the base into four groups. This was first seen in E.tetragona and the condition was considered sufficiently unique and distinct from the arrangement in other known eucalypts that this species was made a separate genus, Eudesmia. The clustering of the stamens was later not considered fundamental and Eudesmia tetragona was transfereed into Eucalyptus. Since then several other eucalypts have been found to have the stamens clustered, e.g. E.microcorys.

The female reproductory structures in the bud are the ovary, style and stigma. The ovary is usually bulbous and is situated out of sight by being immersed in the base of the bud. It consists of from 2 to about 10 chambers, each with a placenta bearing ovules. In a very few species the ovary is only half-immersed and the top is visible above the rim at flowering, e.g. E.camaldulensis and E.microtheca. Above the ovary are the style and stigma.

(7) Flowering

Eucalypts in their natural environment usually flower within distinct seasons. This pattern is often upset when eucalypts are grown in areas away from their natural habitats and time of flowering is a character of low reliability.

At flowering, the operculum is shed and the stamens spread. The flowers are white or cream in most species but spectacularly coloured in others, e.g. E.ficifolia, E.leucoxylon, E.macrocarpa. In some species the flowers are regularly pink, e.g. E.sideroxylon and in some they are rarely coloured, e.g. E.melliodora and E.blakelyi.

At the time of flowering the pollen is viable and immediately shed. The ovules of the same flower take several days after the onset of flowering before they are receptive to the pollen. This feature ensures that individual flowers are not self-fertilized. The system favours outcrossing but is not a strong mechanism as the pollen from one flower can fertilize the ovules of another on the same tree providing the flower has opened several days earlier. Flowering on one tree can take place over several weeks.

(8) Fruit development

After flowering the stamens fall and the bud (minus operculum and stamens) grows in size and becomes woody. At maturity it becomes the fruit. Inside, the fertilized ovules mature and become the seed.

As the buds develop into fruit, the shape as well as the size can change considerably. Of most importance in keys to identification is the **recognition** of the disc (Figure 4). This is the band of tissue that lines the inside of the bud cavity between the rim and the top of the sunken ovary.

In many species the disc remains in this position to the fruiting stage and the fruit is relatively thin-rimmed, e.g. E.botryoides, E.crebra, E.rummeryi.

In other species the disc finally extends upwards and is a prominent ascending band of tissue making the fruit conspicuously thick-rimmed, e.g. E.bicostata, E.gomphocephala, E.tereticornis.

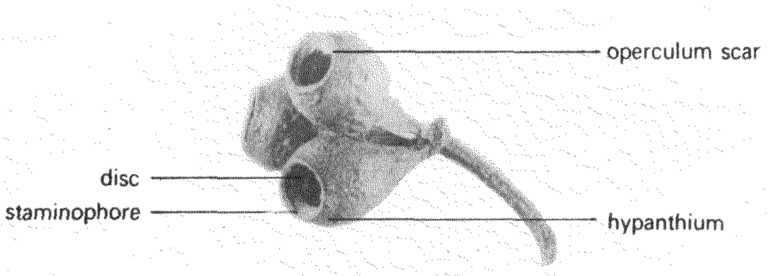
When the fruit is mature, the top of the ovary splits into valves which become erect and allow the chaff and seed to shed (Figure 5). If the ovary of the fruit remains sunken, i.e. well below the rim, the valves are usually not conspicuous, e.g. E.cladocalyx, E.diversicolor, E.obliqua. In other species, the ovary roof is near the rim and the opened valves extend well beyond the rim e.g. E.baxteri, E.microtheca, E.resinifera.

In a very few species the valves remain attached at their tips and the seed shed through gaps between them, e.g. E.robusta.

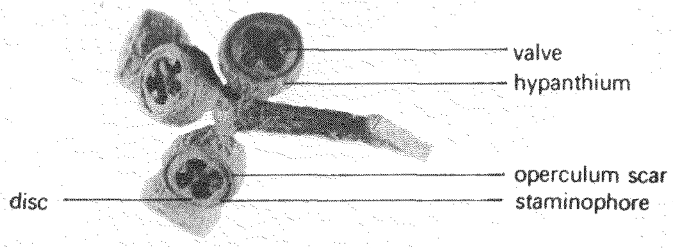
Valve characters can be important in distinguishing some closely related species. For example, in E.saligna the valves are erect and in E.grandis they are incurved.

(9) Seed shed

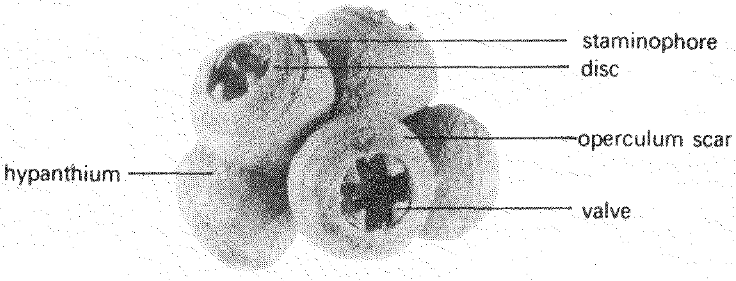
The time from flowering to the formation of mature fruit (i.e. with viable seed) varies greatly between species. In E.tessellaris it may take only a



E. obliqua x 1.5

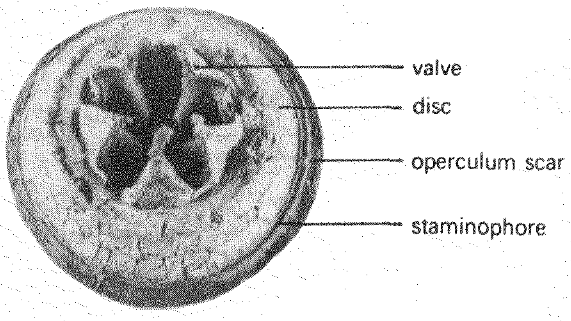


E. umbra subsp. *carnea* x 1.3



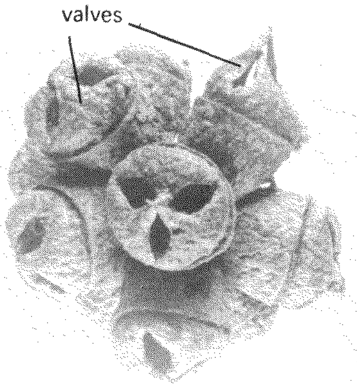
E. baxteri x 1.5

E. microtheca x 3.0

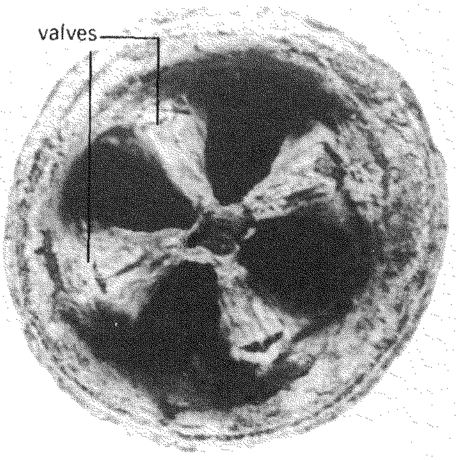


E. burracoppinensis x 2.0

Figure 4. Fruit of five species showing discs of contrasting forms



E. cornuta x 1.2



E. robusta x 6.0 valve tips remain united

E. transcontinentalis x 2.5

slenaer style remnants surmount obscure sunken valves

Figure 5.

few days while in most species it takes weeks or months. Awareness of the time factor is vital when judging the time to collect fruit for seed after having observed flowering. In the case of E.tessellaris and E.papuana which may grow in remote places, it is extremely difficult to time seed collecting trips as these must be put into operation within days of flowering.

The viable seed in eucalypts are formed at the base of the fruit. This means that the chaff sheds first then the seed. In some species the seed may remain jammed in the base of the fruit but complete drying should allow their release.

Characters used in assessing a eucalypt for identification

Arranged in alphabetical order

adult leaves opposite
adult leaf shape
amount of rough bark (butt only, 1.3, 1/2. 3/4-barked, whole trunk, also limbs)
bark colour
bark ribboning
bark rough in other form than ironbark
bark texture (rough or smooth)
bud colour
bud number
buds and/or fruit pendulous
buds fused at the base
difference of colour between upper and lower edges of adult leaf
flower colour
flowering time
fruit shape
habit of plant (tree, mallee or mallet)
habitat preference
inflorescence type (axillary, terminal, simple, paired, compound)
ironbark
juvenile leaves connate
juvenile leaves decurrent
juvenile leaves distinctly sessile or petiolate
juvenile leaves hairy
juvenile leaves opposite
juvenile leaves peltate
leaf colour
leaf shine
leaf venation
lemon-scented oil in leaves
lignotuber present or absent
ovule row numbers
oil glands in leaf present or absent
pith glands present or absent
powderiness of the smooth bark surface
seed - all characters
seed colour
seed sculpture (surface markings)
sepals present or absent
single or double operculum
size of bud or fruit
size of tree or mallee
square buds (in section)
square stems (in section)
stamen inflexion
stamens grouped in 4 bundles
staminodes present
time of shedding outer operculum (early or late in bud development)
valve exsertness
valve number
waxiness of any organ

Low

amount of rough bark (butt only, 1/3, 1/2, 3/4-barked, whole trunk, also limbs
bark colour
bark rough in any form other than ironbark
bud colour
buds and/or fruit pendulous
flowering time
fruit shape
habit (tree, mallee or mallet)
habitat preference
lignotuber present or absent
seed colour
size of bud or fruit
size of tree, mallee or mallet
square stems (in section)
valve exsertness
waxiness of any organ

Nil

adult leaf shape

Characters used in assessing a eucalypt for identification

Arranged in categories of reliability

Absolute

Single or double operculum (Appendix 1)

High

anther shape (Appendix 2)
bud number (Appendix 1)
buds fused at the base
adult leaves opposite
inflorescence type (axillary, terminal, simple, paired, compound) (Appendix 1)
ironbark
juvenile leaves connate (
juvenile leaves decurrent (
juvenile leaves hairy (Appendix 2
juvenile leaves peltate (
lemon-scented oil in leaves (
ovule row numbers (Appendix 2)
seed - all characters
shape of cotyledons (Appendix 2)
stamen inflexion (Appendix 2)
stamens grouped into 4 bundles
staminodes present (Appendix 3)

Medium

bark ribboning
bark texture (rough or smooth) (Appendix 3)
difference of colour between upper and lower side of adult leaf (Appendix 3)
flower colour
juvenile leaves distinctly sessile or petiolate
juvenile leaves opposite
leaf colour
leaf shine
leaf venation
oil glands in leaf present or absent
pith glands present or absent
powderiness of the smooth bark surface
seed sculpture (surface markings)
sepals present or absent (Appendix 1)
square buds (in section)
time of shedding outer operculum (early or late in bud development)
valve number

Appendix 1.

	operculum characters					inflorescences					
	operculum		if double, outer operculum lost		sepals instead of outer operculum	axillary		terminal	bud numbers		
	single	double	early	late		simple	compound	compound	1	3	7
calyptus alba		x	x			x					x
" amygdalina	x					x					
" baxteri	x					x					x
" bicostata		x	x			x				x	
" bicolor(largiflorens)		x		x				x			x
" bosistoana		x		x		x		x			x
" botryoides		x	x			x					x
" bridgesiana		x	x			x					x
" camaldulensis		x	x			x					x
" cambageana		x	x					x			x
" citriodora		x		x			x			x	
" cladocalyx		x	x			x[2]					x
" cloeziana	x				x (shed early)		x				x
" crebra		x	x					x			x
" delegatensis[3]	x					x					x
" dives	x					x					
" diversicolor		x	x			x					x
" drepanophylla		x	x					x			x
" fastigata	x					x					
" globulus		x	x			x			x		
" gomphocephala		x	x			x					x
" goniocalyx		x	x			x					x
" grandis		x	x			x					x
" gummifera		x		x				x			x
" longifolia		x	x			x				x	
" macarthurii		x	x			x					x
" macrorhyncha	x					x					x
" maculata		x		x			x			x	
" maidenii		x	x			x					x
" melliodora		x		x		x				(x)	x
" microcorys	x				x (shed early)	x[5]					x
" microtheca		x	x					x			x
" muelleriana	x					x					x
" nitens		x	x			x					x
" nova-anglica		x	x			x					x
" nubilis (fibrosa subsp. nubila)		x	x					x			x
" ovata		x	x			x					x
" obliqua	x					x					
" occidentalis		x	x			x					x
" paniculata		x	x					x			x
" pilularis	x					x					x
" populnea		x	x					x			x
" punctata		x	x	x[6]		x					x
" regnans	x					x					x
" resinifera		x	x			x					x
" robusta		x	x			x					(x)
" rubida		x	x			x				x	
" rummeryi		x	x					x			x
" saligna		x	x			x					x
" salmonophloia		x	x			x					x
" (scabra) globoidea	x					x					
" sideroxylon		x		x		x				x[7]	x
" tereticornis		x	x			x					x
" tessellaris		x	x				x			x	x
" (triantha) acmenoides	x					x[5]					x
" urophylla		x	x			x					x
" viminalis		x	x			x				x	(x)

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[1] E. camaldulensis var. camaldulensis (south-east Australia only) has beaked opercula with inflexed stamens. E. camaldulensi var. obtusa (elsewhere) has conical opercula with erect stamens

[2] inflorescences occur on leafless shoots below current leafy branchlet

[3] E delegatensis is the earliest name for this species, later named E. gigantea

[4] stamens are pressed in radially under dome-shaped operculum

[5] inflorescences may be clustered towards ends of branchlets appearing terminal

[6] outer operculum of E. punctata var. didyma sheds late

[7] E. sideroxylon subsp. tricarpa is 3-flowered

decaisneana = ? alba or ? urophylla
gigantea = delegatensis
salicifolia = amygdalina

Appendix 2.

	cotyledons			seedling leaves			stamens			anther shape			ovule row numbers				
	reniform	bilobed	bisected	peltate(+)	hairy(+)	connate(+)	erect	inflexed	various	oblong	reniform	irregular	2	4	6	8(+)	
alba	x	x		-	-	-		x		x					x		
amygdalina	x			-	-	-		x			x		x				
baxteri	x			-	+	-			x		x		x				
bicostata		x		-	-	-			x	x					x		
bicolor(largiflorens)	x			-	-	-			x			x		x			
bosistoana	x	x		-	-	-		x	x			x		x			
botryoides		x		-	-	-		x		x				x			
bridgesiana	x	x		-	-	-			x	x				x			
camaldulensis	x			-	-	-	x^1	x^1		x					x		
cambageana	x			-	-	-		x	x			x			x		
citriodora	x			+	+	-		x		x				?	? (rows obscure)		
cladocalyx		x	x	-	-	-		x		x				x			
cloeziana	x	x		-	±	-					x			x			
crebra	x			-	-	-			x			x		x			
delegatensis^3	x			-	-	-		x	x		x		x				
dives	x			-	-	±		x			x		x				
diversicolor		x		-	-	-		x		x				x			
drepanophylla	x			-	-	-			x			x		x			
fastigata	x			-	-	-		x	x		x		x				
globulus		x		-	-	-			x	x						x	
gomphocephala		x	x	-	-	-	x^4			x				x			
goniocalyx	x	x		-	-	-			x	x				x			
grandis	x			-	-	-		x	x	x				x			
gummifera	x			+	+	-		x		x				x			
longifolia		x		-	-	-		x		x					x		
macarthurii	x	x		-	-	-			x	x				x			
macrorhyncha	x			-	+	-			x		x		x				
maculata	x			+	+	-		x		x				?	? (rows obscure)		
maidenii		x		-	-	-		x	x	x				x			
melliodora	x			-	-	-		x		x				x			
microcorys	x			-	-	-		x			x			x			
microtheca	x			-	-	-			x			x		x			
muelleriana	x			-	±	-			x		x		x				
nitens	x	x		-	-	-		x		x				x			
nova-anglica	x	x		-	-	-			x	x				x			
nubilis (fibrosa subsp.	x			-	-	-	x					x		x			
ovata	x	x		-	-	-			x	x				x			
obliqua	x			-	±	-			x		x		x				
occidentalis			x	-	-	-	x			x				x			
paniculata	x			-	-	-		x		x				x			
pilularis	x			-	-	-		x			x		x				
populnea	x			-	-	-			x			x		x			
punctata		x		-	-	-		x		x				x			
regnans	x			-	-	-			x		x		x				
resinifera		x		-	-	-		x		x					x		
robusta		x		-	-	-		x		x						x	
rubida	x	x		-	-	-			x	x				x			
rummeryi	x			-	-	-			x			x		x			
saligna	x			-	-	-			x	x				x			
salmonophloia			x	-	-	-			x			x		x			
(scabra) globoidea	x			-	+	-			x		x		x				
sideroxylon	x			-	-	-		x		x				x			
tereticornis	x			-	-	-	x			x					x		
tessellaris	x			-	±	-		x		x				x			
(triantha) acmenoides	x			-	-	-			x		x		x				
urophylla		x		-	-	-		x		x					x	x	
viminalis	x	x		-	-	-			x	x				x			

Appendix 3

	staminodes	adult leaves	bark	
	present	discoloured	smooth (s) rough (r)	type
alba	−	−	s	gum
amygdalina	−	−	r	peppermint
baxteri	−	−	r	stringy
bicostata	−	−	r/s	gum/flaky
bicolor (largiflorens)	−	−	r	box
bosistoana	−	−	r/s	gum/box
botryoides	−	++	r	fibrous
bridgesiana	−	−	r	box
camaldulensis	−	−	r/s	gum/flaky
cambageana	−	−+	r	tessellated
citriodora	−	−	s	gum
cladocalyx	−	++	s	gum
cloeziana	−	+	r	tessellated
crebra	−	−	r	ironbark
delegatensis[3]	−	−	r	stringy
dives	−	−	r	peppermint
diversicolor	−	++	s	gum
drepanophylla	−	−	r	ironbark
fastigata	−	−	r	stringy
globulus	−	−+	r/s	gum/flaky
gomphocephala	−	−	r	box
goniocalyx	−	−	r	box
grandis	−	++	r/s	gum/fibrous
gummifera	−	++	r	tessellated
longifolia	−	−	r/s	gum/box
macarthurii	−	−	r	fibrous
macrorhyncha	−	−+	r	stringy
maculata	−	−	s	gum
maidenii	−	−	r/s	gum/flaky
melliodora	+	−	r	fibrous
microcorys	+	++	r	fibrous
microtheca	−	−+	r/s	gum/box
muelleriana	−	−	r	stringy
nitens	−	−	s	gum
nova-anglica	−	−	r	box/fibrous
nubilis(fibrosa)	−	−	r	ironbark
ovata	−	−	r/s	gum/flaky
obliqua	−	−	r	stringy
occidentalis	−	−	r	fibrous
paniculata	+	+	r	ironbark
pilularis	−	−	r	stringy
populnea	−	−	r	box
punctata	−	+	s	gum
regnans	−	−	r	stringy
resinifera	−	++	r	fibrous
robusta	−	++	r	fibrous
rubida	−	−	s	gum
rummeryi	−	+	r	box
saligna	−	++	r/s	gum/fibrous
salmonophloia	−	−	s	gum
(scabra)globoidea	−	−	r	stringy
sideroxylon	+	−	r	ironbark
tereticornis	−	−	s	gum
tessellaris	−	+	r	tessellated
(triantha)acmenoides	−	+	r	stringy
urophylla	−	+	r/s	gum/fibrous
viminalis	−	−	r/s	gum/fibrous

A KEY TO EUCALYPTUS SPECIES

by M.I.H. Brooker

The key is put together to include all commonly planted eucalypts in the region.

The scheme is dichotomous i.e. every entry has an alternative entry, e.g. buds smooth versus buds warty.

A whole range of characters is used and it is to be hoped that juvenile and adult leaves, buds and fruit are present on the trees and specimens to be identified. The characters have different degrees of reliability as discussed elsewhere.

Few species have unique characters. This is a reflection on their evolution in that the vast majority of species are obviously related to some others and the distinctions between them often consists of a group of only slightly divigerent characters. Unique characters would make a key easy to produce, but the key would then consist of a long series of single steps. In the case of E.citriodora, it is reasonable to begin with the single unique character of lemon-scented leaves which is so easily recognised. For the remainder, however, the key attempts, where possible, the less cumbersome scheme of using characters that divide the species into two approximately equal numbers of species.

Local conditions may affect certain features such as the bark and the leaves, i.e. the characters of medium or low reliability. This may result in the species not keying out according to its usual characteristics. The alternative entries will then have to be used. Absolute and high reliability characters appear early in the key.

In some parts of the key where two or more species come together and belong to a natural group, the name of the group is shown in brackets, e.g. entry 31 consists wholly of boxes. This does not mean, however, that boxes do not occur elsewhere in key. An example is E.rummeryi, a box species, but which keys out more easily elsewhere than its allies because of its discolorous leaves - as seen in natural populations in Australia.

A 10x lens is essential in using parts of the key.

Key to Eucalyptus Species

1. Leaves lemon-scented	*E.citriodora*
1. Leaves not lemon-scented	
2. Buds mostly single in axils	*E.globulus*
2. Buds with 3 or more in axils	
3. Buds in 3's	
4. Buds and fruit pendulous; buds to 2.6 x 1.6cm; valves of fruit not prominent	*E.longifolia*
4. Otherwise	
5. Buds and fruit warty, glaucous; fruit to 1.7 x 2cm	*E.bicostata*
5. Buds and fruit smooth; fruit to 0.8 x 0.9cm (mountain gums)	
6. Juvenile leaves orbicular, glaucous	*E.rubida*
6. Juvenile leaves lanceolate, green	*E.viminalis*
3. Buds in 7's or more	
7. Adult leaves distinctly discolorous	
8. Buds and fruit forming on leafless branchlets inside crown; bark smooth	*E.cladocalyx*
8. Buds and fruit forming in axils of leaves	
9. Buds in compound arrangement in axils of leaves	
10. Fruit woody, thick-walled	*E.cloeziana*
10. Fruit fragile, thin-walled	*E.tessellaris*
9. Buds grouped on simple peduncles in axils of leaves - may be in clusters at ends of branchlets	

11. Bark hard and deeply furrowed; valves of fruit 5 *E.paniculata*

11. Otherwise

    12. Bark rough over whole trunk

        13. Valves of fruit remaining joined at centre *E.robusta*

        13. Valves of fruit free

            14. Fruit urceolate, to 2x1.4cm; inflorescence large at leafless ends of branchlets *E.gummifera*

            14. Otherwise

                15. Operculum showing cross-sutures; stamens in 4 groups; fruit thin-walled, funnel-shaped, to 0.9 x 0.6cm *E.microcorys*

                15. Otherwise

                    16. Bud without operculum scar showing; inflorescences at leafy ends of branchlets *E.acmenoides*

                    16. Bud with operculum scar showing

                        17. Valves of fruit strongly exserted *E.resinifera*

                        17. Valves sunken, rim level, or scarcely exserted

                            18. Inflorescences simple in axils of leaves (red mahoganies)

                                19. Fruit more or less sessile, barrel-shaped or with parallel sides, to 1.2 x 0.9cm *E.botryoides*

- 19. Fruit pedicellate, funnel-shaped, campanulate or cup-shaped, to 0.8 x 1.8cm — E.urophylla
- 18. Inflorescences compound, at leafless ends of branchlets; fruit to 0.5 x 0.4cm — E.rummeryi

- 12. Bark smooth or rough over only part of trunk
  - 20. Valves of fruit sunken; fruit barrel-shaped, to 1.2 x 1cm; bark smooth — E.diversicolor
  - 20. Valves of fruit visible, to rim level or exserted
    - 21. Bark smooth over whole trunk, mottled; fruit hemispherical or cup-shaped — E.punctata
    - 21. Bark rough over part of trunk or, if smooth, rim of fruit thin
      - 22. Valves of fruit incurved; fruit subsessile to shortly pedicellate, often glaucous — E.grandis
      - 22. Valves of fruit erect
        - 23. Fruit subsessile to shortly pedicellate, funnel-shaped, campanulate or cup-shaped — E.urophylla
        - 23. Fruit subsessile to shortly pedicellate, funnel-shaped to slightly pyriform — E.saligna

- 7. Adult leaves concolorous
  - 24. Ironbarks (ironbarks)
    - 25. Bud without operculum scar showing; fruit to 1 x 0.9cm, with deciduous black band on rim (staminophore) — E.sideroxylon

25. Bud with operculum scar showing
    26. Bud with fruit usually glaucous; bud elongated to 2 x 0.5cm; operculum long, conical; valves of fruit usually exserted; adult leaves to 2.5cm wide ... E.nubilis
    26. Buds and fruit usually not glaucous, smaller; operculum short, about equal to base of bud
        27. Adult leaves narrow-lanceolate, to 1.5 x 1.3cm ... E.crebra
        27. Adult leaves lanceolate, to 1.5 x 2cm ... E.drepanophylla

24.Bark smooth, fibrous, or stringy,not ironbarks,
  28. Buds in compound arrangement in axils of leaves; bark smooth, mottled ... E.maculata
  28. Buds in simple arrangement in axils of leaves or in compound inflorescences at leafless ends of branchlets
    29. Buds elongated, to 3 x 0.6cm; operculum horn-shaped, much longer than base; stamens all erect; bark rough at base at least ... E.occidentalis
    29. Otherwise
        30. Bud with operculum scar showing
            31. Buds in compound inflorescences at leafless ends of branchlets (boxes)
                32. Adult leaves glossy, ovate to orbicular; bark rough over whole trunk ... E.populnea
                32. Adult leaves dull, lanceolate
                    33. Valves of fruit sunken or to rim level
                        34. Bark tessellated in lower half of trunk; fruit funnel-shaped to

subpyriform to 0.7 x 0.5cm,
valves enclosed *E.cambageana*
34. Bark rough over most of or over whole
trunk; fruit hemispherical, ovoid,
or funnel-shaped, to 0.6 x 0.5cm *E.bicolor (largiflorens)*
33. Valves strongly exserted *E.microtheca*
31. Buds in axils of leaves
35. Buds and fruit sessile
36. Juvenile leaves sessile; bark mostly smooth
(southern blue gums)
37. Buds to 0.7 x 0.3cm *E.nitens*
37. Buds to 1 x 0.7cm *E.maidenii*
36. Juvenile leaves petiolate; buds to 2 x 1.2cm;
operculum thick, domed; bark rough *E.gomphocephala*
35. Buds and fruit pedicellate
38. Operculum much longer than base of bud *E.tereticornis*
38. Otherwise
39. Adult leaves ovate, glossy, undulate;
fruit funnel-shaped *E.ovata*
39. Otherwise
40. Juvenile leaves conspicuously
glaucous, more or less sessile
41. Buds with stout pedicels, to
1 x 0.7cm; fruit to 1.1 x 1cm;
bark smooth or rough *E.maidenii*

- 41. Buds with slender pedicels; buds and fruit smaller; bark rough
    - 42. Juvenile leaves crenulate; branchlets, buds and fruit not glaucous *E.bridgesiana*
    - 42. Juvenile leaves with smooth edges, branchlets, buds and fruit glaucous *E.nova-anglica*
- 40. Juvenile leaves not conspicuously glaucous
    - 43. Bark rough over whole trunk; juvenile leaves sessile; adult leaves narrow-lanceolate, to 16 x 1.5cm *E.macarthurii*
    - 43. Bark wholly or mostly smooth
        - 44. Adult leaves bright glossy green; buds to 0.6 x 0.4cm; fruit to 0.5 x 0.5cm; bark smooth *E.salmonophloia*
        - 44. Adult leaves not or scarcely glossy (red gums)
            - 45. Bark smooth over whole trunk; valves of fruit not prominent *E.alba*

45. Bark usually rough at base; valves prominently exserted E.camaldulensis

30. Buds without operculum scar showing

46. Valves of fruit 5 or 6; bark usually rough (boxes)

47. Rim of fruit with deciduous staminophore; stamens inflexed E.melliodora

47. Rim of fruit without staminophore; stamens irregularly flexed E.bosistoana

46. Valves of fruit 3 to 4; bark rough over part of most of trunk

48. Inflorescences paired in the axils of leaves (mountain ashes)

49. Bark rough over whole trunk E.fastigata

49. Bark rough over lower half of trunk E.regnans

48. Inflorescences single in the axils of leaves

50. Juvenile leaves opposite more or less sessile for many pairs

51. Adult leaves narrow-lanceolate, to 0.9 wide; fruit to 0.7 x 0.7cm A.amygdalina

51. Adult leaves lanceolate or falcate, to 3cm wide

52. Leaves with strong peppermint smell; fruit to 0.7 x 0.7cm, cupular abconical or hemispherical E.dives

- 52. Leaves without strong peppermint smell; fruit to 1.1 x 1.1cm, hemispherical to truncate-globose E.pilularis

50. Juvenile leaves alternate, petiolate

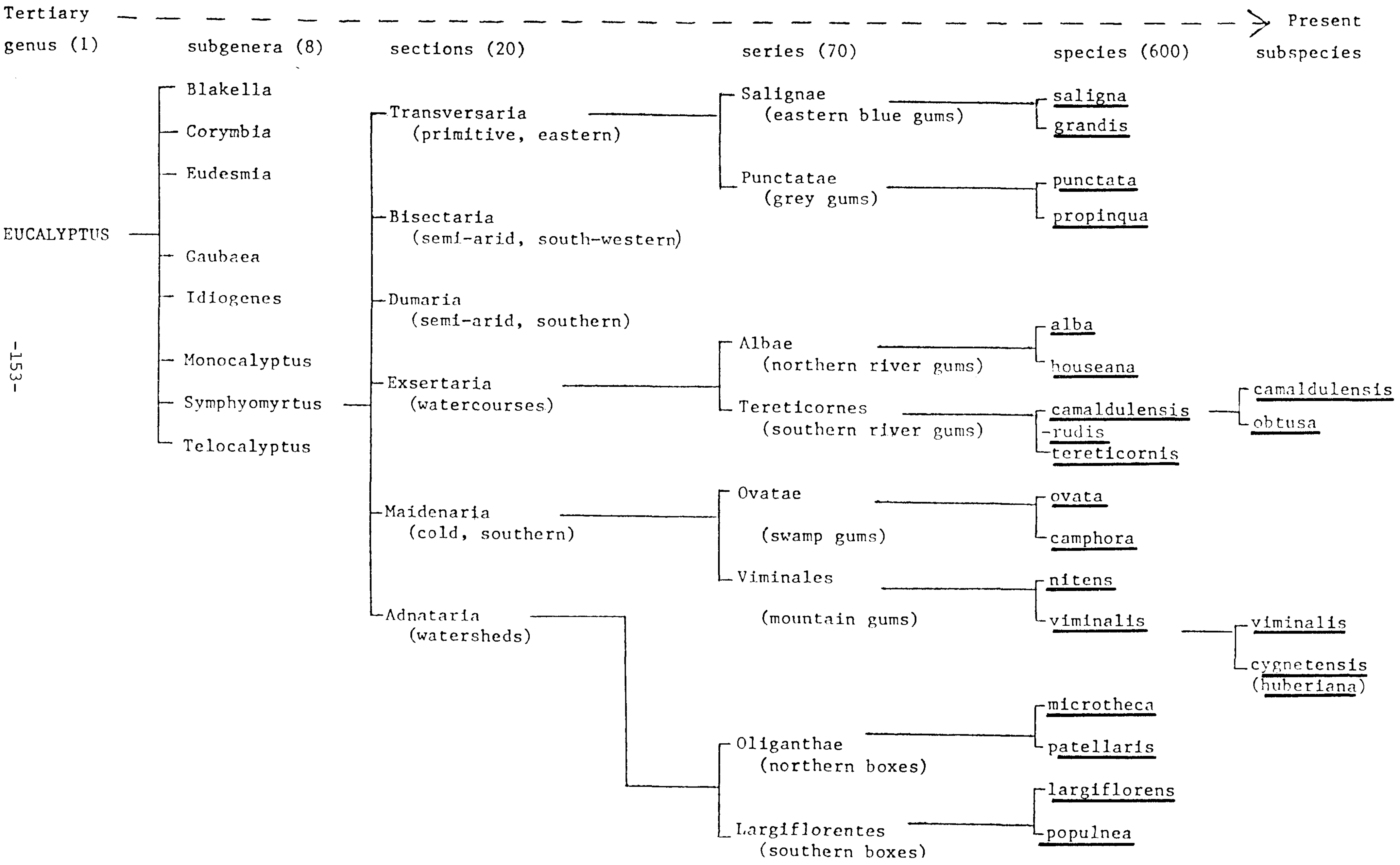
- 53. Fruit about as broad as long, with thick rim; disc broad, prominent (stringy barks)
  - 54. Operculum strongly beaked E.macrorhyncha
  - 54. Operculum not strongly beaked
    - 55. Buds sessile or with short stout pedicel, often warty
      - 56. Fruit to 1.1 x 1.6cm; operculum hemispherical or obtusely conical, warty E.baxteri
      - 56. Fruit to 0.7cm; operculum acutely conical E.globoidea
    - 55. Buds with distinct pedicels, not warty E.muelleriana

53. Fruit usually longer than broad, obconical to barrel-shaped (ashes)

  57. Adult leaves bright glossy green; juvenile leaves glossy green; bark rough over whole trunk *E.obliqua*

  57. Adult leaves glossy green to grey-green; juvenile leaves dull blue-green; bark rough over lower half *E.delegatensis*

Scheme of classification of the eucalypts (after Pryor and Johnson, 1971)
with examples of well-known species



List of technical words used in Eucalyptus studies

adult leaf	leaf in a mature crown
anther	organ at the tip of the stamen, containing the pollen
axil	angle between the leaf (or leaf stalk) and stem
bifid	structure divided into two approximately equal branches
bi-operculate	with an outer and inner operculum
bloodwood	group of eucalypts with large woody fruit and often with tessellated bark
box	group of eucalypts with grey short-fibred rough bark
campanulate	bell-shaped (inverted)
chaff	the upper infertile contents of the fruit of a eucalypt derived from unfertilisable or unfertilised ovules
compound	refers to a branched, leafless inflorescence
concoloredness	with the same colour both sides of leaf (concolorous)
coppice	new growth from stump after felling of tree, also juvenile growth on trunk and branches
cotyledon	first leaves after germination
crenulate	with leaf edge scalloped
cross-sutures	lines on operculum indicating join of petals
decortication	shedding of bark
disc	band of tissue between rim and ovary on bud or fruit
discoloredness	with upper side of leaf darker than underside (discolorous)
divergence	morphological separation of forms from a common ancestor
endemic	naturally occurring only in a defined area
Eucalyptus	genus of woody plants; about 600 species; Greek eu - well, calyptus - covered (referring to operculum)
falcate	sickle-shaped, i.e. a narrow curved leaf
genus	(plural genera) a group of related species, e.g. Eucalyptus, Acacia, Casuarina
glaucous	covered with a white wax
gum	any smooth-barked eucalypt
heterophylly	with different forms of leaf during age of tree (heterophyllous)
hilum	scar on ventral side of seed caused by breaking from placenta
homophylly	with only minor differences, or none, in leaf form during age of plant
inflexed	stamens which are firstly erect then sharply down-turned
inflorescence	specialised arrangement of flowers on a plant stem
ironbark	thick, deeply-furrowed, hard, rough bark in eucalypts
jarrah	eucalypt with rough bark, endemic to south-west Western Australia
lanceolate	shaped like a spearhead

laterisation	accumulation of ironstone in soil
leaf phases	seedling, juvenile, intermediate, adult - the sequence of different leaf forms seen in developing eucalypt
lignotuber	large woody mass at ground level of eucalypt stem or trunk; contains numerous dormant vegetative buds
mallee	multi-stemmed eucalypt
marri	coastal eucalypt, a bloodwood with large woody fruit
maturity of leaves	fully grown stage of a leaf of any growth phase, juvenile to adult
morphology	study of shape, form, colour, texture, etc., in plants
Oligocene	geological age (epoch) about 30 million years ago
operculum	bud cap in eucalypts
orbicular	round or almost round
ovary	basal, female, reproductory organ in plants; contains the ovules ; extended on top into style and stigma
ovule	organ attached to placenta in ovary that matures into a seed after fertilisation by male nucleus from pollen
paired	refers to the occurrence of 2 simple inflorescences in the same axil
pedicel	bud stalk
peduncle	stalk of inflorescence that bears individual buds at top
peltate	with the leaf stalk attached to the underside of the leaf, not at the end
pendulous	hanging freely, not rigid or upright
peppermint	fine, criss-crossed, long-fibred, rough bark in eucalypts
petal	soft inner ring of structures protecting a flower, united into an operculum in eucalypts
petiole	leaf stalk
pinnate	leaf venation when many side veins leave the midribs at a wide angle
placenta	organ in ovary which bears the ovules
phylogeny	study of scheme of natural descent, i.e. by evolution
powder-bark	a smooth-barked species whose powdery bark surface is recognised by brushing with the hand
pyriform	pear-shaped
receptacle	organ which bears individual flower parts, enlarged and hollowed in eucalypts
reniform	kidney-shaped
reticulation	network of veins in a leaf
sepal	outer ring of structures protecting a flower, united to form outer operculum in many eucalypts
sessile	without a stalk (leaf or flower)

simple	refers to an inflorescence consisting of a peduncle bearing 1-many individual flower buds
stamen	male reproductory organ, consists of a filament and anther
staminophore	ring of tissue bearing stamens, black and finally shed in E.sideroxylon
stigma	organ at tip of style which becomes receptive to pollen when ovules mature
stringybark	coarse, criss-crossed, long-fibred, rough bark in eucalypts
style	filament above ovary, surmounted by stigma
subgenus	category in classification of living things below genus, two or more subgenera compose a genus
taxonomy	classification based on natural relationships
terminal	refers to the inflorescence at the end of a branchlet
Tertiary	geology period, 2,5 - 65 million years ago
tessellated	broken into "squares" as in bark of some eucalypts
topographic	of land surface features
truncate-globose	fruit shape in which outline is more or less spherical but cut off at top
tuart	a rough-barked eucalypt growing on a coastal strip in south-west Western Australia
urceolate	urn-shaped, fruit shape being more or less oval in outline and with a neck at top
valve	section of ovary roof which lifts to allow seed-shed
ventral	underside, side of seed which is attached to placenta
wandoo	a smooth-barked eucalypt of south-west Western Australia

TAXONOMY OF CASUARINAS

by D.J. Boland

GENERAL

Casuarinas are very distinctive, and superficially resemble conifers with their wire-like foliage and woody fruiting structures. The name Casuarina is derived from the Malay Kasuari and alludes to similarity between the drooping foliage of the genus and that of the feathers of the cassowary bird.

The family Casuarinaceae consists of about 60 species and has been recently divided into three genera, viz: Casuarina, Allocasuarina, Gymnostoma. A fourth genus will be proposed soon. The natural distribution of the first three genera is given in Figures 1, 2, and 3. A key to the genera is given in Table 1.

The Casuarinaceae are an old southern family and fossil evidence suggests their presence in Gondwanic times. The oldest genus is believed to be Gymnostoma which has only one Australian representative, viz: G. "a" sp. nov. in northern Queensland. The true Casuarinas are quite widespread in Australia but also occur on islands to the north. They are likely to have arisen and been dispersed by early Tertiary times and show a preference for more fertile soils. The truly derived Australian genus, Allocasuarina, contains most of the species in the family and these appear to be specialised for nutrient deficient sites and their vegetative and floral parts show considerable scleromorphy.

Individual casuarina species range in size from bushes a few centimetres high (e.g.C.microstachya) to tall forest trees some 20-30m tall (e.g. C. cunninghamiana, C.equisetifolia, C.torulosa). Species typically regenerate from seed but C.glauca and allies can spread clonally from root suckers and C.equisetifolia can be propagated from cuttings. Some species are able to regenerate rapidly after fire by producing shoots from thick woody rootstocks (e.g. C.nana)while others can coppice from concealed buds in the tree trunk (e.g. C.torulosa).The bark of most species is rather hard but some are corky (e.g. C.torulosa) and one (C.inophloia)has loose, finely shredded bark. The photosynthetic branchlets in some species are long and weeping (e.g. C.equisetifolia) while in others they are upright and spiky as in C.striata.

Many casuarinas occur early in the ecological succession of new sites, are very keen light demanders and occupy a wide range of habitat types. Some specific examples and sites are *C.equisetifolia* which grows on coastal headlands and *C.cunninghamiana* which inhabits fresh-water river banks. In addition many of the *Casuarina* species occur on sites of very poor fertility, e.g. *C.drummondiana* inhabits sandy sites in Western Australia. Further, it is believed that the ability of casuarinas to grow on poor sites is enhanced by their capacity to form symbiotic root nodules which are capable of fixing atmospheric nitrogen. The nodules contain Actinomycete bacteria thought to belong to the genus *Frankia*. Casuarinas are the only non-leguminous angiosperms in Australia (with the possible exception of one species of *Discaria*) which are known to possess such nodules. Casuarinas are also known to develop proteoid roots and extensive mycorrhizal associations which probably assist in their nutrition.

The wood of most casuarinas (broad sense) is dense and very hard. It makes an excellent fuel, used particularly in India and China, producing good heat and being relatively smokeless when burnt (*C.equisetifolia* is reputed to be the best fuelwood species in the world). The appearance of the wood, caused by dark-coloured, wide medullary rays, makes it attractive for wood turning and parquetry. The timber is also used for pulp in the Philippines and Okinawa. *C.equisetifolia* is widely grown as a windbreak in southern coastal China and also around citrus groves in Florida. The bark of *C.equisetifolia* has been used in tanning, in medicine and for the extraction of dyes. Several species are widely planted as street trees and in parks, for sand stabilization after beach mining activities, and on mining spoil dumps; individual trees lend themselves for ornamental purposes such as topiary and hedges. The branchlets of some species (e.g. *C. cristata*, *C.stricta*) can be lopped and fed to stock during periods of drought. A sterile hybrid casuarina, known as *C.junghuhniana*, is widely cultivated vegetatively in Thailand for marine poles and is used particularly for house foundation supports in Bangkok.

MORPHOLOGY

Both the vegetative and reproductive structures of Casuarinas show considerable reduction and for this reason they have remained somewhat of an enigma both taxonomically and phylogenetically. Some basic features are as follows:

(a) Foliage

The foliage typically consists of jointed photosynthetic branchlets that have grooves running along their length in which the stomata are located. The ridges between the grooves terminate in small triangular teeth, or free leaf tips, and collectively these form a whorl of minute leaves at the joint. The foliage is borne on both persistent branches, the permanent branches of indeterminate length, and deciduous branchlets, the non-permanent branches of determinate length which fall as entire units after 1-3 years of growth. In Gymnostoma there is no clear morphological difference between deciduous and permanent branches whereas in the other genera they differ. One exception is in the Allocasuarina microstachys where the juvenile condition is maintained on the adult tree.

The anatomy of the branches is of note and provides information on the true structure of the leaves. The fused-stem-and-leaf nature of the branchlets is clearly shown in Fig. 4. In the centre of the branchlet is a cylinder of vascular bundles, the conducting system of the stem. In a ring outside these bundles are the leaf bundles. They alternate with the stem bundles and are located opposite the leaf ridges. The true internodes, therefore, are really very short and are located just above the leaf whorl itself.

The morphology of the branchlets is very important in casuarina taxonomy. In the genus Gymnostoma, the branchlets are always quadrangular with the stomates located on the faces of the branchlets. In the rest of the family the number of leaf ridges ranges from 4 to about 16, so that the cross-sectional shape of the branchlet is often circular. The stomates are hidden in deep furrows between the ridges.

(b) Flowers and Fruits

The flowers are unisexual and the male and female inflorescences are quite different in appearance. Some species are monoecious but more are dioecious, while some have both monoecious and dioecious 'races'. The male flowers appear in terminal or lateral spikes in whorls. The internodes between whorls are short and at every node there is a cup-like structure consisting of laterally fused leaf-teeth; these structures are homologous with the leaf-teeth of the branchlets. At anthesis, one stamen hangs out over each leaf. Each male flower consists of 1 anther and 1-2 perianth parts, which are often hooded over the top of the anther; there are 2 lateral bracteoles below each flower, and both the perianth parts and the bracteoles are closely appressed to the stamen before anthesis. The anthers vary in colour from dusty-brown, to red, to yellow depending upon the colour of the pollen. The pollen is disseminated by wind.

The female flowers terminate very short lateral shoots and are borne in dense, compact, ovoid or globular heads. There is a single flower in the axil of each bract. There are no perianth parts but there are two lateral bracteoles supported by a single bract enclosing a one-locular ovary. The long styles stand out beyond the bracts, facilitating wind pollination; after fertilization the whole head becomes woody. This structure (the infructescence, i.e. the fruiting inflorescence) is commonly called a 'cone' and the woody bracteoles are known as valves. Each fruit (a samara) in the cone is very seed-like and is flattened and has a terminal wing which is part of the pericarp; the remains of the style can be seen in the centre of the wing. When the fruits in the cone are ripe, the bracteoles retract and the fruits are released.

The fruiting cones in Gymnostoma have simple, beak-like valves subtended by a broad bract, while the cones of the other genera are often more strongly differentiated, and have less broadened outer faces to the bracts. The cone of Allocasuarina is complex with short cone valves which usually bear dorsal appendages which take many forms (see Fig. 5). The cones of Casuarina sensu stricto have light-coloured fruits with thin, weakly woody, simple valves.

(c) Seedlings

The seedlings of Casuarina uuually consist of two oval cotyledons followed at node 2 with two leaf teeth, then a progressive increase in leaf teeth at successively higher nodes. Initially there is no easily apparent distinction in morphology between the permanent and deciduous branchlets. In two species of Allocasuarina, viz. A.campestris and A.acutivalvis, the seedling leaves are enlarged and succulent for the first few nodes before switching to the more normal branchlets with closely appressed leaf teeth.

TAXONOMIC KEYS

There is no key at present to all the species of Casuarina. It is expected that a key to all the Australian casuarinas will be prepared for the 'Flora of Australia' project. Notes on the genera and lists of individual species is given in Table 2.

Several regional keys to Casuarina have been prepared at various times (see Table 3). While these are of local value they are quite worthless for trying to identify plants overseas. Most regional keys have used such characters as the colour and stiffness of the branchlets, the number of leaves at a joint, the shape and size of the 'cones', and the character of the bracteoles (valves) and the protuberances or markings on the back of the bracteoles. However, individual characters are often found to be variable within a species and thus make classification difficult.

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TABLE 1. KEY TO THE THREE GENERA IN FAMILY CASUARINACEAE

KEY TO GENERA

1. Grooves of branchlets shallow and open, exposing the stomata; teeth 4 per whorl; fruiting cones with a broad bract beneath each pair of bracteoles. NE.Q, Malesia to New Caledonia and Fiji ......Gymnostoma L.A.S.Johnson

1. Grooves of branchlets deep and narrow, the stomata not visible; teeth 4 to many; cone bracts mostly thin at outer face, not conspicuous .....2.

2. Samaras grey or tawny, rather dull; bracteoles of fruiting cone thin and without any dorsal protuberances; teeth 5 to many. All States except Tas; SE. Asia to Pacific islands ....Casuarina L. ex Adans.

2. Samaras dark brown or blackish, shining; bracteoles of fruiting cone thick and convex, often with a more or less separate angular, divided or spiny protuberance; teeth 4 to many.
S. WA, S. NT, E.Q, SA, NSW, Vic, Tas.....Allocasuarina L.Johnson.

TABLE 2. DESCRIPTION OF GENERA AND NOTES ON INDIVIDUAL SPECIES

1. GYMNOSTOMA L.A.S. Johnson

Persistent branchlets similar, as new shoots, to the deciduous branchlets; all branchlets 4-ribbed, the intercostal furrows shallow and open, exposing the stomates. Leaves in whorls of 4. Male inflorescences borne on branchlets differing little from the vegetative ones, simple or appearing compound owing to condensation of branching; female inflorescences borne on branchlets that are short or elongated but similar in aspect to vegetative branchlets. Infructescences ('cones') mostly borne amongst the assimilatory branchlets; bracts expanded distally with the abaxial surface vertical below the apex and broader than high; bracteoles protruding, convex on the back but neither split nor furnished with a protuberance. Chromosome number n = 8, so far as known.

18 species from Malesia to N.E.Australia, Fiji, and New Caledonia. Only one species endemic to Australia.

The name is derived from the Greek gymnos = naked, and stoma = mouth, referring to the exposed position of the stomata on the branchlets.

Type species G.nodiflorum

Alphabetic list of species in Gymnostoma

G.chamaecyparis (Poiss.)	New Caledonia
G.deplancheanum (Miq.)	New Caledonia
G.glaucescens (Schlechter)	New Caledonia
G.intermedium (Poiss.)	? ?
G.leucodon (Poiss.)	New Caledonia
G.nobile (Whitemore)	
G.nodiflorum (Thunb.)	New Caledonia
G.papuanum (S.Moore)	Papua New Guinea
G.poissonianum (Schlechter)	New Caledonia
G.rumphiana (Miq.)	Ambon (Indonesia)
G.sumatranum (Jungh. ex de Vriese)	Indonesia
G.vitiense	Vitu Levu (Fiji)
G.webbianum (Miq.)	New Caledonia

2. CEUTHOSTOMA *

Two species C."terminale", C."palawanensis" N. Borneo, Palawan

This proposed genus has stomates in deep grooves and is therefore unlike Gymnostoma. However, its fruits have the typical simple fruits of Gymnostoma with beck-like valves subtended by a broad bract.

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* Johnson L.A.S. (1985).
Notes on Casuarinaceae III. Telopea (in press).

3. CASUARINA

Young persistent branchlets usually distinguishable from the deciduous branchlets; branchlets 5 to many ribbed, intercostal furrows deep, concealing the stomates; bracteoles of infructescences thin, without any dorsal protuberances; samaras grey or tawny.

Chromosomes 'n' = 9, smaller than in Allocasuarina.

Alphabetic list of species in Casuarina

1.	Casuarina equisetifolia Forst. et Forst. f.	
	subsp. equisetifolia	Coastal Malaysia, Australia, Pacific.
	subsp. incana (Benth.) L.Johnson	Coastal Aust., New Caledonia
2.	C.junghuhniana Miq.	Lombok, East Java, Bali, Sumbawa, Flores
	C."o"	Irian Jaya, Indonesia
	C."t"	Timor, Sumba, Wetar
	C.cunninghamiana Miq.	
	subsp. cunninghamiana	E. Qld., NSW
	subsp. miodon	N.W. Qld. and N.T.
	C.grandis L.Johnson	Papua New Guinea
	C."r"	Philippines
	C.oligodon L.Johnson	
	subsp. oligodon	East Papua New Guinea
	subsp. abbreviata	Irian Jaya (Indonesia)
	C."c"	Celebes
3.	C.collina Poiss. ex Panch. and Seb.	New Caledonia
	C.teres Schlechter	New Caledonia
	C."p"	New Hebrides, Espiritu Santo
	C."e"	New Hebrides
	C.glauca Sieb. ex Spreng.	S. Qld and NSW
	C.obesa Miq.	W.A. (Mainly) NSW, Vic., S.A.
	C.cristata Miq.	
	subsp.cristata	Qld. NSW
	subsp.pauper (F.Muell.) L.Johnson	S.W.Qld., NSW, WA., S.A., Vic.

4. ALLOCASUARINA

Young persistent branchlets usually but not always distinguished from the deciduous branchlets; branchlets 4-13-ribbed, intercostal furrows deep, concealing the stomates as in Casuarina. Male flowers in simple short to long spikes, which in the flowering region are usually distinctly different from the vegetative branchlets. Female inflorescences as in Casuarina. Infructescences ("cones") borne amongst or below the assimilatory branchlets pedunculate or sessile; bracts thin in the exposed portion, not vertically expanded; bracteoles considerably thickened and often divided so that the dorsal portion forms one or more distinct protuberances. Body of samara brown to black.

Chromosomes n = 10, 11, 12, 13 or 14, larger than in Casuarina.

Type species: A.torulosa (Ait.) L. Johnson

About 46 species, chiefly in the southern part of Australia but four species extending to NE. Queensland and one in tropical and subtropical parts of the eremaean region, usually on soils markedly deficient in nutrients.

The name is from the Greek 'allos' = 'other', and Casuarina, which was first used by Rumphius in allusion to the supposed resemblance of the "foliage" of C.equisetifolia to the plumage of the Cassowary, the name of the latter being latinised as Casuarius.

Alphabetic list of species in Allocasuarina

Allocasuarina acuaria (F.Muell.)

A.acutivalvis (F.Muell.)

subsp.pinsepiana (C.Andrews)

A.campestris (Diels)

- subsp. campestris
- subsp.eriochlamys (L.Johnson)
- subsp. grossa (L.Johnson)
- subsp.tessellata (C.A.Gardner)

A.corniculata (F.Muell.)

A.decaisneana (F.Muell.)

A.decussata (Benth)

A.distyla (Vent.)

A.drummondiana (Miq.)

A.fibrosa (C.A.Gardner)

A.fraseriana (Miq.)

A.grevilleoides (Diels)

A.helmsii (Ewert and Gordon)

A.huegliana (Miq.)

A.humilis (Otto'Dietr.)

A.inophloia (F.Muell. and F.M.Bailey)

A.lehmaniana (Miq.)

A.littoralis (Salisb.)
A.luehmannii (R.T.Baker)
A.microstachya (Miq.)
A.monilifera (L.Johnson)
A.muelleriana (Miq.)
A.nana (Sieber ex Spreng)
A.paludosa (Sieber ex Spreng)
A.paradoxa (Macklin)
A.pinaster (C.A.Gardner)
A.pusilla (Macklin)
A.ramosissima (C.A.Gardner)
A.rigida (Miq.)
A.robusta (Macklin)
A.scleroclada (L.Johnson)
A.striata (Macklin)
A.tessellata (C.A.Gardner)
A.thuyoides (Miq.)
A.torulosa (Ait.)
A.trichodon (Miq.)
A.verticillata (Lam.)

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TABLE 3 TYPICAL CASUARINA KEY

Key taken from "The Trees of New South Wales" by R.H.Anderson. (Genera have been altered).

Family Casuarinaceae

1. Casuarina (She Oaks)

a. Teeth at the joints of the branchlets, 9-16 in the whorl
b. Branchlets drooping. Cones 1-2 inches long
A.verticellata (Drooping She Oak)

*b. Branchlets erect. Cones usually less than 1 inch long

c. Cones flattened, much broader than long
A.luehmannii (Bull Oak)
*c. Cones rarely flattened, as long as or longer than broad

d. Cones nearly 1 inch diameter
C.cristata (Belah)
*d. Cones half inch diameter or less
C.glauca (Swamp Oak)

*a. Teeth less than 9 in the whorl

e. Teeth 4 in the whorl
A.torulosa (Forest Oak)
*e. Teeth 6-8 in the whorl

f. Cones about 1/3 inch diameter. Tree found along fresh watercourses
C.cunninghamiana (River Oak)

*f. Cones half inch diameter or more

g. Bark stringy or fibrous
A.inophloia (Stringybark She Oak)
*g. Bark hard and rugged

h. Branchlets and cones downy
C.equisetifolia var incana
*h. Branchlets and cones not downy (widely distributed)
A.littoralis (Black She Oak)

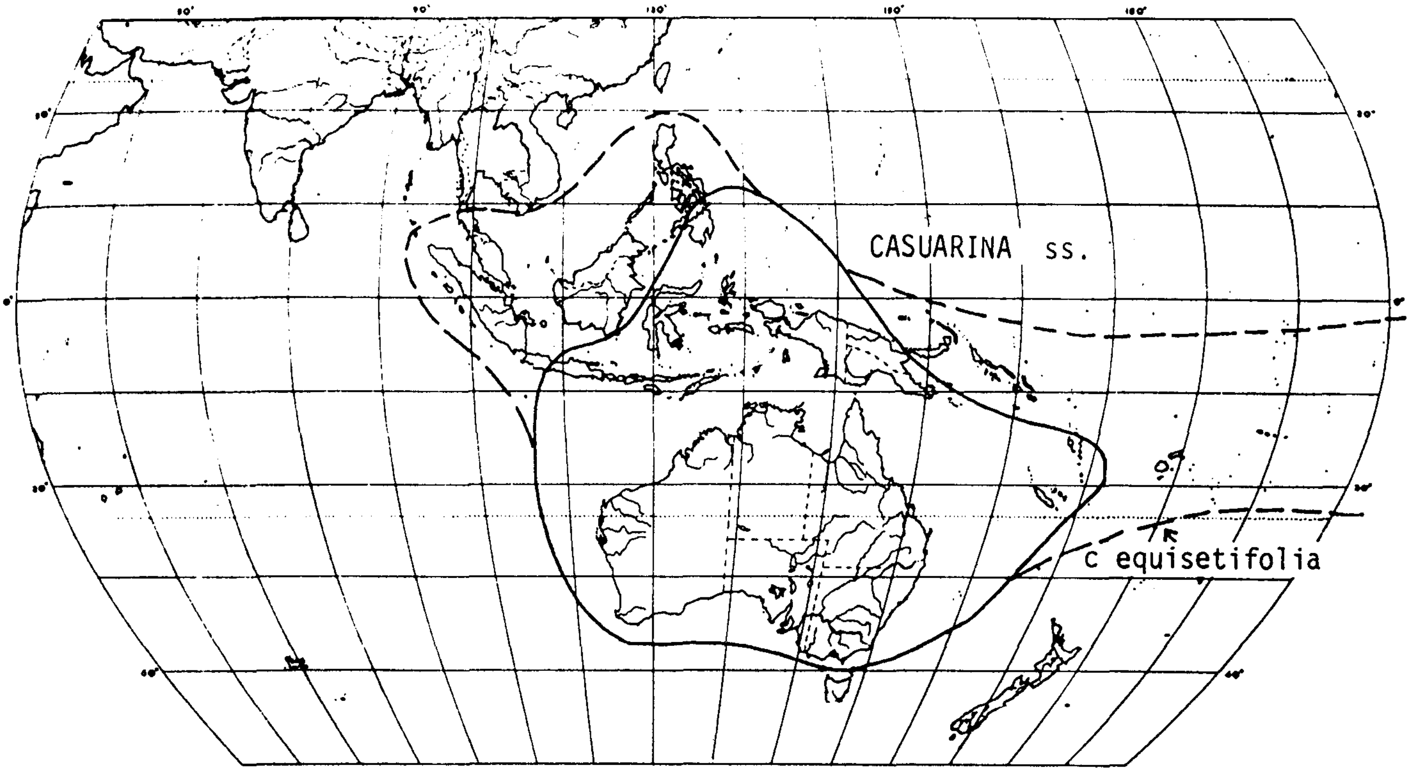


Fig. / Geographical distribution of *Casuarina sensu stricto.*

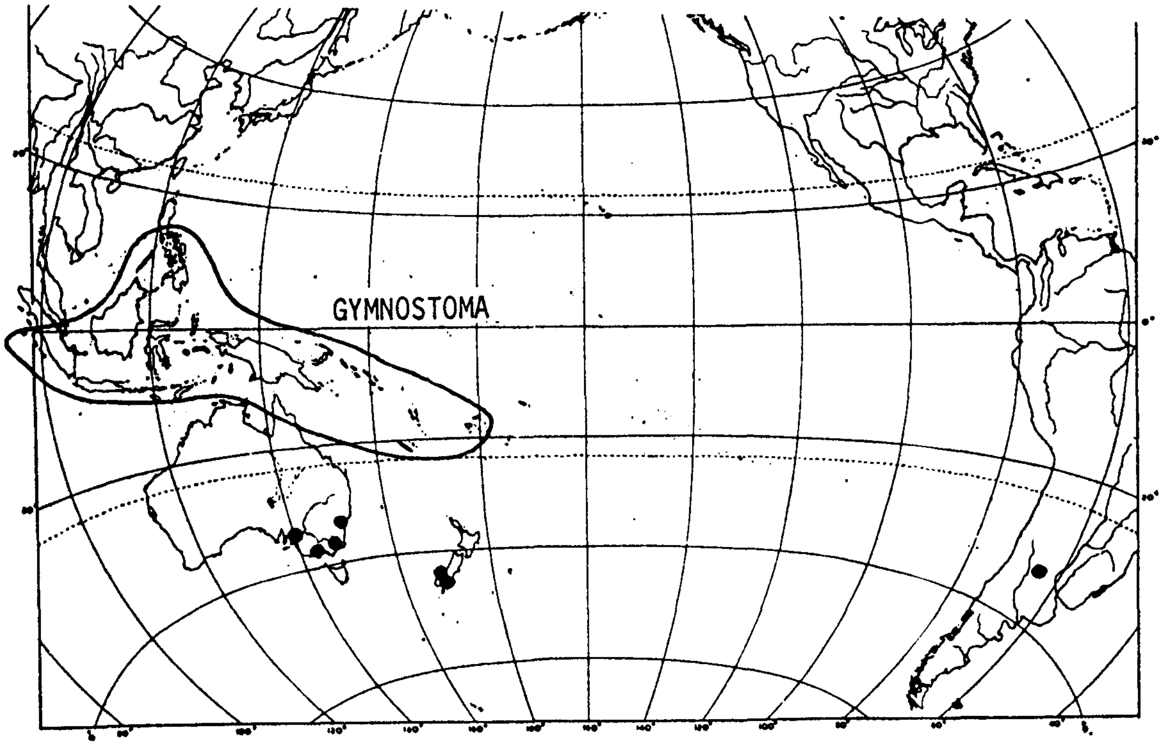


Fig. 2 Geographical distribution of *Gymnostoma* (outlined). Macrofossil sites are shown by ●.

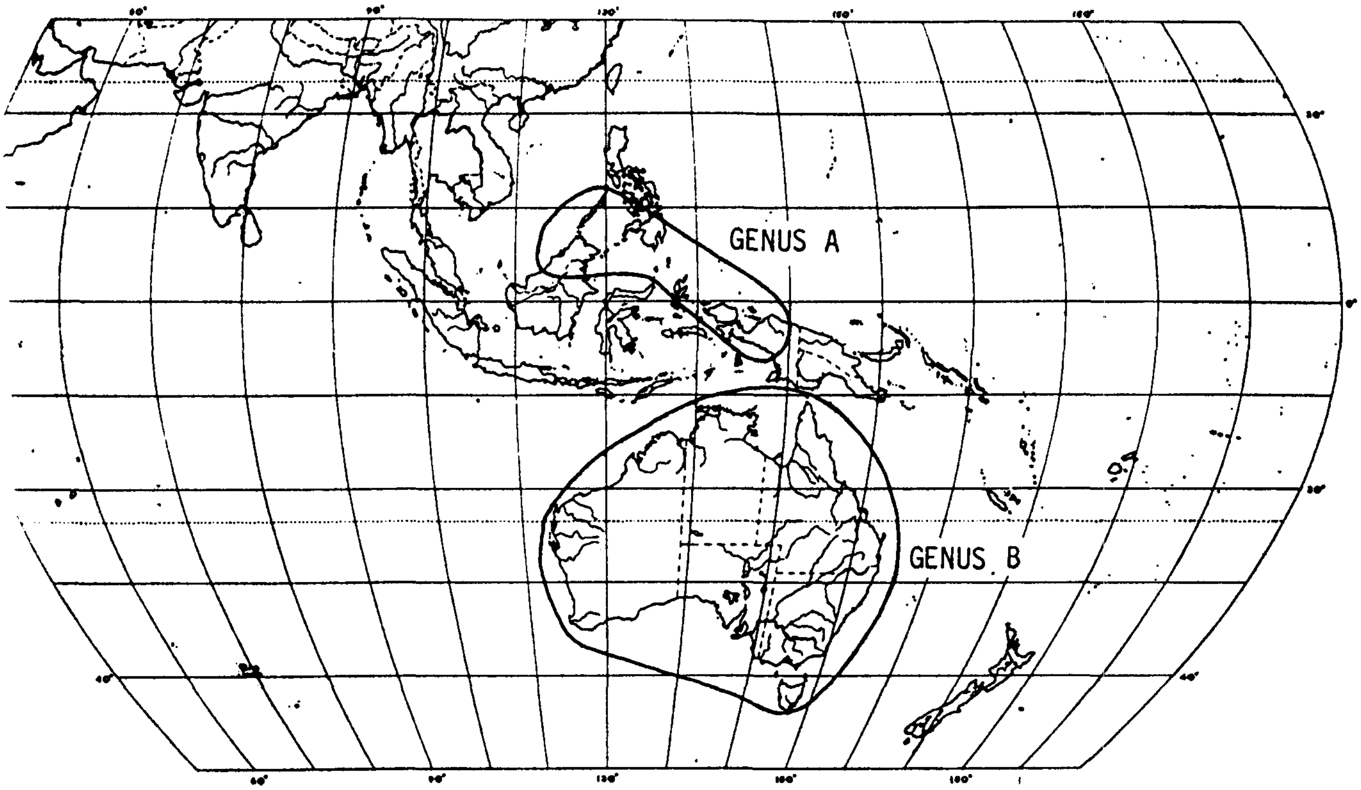


Fig. 3. Geographical distributions of Genus A and Genus B

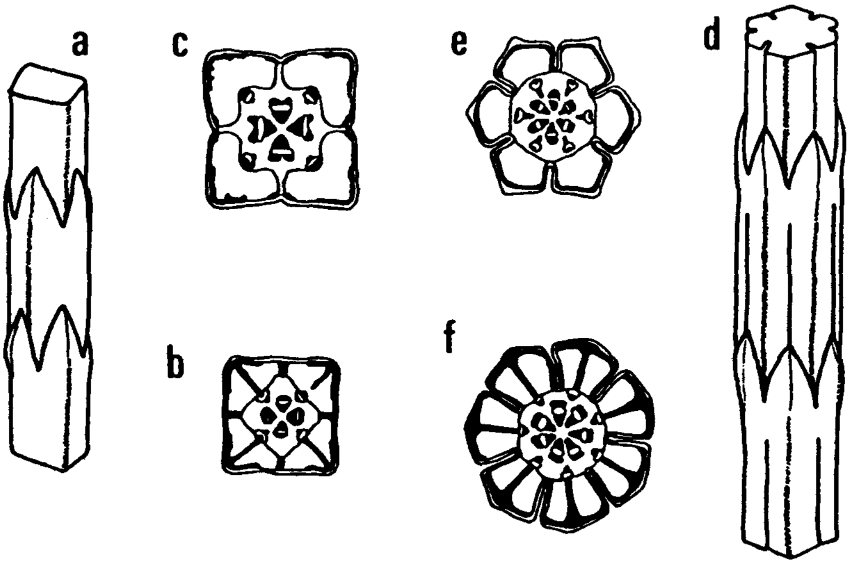
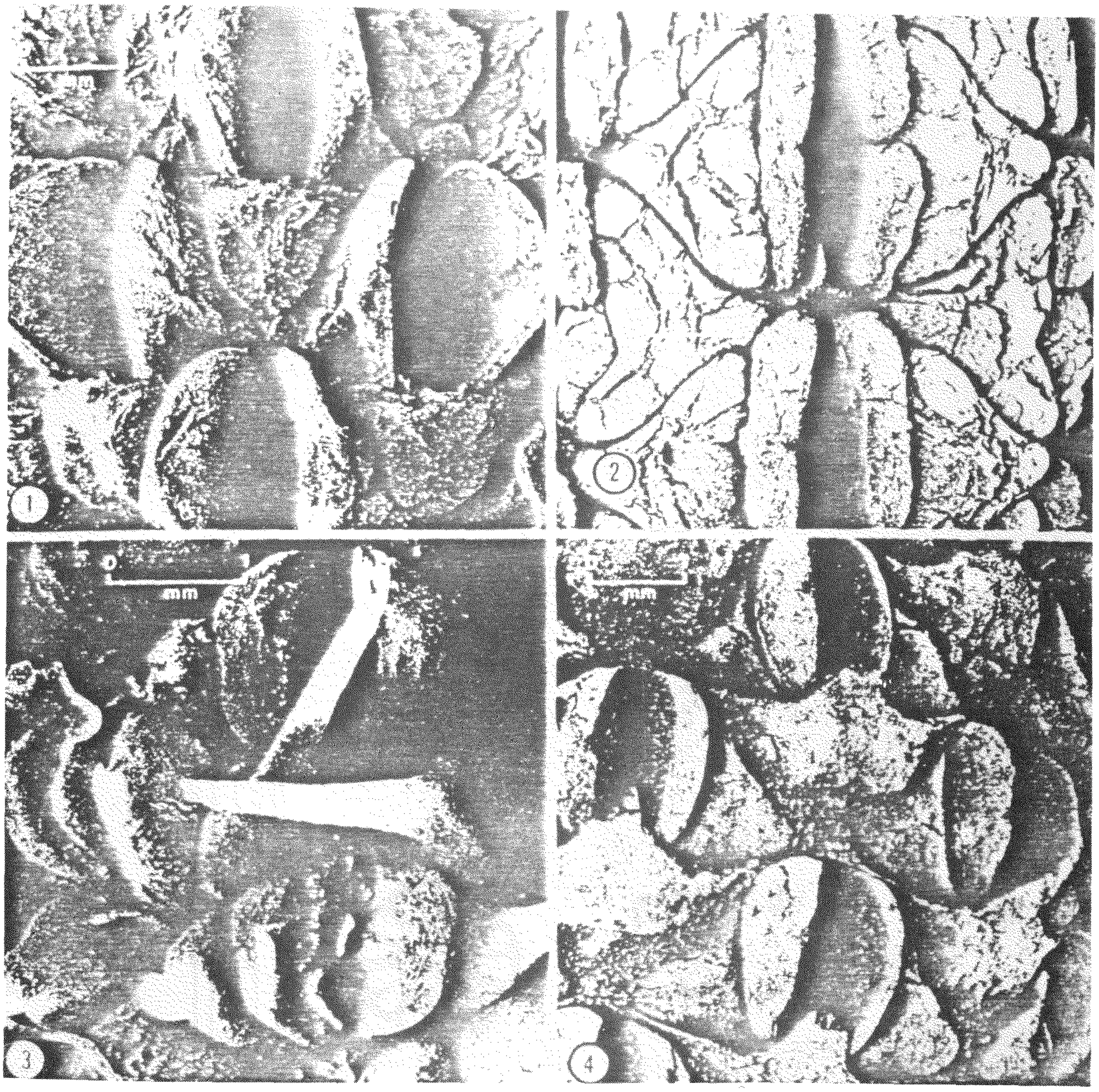


Fig. 4. (a) Branchlet of a member of the genus *Gymnostoma*, × 20; (b) branchlet of a member of the genus *Casuarina*, × 20, (c), (d) branchlet anatomy of two species of *Gymnostoma*, × 40; (e), (f) branchlet anatomy of two species of Genus B × 40.



Casuarinas: (*Ccu*) *Casuarina cunninghamiana* (*Ch*) *Casuarina helmsii*
(*Cco*) *Casuarina corniculatum* (*Cs*) *Casuarina striata*

Photographs of small sections of 'cones' of each of four casuarina species, illustrating the kinds of variation that occur in bract and bracteole characters:
1. (*Ccu*) showing thin bracteoles with no easily discernible surface markings on their outer surfaces 2. (*Ch*) showing bracteoles with tessellations on their outer surfaces: such patterns are very distinctive in some species—the bracts here are relatively thin 3. (*Cco*) showing long sharp spines that have developed as outgrowths on the back of the bracteoles: these spines are sharp and stiff making the 'cones' difficult to handle 4. (*Cs*) showing large and conspicuous trifid bracts: the bracteoles are woody and not prominently marked on their outer surfaces

PRINCIPLES OF FOREST GENETICS

by K.G.Eldridge

Introduction

Forest genetics is an applied science which supports tree breeding. Without the predictions resulting from an understanding of quantitive forest genetics it is difficult to make wise choices between alternative breeding strategies. Since it takes decades, not years, to obtain the benefits from tree breeding, it is important to have good plans; mistakes would take decades to correct, not years.

If an investment is made in a 20,000 ha plantation with unsuitable trees (such as the wrong species, the wrong provenance, or the inbred descendants of a single tree), correcting the mistake not only costs time, it can cost millions of dollars in wasted foreign exchange and loss of production from a proposed pulp and paper industry. Extreme mistakes like this have been made. For a small-scale investment in 200 trees for a village woodlot such mistakes are keenly felt by the people involved. Tree breeding is a serious business.

It would be hard to justify spending as much on tree breeding as on, say, breeding maize or other crops with a very high value per hectare per year. Wood for industrial and domestic use must be cheap and so there are limits as to how expensive the products of tree breeding can be, expressed as price per plant in the nursery.

However, with a combination of biological knowledge and some good luck, several tree breeding projects in various parts of the world employing relatively simple and cheap procedures have already achieved considerable improvement in growth rate and tree form. This is because almost any bioligically sound approach to selection in wild outcrossed species, like forest trees, will result in some improvement. The more knowledge one has of forest genetics, the better the prospects for devising a simple, achievable tree breeding strategy maximizing genetic gain in relation to the time, skill and money invested. Although the seedlings have to be cheap, the thinking and planning behind them may be expensive. Some suggested references include:

1. Allard, R.W. (1960). Principles of plant breeding, Wiley, New York.

   or

or

Brewbaker, J.L. (1964). Agricultural genetics. Prentice-Hall New Jersey.

or

Simmonds, N.W. (1979). Principles of crop improvement. Longman, London. (Read the sections on breeding outcrossing plants, and miss the sections on inbreeding and chromosomes).

2. Zobel, B.J. and Talbert, J.T. (1984). Applied forest tree improvement. Wiley, New York.

   or

   Wright, J.W. (1976). Introduction to forest genetics. Academic Press, New York.

   A person wishing to go further into forest genetics needs to know basic statistics - probability theory, analysis of variance and covariance, regression, and design and analysis of field trials.

3. Falconer, D.S. (1983). Introduction to quantitative genetics. 2nd edition. Longman, London.

4. Namkoong, G. (1979). Introduction to quantitative genetics in forestry. Tech. Bull. No. 1588, Forest Service,USDA, Washington.

   and

   Becker, W.A. (1985). Manual of quantitative genetics. 4th Ed. Academic Ent., Pullman, Washington.

Foresters with responsibility for choosing a good seed source and obtaining supplies of seed do not themselves need to go deeply into forest genetics.

However, some basic principles of forest genetics should be kept in mind when trying to grow better crops of wood. These include:

- the processes of organic evolution;
- recognition of the levels of variability in natural and planted forests;
- the concept of heritability;
- how to estimate genetic gain from selection;
- the benefits from avoiding inbreeding;
- that breeding strategies should be considered in terms of four populations - base population, breeding population, seed production population, wood production population;

- that all four can be combined in multiple populations;
- how it is that mass-selection with open-pollination in seed production areas is successful in improving trees.

Domestication

Foresters growing trees in plantations are bringing wild plants into cultivation and starting to make genetic changes, just as our ancestors did 10,000 years ago with wheat, rice, and other agricultural crop plants. With imaginative application of our present knowledge of genetics we can make large and relatively quick improvements in any one of several traits. Many wild forests have proved to be good seed sources immediately useful for plantations. Even such wild trees can have a harvest index of 100% (the whole tree can be used for fuel) whereas food crop plants have a harvest index of 30 to 40%. The Petford provenance of *Eucalyptus camaldulensis* is a case of an outstanding ready-to-use wild population. There may be many other ready-made cultivars, waiting for discovery and use.

Plantation growers soon notice that some trees in a plantation are better than others. It is this recognition of variations together with dissatisfaction with the growth rate and quality of present plantations which leads to investment in tree breeding.

Tree breeders are at the Neanderthal stage of bringing new wood crop plants into cultivation and changing them genetically to make them more useful by selection. With understanding of the principles of forest genetics and ability to plan ahead, we can expect to be much quicker and more efficient than our ancestors were.

Selection criteria

There are many traits that tree breeders often wish to improve.

However, everyone wants big, straight trees quickly. Some of the other traits considered for selection are thinner, more numerous branches, higher wood density, less splitting of logs, resistance to certain insect pests and fungus diseases, unpalatability of the juvenile leaves within reach of grazing animals, greater palatability and fodder value of the leaves higher on the tree (someone has to climb and cut the foliage to feed to farm animals), greater coppicing ability, higher production of oils, gums, resins or tannin, greater ability to fix nitrogen in root nodules, and higher production of fruit and seed.

If we select for a large number of traits at once, none of them is improved much. It is necessary to decide on the most important traits, perhaps two or three, and concentrate on them. Increased yield of wood is always important because higher yield means less good land is committed to wood production and more is available for food crops.

Processes of evolution

There are five processes of organic evolution

- gene mutation
- changes in chromosome structure and number
- genetic recombination, which results from intercrossing between individuals of the population as well as between them and occasional new genotypes which enter by migration
- natural selection (the 'fittest' individuals produce the most offspring)
- reproductive isolation

The first three provide the genetic variability without which change cannot take place; natural selection and reproductive isolation produce progressive change in the population which keeps it adapted to the changing environment (G.L.Stebbins 1971, Processes of organic evolution, Prentice-Hall).

These processes are acting in natural populations of trees and also in the plantation populations which tree breeders manipulate. Since domestication is only just beginning, tree populations are still genetically very diverse and there is no need yet to promote changes in genes or chromosomes as wheat breeders do. Selection and mating involving genetic recombination are the two basic operations of the tree breeder.

Variability

The great variability of natural populations of fast-growing trees has been carried over into plantations. Look carefully at neighbouring trees in a plantation and you will soon see large and small, crooked and straight, differences in size and shape of leaves, texture of bark, time of flowering, and so on. Variation is the basis of selection. Selection for a trait which is highly variable in a population will lead to genetic gain; no genetic variation - no gain.

Variation which we can see and measure is called phenotypic variation and is the expression of the individual's genotype (its genetic make-up) under the influence of all the factors of the environment during the development of the individual. The phenotypic variation of a population is best illustrated by the familiar bell-shaped curve of the normal distribution, with a mean $\bar{x}$ and standard deviation σ_p (the phenotypic standard deviation of the population). If the trait is tree diameter, a lot of individuals are close to the mean diameter, and only a few are much bigger or much smaller.

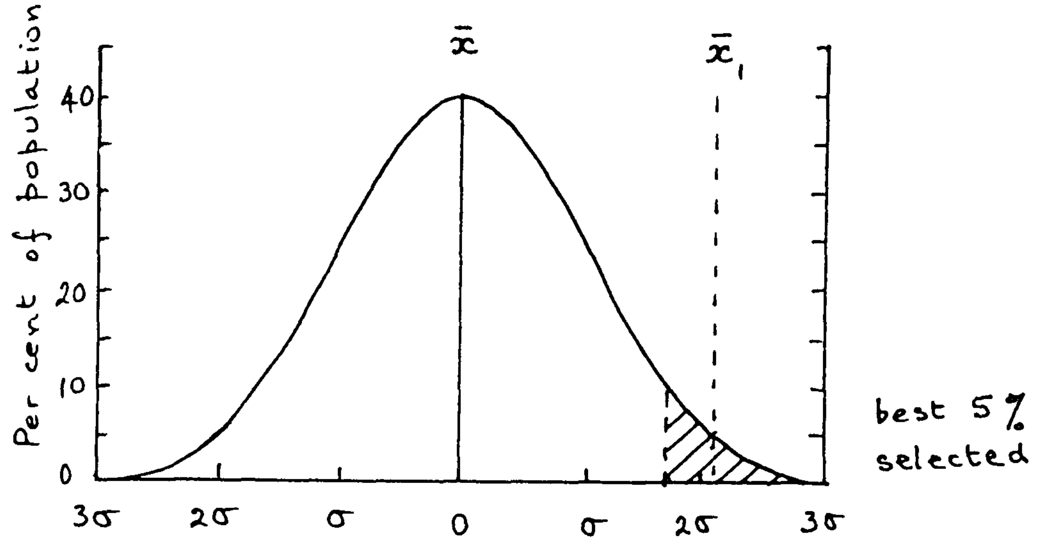


Figure 1.

The variation within a population in a uniform environment is due primarily to different genes being present in the different trees. Some single genes have large effects, like the dominant allele of the gene for no horns in cattle (an example of a non-additive gene), but nearly all the traits tree breeders select for are the result of joint action of many genes.

When the progenies of a large number of trees are grown together in a well-replicated field trial and the data subject to an analysis of variance, it is possible to estimate both phenotypic variance, σ_P^2 (the square of the phenotypic standard deviation) and the additive genetic variance, σ_A^2.

Heritability

Heritability is a measure of how strongly a trait is influenced by genetics and how much by environment. Whether our eyes are brown or blue is entirely determined by inheritance, but whether we grow to be tall is partly determined by how tall our parents were and partly by how well fed we were as children.

Heritability is the statistical expression for the relative contributions of genotype and environment to the phenotype, and is useful in predicting gain from selection. Heritability in the narrow sense (h^2) is the ratio of additive genetic variance (σ_A^2) to the total phenotypic variance (σ_P^2), $h^2 = \sigma_A^2 / \sigma_P^2$. Narrow sense heritability can be estimated either from the variance components (σ_A^2, σ_P^2) of an analysis of variance of progeny data, or from the regression of parental performance on offspring performance. Heritability in the broad sense, used in studies of clones, is the ratio of total genetic variance (additive plus non-additive) to phenotypic variance.

An estimate of heritability only has meaning when several qualifications are stated. These include whether heritability is:

- used in the broad or narrow sense;
- calculated from variance components or parent-offspring regression;
- based on individual values or family means;
- assessed in one or several environments;
- assessed when trees are very young or near rotation age;
- estimated with wide or narrow confidence limits depending on the number of parents, offspring, and replications;
- for a particular population.

It should be emphasized that heritability is only a derivation from the analysis of variance, and the significance of the genetic differences between and within families is of primary interest. If the families do not differ significantly, an estimate of family heritability is not justified.

Selection

Estimates of heritability can be used to predict genetic gain per generation from selection. Genetic gain is the product of three variables, intensity of selection (i) expressed in units, standard deviation, an estimate of the phenotypic standard deviation of the parental value of the trait (σ_P), and an appropriate estimate of heritability (h^2).

$$\text{gain} = i\,\sigma_P h^2$$

Intensity of selection (i) is obtained from tables, for example:

No. trees selected/no. scanned	1/2	1/4	1/5	1/10	1/20	1/50	1/100
(i)	0.80	1.26	1.40	1.76	2.06	2.42	2.64

Variation (σ_P) can sometimes be guessed close enough to make a rough calculation of gain. For example, variation between open-pollinated families in several traits (volume, straightness, etc.) is often about 10 to 20% when expressed as coefficient of variation, i.e. standard deviation of plot means divided by the general mean. Similarly, heritability is often about 0.1 for growth traits and about 0.4 for wood density.

Consider selection of two traits, wood density and tree diameter. Density is expensive to measure and therefore a selection intensity of 1 in 4 (i = 1.26) might be appropriate. Variation in density is not extreme; say for a mean density of 400 Kg m^{-3}, the standard deviation is 40 Kg m^{-3}, i.e. the coefficient of variation is 10% and $\sigma_P = 0.10$. Heritability of density is high ($h^2 = 0.40$ approx.). Genetic gain per generation for density would be:

$$1.26 \times 0.10 \times 0.40 = 5.0\%$$

Diameter is cheap and easy to measure and a selection intensity of 1 in 100 (i = 2.64) might be appropriate. There is considerable variation between trees in diameter, say 20 ± 4cm ($\sigma_P = 0.20$. Heritability of diameter is low ($h^2 = 0.10$ approx.). Genetic gain per generation would be:

$$2.64 \times 0.20 \times 0.10 = 5.3\%$$

Such rough calculations can give the tree breeder an idea of how much gain to expect per generation by simple mass selection with open-pollination, commonly about 5% per generation per trait. Elaborate and expensive procedures of controlled pollination and progeny testing are needed to obtain more than 20% gain per generation trait. (see Figure 2).

Much greater genetic gains, 100% or more in wood volume, have been obtained by wise choice of species or provenance when the previously used species or provenance was unsuitable. Also very large genetic gains have been made by large-scal vegetative propagation of selected outstanding individuals. However, both these spectacular cases were once-only events. Having obtained a well-adapted variety twice as productive as the inferior variety used previously, the next round of selection will produce more modest gains, but repeatable each generation.

The number of traits being selected at one time must be small, otherwise each trait can be selected only at low intensity. For example, assuming 1 tree in 100 is selected for each trait, and they are independent, uncorrelated traits:

1 tree is obtained from 100 trees if selection is for 1 trait
1 tree is obtained from 10 000 trees if selection is for 2 traits
1 tree is obtained from 1 000 000 trees if selection is for 3 traits.

Genetic correlation

If two traits being selected are positively correlated, then fewer than 10 000 trees need be selected to find the 1-in-100 quality in both traits. This would be the case with radiata pine in selecting for both straighter stems and more frequent branch whorls. However, when longer internodes are required and uninodal trees are selected, crooked trees result because of the positive correlation of number of branch whorls and stem straightness. There are a few uninodal, straight radiata pines and these rare 'correlation breakers' might be used directly for vegetative propagation (once we learn how to rejuvenate and make cuttings from mature trees).

There are several other disadvantageous genetic correlations in breeding radiata pine - faster growth and lower density, more branch whorls and more stem cones, uninodallity and slower growth, branch thickness and faster growth.

Genetic correlations can be estimated statistically in suitable progeny tests.

Inbreeding

In an ongoing breeding program that is concerned with genetic gain in both the near future and also many breeding generations from now, it is essential to have an indication of how much inbreeding will result from mating of relatives in the breeding population.

The common fast-growing plantation trees are mostly outcrossing. Casuarinas and poplars certainly are; the male and female flowers are on different trees, resulting in 100% outcrossing. Pine seed is about 95% outcrossed and 5% selfed, eucalypts about 70% outcrossed, and acacias probably also about 70% outcrossed. In the pines and eucalypts, trees resulting from selfing generally grow slowly. The proportion by which they grow slower than trees resulting from outcrossing unrelated individuals is called inbreeding depression (A). Selfed progeny of radiata pine have been found to grow about 27% slower than outcrossed progeny. In a dense plantation with a mixture of selfed and outcrossed progeny, the selfed progeny usually become suppressed and die. It is possible that the amount of inbreeding depression in eucalypts is of similar magnitude to that in radiata pine.

Self-pollinated trees, like Leucaena leucocephala, do not suffer from inbreeding depression. Breeding selfed plants is in some ways easier than outcrossed, but we will concentrate on outcrossed tree crops which are more widely used.

The degree of relationship between mating pairs is called the coefficient of inbreeding (F). With outcrossing of unrelated individuals F = 0 and for selfing F = 0.5. Over 2 or 3 generations the value of F, and thus of A, can increase greatly if the population is founded on a small number of trees (N = 10, see table of inbreeding depression). In this case the genetic gain from selection (say 5%) would be reduced by the genetic loss due to inbreeding depression (about 4.2%). A fairly large base population (N = 30) would allow genetic gain from selection to exceed the small accumulation of inbreeding depression.

The extreme case of starting a plantation scheme with seed from one good tree, as appeart to have been the case with "12 ABL" in the Congo, is completely unsuitable for future selection over several generations.

Table of inbreeding depression

This table shows the average inbreeding coefficient (F) and corresponding percent inbreeding depression (A) in each generation of open-pollinated matings in sublines of constant size N = 50 parents, N = 30, N = 10 and N = 1. Inbreeding depression is calculated first on the basis of a 5.5% decrease in mean performance of the population for each 0.1 increase in F (based on research on Pinus radiata), and then on 10% decrease which may be more appropriate for eucalypts.

Increase in F per generation for open-pollination is taken to be F = 1/1.3 N, approximately. Inbreeding depression is calculated first as A = -0.55(F/0.1), and then as A = -0.10(F/0.1). (Based on P.P. Cotterill, Silvae Genetica, in press).

	N = 50		N = 30		N = 10		N = 1	
	F	A (%)	F	A (%)	F	A (%)	F	A (%)
<u>For A = -(F/0.1) x 0.55 (pines?)</u>								
Generation								
1	0	0	0	0	0	0	0	0
2	.015	-0.8	.026	-1.4	.077	-4.2	.77	-42
3	.030	-1.7	.051	-2.8	.154	-8.2		
4	.045	-2.5	.077	-4.2	.257	-12.7		
10	.154	-8.5	.231	-12.7	.77	-42		
<u>For A = -(F/0.1) x 0.1 (eucalypts ?)</u>								
Generation								
1	0	0	0	0	0	0	0	0
2	.015	-1.5	.026	-2.6	.077	-7.7	.77	-77
3	.030	-3.0	.051	-5.1	.154	-15.4		
4	.045	-4.5	.077	-7.7	.257	-26		
10	.154	-15.4	.231	-23.1	.77	-77		

Breeding strategies

All tree breeding programs must be considered in two aspects: a short-term, operational aspect in which variability is reduced by selection to achieve genetic gain, and a long-term developmental aspect which is essential if selection is to be effective in future, especially to meet new selection criteria. To meet these two requirements it is convenient to arrange tree breeding strategies into four populations for domestication as defined by W.J. Libby (1973, Can. J. For. Res. 3, 265-277).

Genetic base population is in the natural forests, in special gene banks, and to some extent in commercial plantations; it maintains extreme variability for future selection.

Breeding population is used for cross pollinations to recombine genes of the best selected unrelated trees, for testing their progeny and selecting even better trees as parents for the next generation. Future improvements will be made within the breeding population by repeated cycles of crossing, testing and selection, with occasional infusions of genes from the base population.

Seed production population takes the products of the breeding population, the newly selected trees, and mass produces their superior gene combinations either as seeds or by mass vegetative propagation.

Plantation populations are where the benefits of selection are captured. Future plantations and some of the present ones are for wood production only and are not suitable for selection or seed production.

Multiple populations

The concept of multiple populations in tree breeding strategy was suggested by Namkoong, Barnes and Burley (C.F.I., Oxford 1980) and is being implemented in breeding programs for eucalypts and pines in Zimbabwe and elsewhere.

The first three populations described under breeding strategy are combined into one plantation, but the idea of the four distinct functions still applies. Also there are 5 or more separate (multiple) populations.

Consider the example of starting with five promising tropical provenances of *E.camaldulensis*. The multiple population strategy would start with seed collections from 30 to 50 well-separated seed trees in each of the five native provenances. One or more plantations of 10ha or so would be made of each provenance, with no identification of families. Now a reasonably broad genetic base population has been established, scattered over several sites.

Each 10ha plantation is then thinned in stages to a wide spacing for seed production for routine plantations. About 30 of the best seed trees are selected near rotation age (selection intensity about 1/1000 to 1/2000) to provide an improved, but variable, foundation for the next generation. Because several sublines (five provenances) are maintained on different sites, and subject to different natural and artificial selection pressures, a large amount of genetic diversity will be maintained over several generations. Additional genetic gain by crossing between the five provenances can be easily and cheaply arranged in future by making new 10ha plantations with mixed seed from selected trees of the 5 provenances. The only paperwork needed is a periodically revised working plan, a record of the ancestry of each of the special 10ha plantations, and a record of operations.

Mass selection in open-pollinated sublines

Each subline is represented by 15 000 bulked, open-pollinated offspring of 30 selected female parents planted on a site isolated to some extent from other sublines to avoid unwanted cross-pollination. At a suitable stage, say 6 years for E.camaldulensis, the 30 phenotypically most superior individuals for a small number of important traits (say volume and straightness) are selected, and the improved subline is regenerated using bulked seedlings grown from the open-pollinated seed collected from each of the 30 selected trees. However, before seed collection, about 2 years before, the genetic quality of the neighbouring trees (which provide pollen to the 30 selected) is improved by heavy culling. None of the 30 selected trees should be near the edge of the stand where unwanted trees in adjacent plantations might pollinate them.

For traits of high heritability (0.4 or more), this form of mass selection would provide considerable improvement over 2 or 3 generations each of about 6 years. Less improvement would be obtained from low heritability traits. This strategy has been investigated theoretically by P.P. Cotterill (CSIRO Brisbane) and found to compare well in genetic gain per year (but not in genetic gain per generation) against much more elaborate and expensive strategies.

There will be outstanding individuals among the 30 trees selected in each subline of each generation.If skilled staff are available, controlled pollinations could be made between such trees, each parent from a different subline, to produce much improved seed for mass vegetative propagation. Also, more elaborate breeding strategies could develop, if required, out of the broad-based sublines.

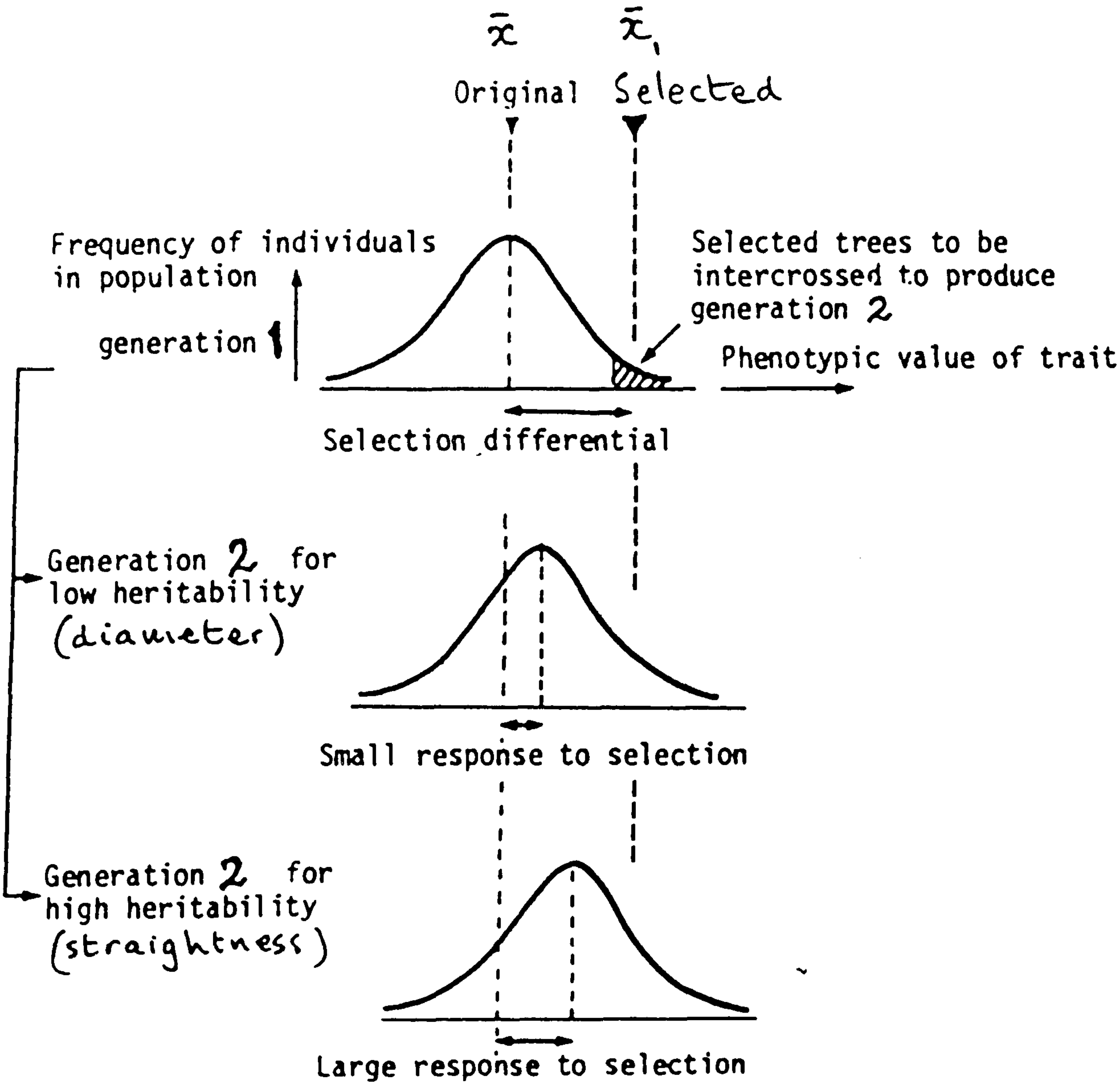


Figure 2.
Results of selection for traits of low and high heritability

MANAGED SEED PRODUCTION: IMPROVED SOURCES

by K.G.Eldridge

Grow your own improved seed

The choice of seed source is one of the very important factors determining profitability of a plantation investment, large or small. It is not wise to obtain the cheapest seed without considering exact origin or genetic history, a common practice in the past. There is always a risk in buying seed from someone else, as several Brazilian companies found to their cost in recent years when imported seed was not up to expectation. The best way to avoid this risk is to GROW YOUR OWN IMPROVED SEED.

The purpose of the following account of managed seed production is to show how to provide a sustained supply of improved seed. The whole account assumes that adequate attention has already been given to finding the best species and provenances for the particular area where plantations are to be established. Even in some of the major plantations of the world, for example *Pinus radiata* in southern Australia, New Zealand and Chile, and *Eucalyptus globulus* in Portugal and Spain, provenance testing started only recently.

There are extensive areas of southern Africa and southeastern Brazil where the Coffs Harbour provenance of *Eucalyptus grandis* is known to be the best. The three examples given here, grafted seed orchards, seedling seed orchards, and seed production areas, are all with that excellent provenance.

Eucalypt breeding system research - what relevance to the forest grower?

The work of tree breeders is aimed at improving the growth rate and quality of the trees by increasing the frequency of desirable individuals, using seed produced by mating selected high quality parents. To achieve this, it is essential to have a good understanding of the flowering biology of each species. For some years scientists have been studying the flowering and seed production biology of eucalypts, particularly *Eucalyptus grandis* and *E.regnans*. The knowledge and understanding they acquire will allow foresters to adopt a number of practical measures for improving the genetic quality of seed to regenerate natural eucalypt forests and establish plantations.

The eucalypts are the dominant trees in 90% of Australia's forests and woodlands and supply about 50% of timber requirements. They are flowering plants or

Angiosperms, and unlike the wind-pollinated conifers, they require animals (insects, birds or mammals) to pollinate the flowers. Each flower produces both pollen and ovules, and experiments have shown that self-pollination will result in seed production. However, if pollination is by another tree (i.e. the plant is outcrossed) then more seed will be produced and the seedlings raised from these seeds will grow more vigorously. Field experiments carried out in Gippsland, Victoria by CSIRO scientists, in collaboration with personnel from A.P.M. Forests Pty Ltd., clearly indicate that seed production should be managed to maximise the proportion of outcrossed seed used by the nurseryman.

Using the technique of isozyme analysis, which allows the parents of particular seed to be identified, we have estimated that in natural eucalypt forest about 75% of the seed produced results from outcrossings. However, trees which are isolated or flower out of phase with surrounding trees may produce only self-fertilized seed.

In a natural stand of Mountain ash (Eucalyptus regnans) a number of trees were cross-pollinated and a number self-pollinated. Open-pollinated (naturally produced) seed was also collected. Seedlings grown from these three seedlots were planted in a randomised mixture which simulated the mix of genotypes in a typical bulk seedlot and their growth rate monitored. After 4 years, the average height of the trees raised from cross-pollinated seed was 10.9m, and that of trees from self-pollinated seed was 9.1m. Trees from open-pollinated seeds were intermediate at 10.1m. An earlier experiment had shown that, by age 13 years, about 70% of trees from self-pollinated seedlots in such a stand were completely suppressed, and many had died. It is important to note that this variation in growth rate is not due to genetic improvement as a result of selection, but solely to manipulation of the type of mating. So it is therefore clear that growers can adopt a number of practical measures for breeding system control, even before they go to the expense of a genetic improvement program.

1. Seed source - natural forest

    a) Collect only from stands of trees following heavy flowering. Particularly avoid isolated trees which may carry heavy, easily collected but genetically undesirable crops of inbred seed. Where contractors are employed for seed collection this prescription must be adequately supervised.

    b) Since inbreeding depression results from matings between relatives as well as selfing, and natural stands often consist of family groups of related trees, seed quality will be enhanced by collecting seed from plantations or direct seeded forest derived from genetically diverse seed. Plans should therefore be made to manage certain stands specifically for seed production. Collection in the natural forests should then be phased out.

2. Seed source - planted trees

a) Avoid collecting from isolated trees or small plantations e.g. wind-breaks.

b) Collect from a number of trees (15+) and bulk the seed. Keep a record of these collections, and avoid collecting from plantations where it is known that the seed was only derived from one or a few parents - otherwise a high proportion of matings between relatives can be expected.

3. Seed source - seed stands or orchards

Where a special seed production plantation is justifiable, then additional steps can be taken to maximise outcrossing:

a) Locate the stand in an environment favourable for regular flowering and for pollinator activity.

b) Design the planting so that each tree has unrelated neighbours.

c) Select parent trees which are matched for flowering time.

d) Encourage pollinators to make flights between different genotypes, e.g. by modified spacing or multi-genotype grafts.

Grafted seed orchards

Near Tzaneen in the north of the Republic of South Africa, two grafted seed orchards of E.grandis have been conducted successfully for some time. Both are on good sites for seed production of this species, though the one at higher elevation, established 1965 on 8 ha, has somewhat lower production due partly to lower temperatures and more rain and cloud. The lower one, at the J.D.M. Keet Forestry Research Station, Zommerkomst, established 1969 on 9 ha, seems to be an ideal site. Average production of seed (as seed plus chaff) after age 4 years from both orchards was 17kg/ha/yr, with a range of 4 to 39kg/ha/yr. This large variation was partly due to some drier years, but mainly to the vigorous attempts to keep the grafts down to a small size by heavy lopping of the crowns every three or four years. For a year or two after lopping no seed is produced. The costs of loss of seed, tying down branches and the lopping itself were thought to be worthwhile to avoid climbing higher and higher each year. The mutilated grafts look like fruit trees and many of them have yielded more than 1kg of seed per year. One orchard contains 1200 grafts and the other 1300, about 16 grafts from each of 78 plus-trees. The spacing is 8.5 x 8.5m. Further details are in a paper by van Wyk and Hodgson (1983).

Like the grafted seed orchards of other trees in other countries, the design of the two South African orchards of E.grandis is based on the simple and much copied procedures developed for pine and spruce in Scandinavia in the 1940s. Outstanding trees (plus-trees) are selected at high intensity in plantations, grafted onto seedling stock, planted in an area somewhat isolated from unwanted pollen of the same species, and managed for maximum seed production. As with other types of tree seed production it is far more important to choose a site on which the species will seed abundantly than to rely on fertilizing, irrigation and other techniques to improve a poor site. Spectacular blunders have been made with various species by unintentionally putting seed orchards on sites where no seed is produced. The site must also have good road access, be suitable for tractors and trucks to drive over it at any time of the year, and be not too far from the supervisor's office (so he or she will visit it frequently). Fortunately, learning from our predecessors' successes and mistakes, we can now choose good sites for seed orchards of the major forest species.

Open-pollinated seedling seed orchards

A cheaper form of seed orchard, with a smaller potential for genetic gain per generation, can be made with open-pollinated seed collected from plus trees selected as for grafted seed orchards. Instead of making expensive grafts 100 or more seedlings are raised from each plus tree and planted in random mixture, as are the grafts in a grafted seed orchard. If the family identity is maintained by labelling and mapping the trees, the poorer families can be culled out after a few years and before the start of major seed production.

Seedling seed orchards are planted at a close spacing, commonly about the same as routine plantations, and they must be thinned early and heavily both to promote seed production and to obtain genetic gain. Selecting and culling the poorer trees within families achieves substantial genetic gain only for traits of high heritability (h^2 greater than about 0.4). For low heritability traits like growth (h^2 less than about 0.2), genetic gain requires selection and culling of whole families, and hence the expense of labelling and mapping.

Seedling seed orchards with families identified are not easy to manage because a balance has to be made between (a) the need to grow the trees close together under normal plantation competition for several years to choose the best families and best individuals within families and (b) the need to thin early enough and heavily enough to maintain a deep crown unshaded by neighbours for good seed production.

In southern Florida, U.S.A., a very successful program of seedling seed orchards of E.grandis was conducted over four generations of selection by George Meskimen (1983). In the first generation of selection the best trees were located in 1961 in several species and provenance trials and their progeny were raised in a plantation which provided both parents for the next generation of selection and a widely spaced stand (10/ha) for commercial seed production. A more elaborate planting was made in 1973 after Carlyle Franklin joined the program. The 1973 grandis population (G.POP.73) of 296 families was planted at 1500/ha as a single-tree plot progeny test of 14 195 seedlings. The test was assessed at 2.4 years for survival (frost was the main problem), height, and diameter, and culled to only 50/ha at 2.9 years. Seed collected at age 4 years from these selected trees became part of the next cycle, the 1977 grandis population (G.POP.77).

Of the 534 families in G.POP.77, 28% were new selections from Australia and elsewhere (1st generation), 40% were from mother trees selected in Florida tests (2nd generation), 24% from Florida grandmothers (3rd generation), and 9% from Florida great-grandmothers (4th generation).

This breeding strategy combines provenance trial, a broad genetic base population, progeny test, and seed orchard. Only 10 trees/ha are left to function as a seed orchard. Capsules are harvested by hand from a travel-tower on a truck and the trees are cut back to 15m. With 30m between trees, self-fertilization may be high enough to reduce genetic gain. Even with that unknown level of loss from selfing, genetic gain is still high and seed yield is good.

After three generations of selection, genetic gain in wood production was nearly threefold, survival of frost improved more than threefold, and stem straightness and branching quality were greatly improved (Franklin and Meskimen 1983).

The success of the E.grandis breeding program in Florida was largely due to the short generation intervals of 4 years, intense selection of both families and individuals within families, and, as in other successful breeding, the perseverance and competence of the staff. The gain in frost resistance was partly true resistance and partly faster growth so crowns were above the coldest layer of air.

Seed production areas

Heavy and early thinning of a suitable stand of the best provenance can produce an improved source of seed relatively cheaply and quickly. Theoretical genetic studies by Paul Cotteril (CSIRO, Brisbane) and by Shelbourne (1969) have shown that a well-planned seed production area program established on a broad genetic base can be a very efficient breeding strategy over several generations of selection. Further economic study is needed to show whether this strategy is the most cost-effective, expressed as dollars gained per year for dollars spent, appropriately discounted.

In the state of Sao Paulo in Brazil, there is a very successful seed production area conducted by Champion Papel e Celulose S.A. In 1967 Prof. Lindsay Pryor of the Australian National University visited the Company and formed the opinion that the eucalypt seed used for planting there since 1958 was unsuitable. The plantations were not producing as much wood as the land was capable of, the seed was a mixture of species,(originating 2 or 3 generations back in the Rio Claro arboretum; Gurgel and Cavalcanti 1978), and was a poor basis for future selection. He recommended a fresh start with seed from botanically pure E.grandis from the vicinity of Coffs Harbour, New South Wales. Subsequent trials confirmed that Coffs Harbour is the best provenance region for the main area of E.grandis plantations in several countries.

A considerable quantity of seed was soon collected under the supervision of an experienced professional forester. The collection was made by a forest foreman and several forest workers in the Bellingen and Bonville areas just south of Coffs Harbour. The young trees selected in natural regrowth as having sufficient seed for felling were of reasonable form as they had to be good enough to sell as case logs (for packing cases) or saw logs. Because of the requirements of seed quantity and acceptable log quality, the trees were some distance apart, probably 50 to 100m. From the memory of some of the people involved in the collection, but unfortunately without detailed written records, it appears that the first collection in March 1968 was about 10kg, a minimum of about 100g per tree, and from between 20 and 50 trees (Eldridge 1981).

Champion planted more than 250ha at 1600/ha with this seed near Mogi Guacu, and Duratex a similar amount, in December 1968 and January 1969. After 7.5 years' growth, the trees had an average height of 25m, diameter 14cm and an annual increment of total solid volume of approximately $35m^3$/ha. Plus trees selected at this time by Champion and Duratex were 30m tall and 27cm diameter.

Thinning was carried out at age 4 years in four areas of 25ha each in the Champion plantations leaving 30% of the original stocking. An isolation strip 500m wide of plantation of the same seed source was left around each area. At 7 1/2 years they were thinned again to 160 trees per hectare, 10% of the original stocking. Seed collection in 1976 yielded 6.5kg/ha. The climbers used spurs and harvested most of the fruit on 30% of the trees in the whole area each year by cutting off small branches with a knife on a pole. Trees were climbed every third year, allowing crowns and fruit crops to recover. The foresters managing the project preferred to leave a large number of trees fairly close together to minimize selfing, and considered that climbing was not excessively dangerous or expensive, and that seed yield was satisfactory.

A study by Zani and Kageyama (1984) showed that the average yield of seed (seed plus chaff) was 12kg/ha/yr over 64ha during 6 years of collection. Since 1981 the Champion seed production area has been divided into four compartments and all the trees in a compartment climbed and branches lopped for seed collection, the next compartment next year, and so on. This 4 year cycle allows much better pollination than the previous regime. Once the trees have recovered from lopping, nearly all neighbouring trees come into flower together. The result is more effective pollination, more seed per tree, and an increase in number of viable seed/kg to 900 000 compared with 700 000 under the old regime. It appears that 15 to 20kg/ha/yr will be the regular yield from the Champion seed production area in future, a similar yield to the grafted seed orchards in South Africa.

Multiple populations

If several seed production areas are established each with open-pollinated seed from 30 or so selected trees of the best provenance, or provenances, a long-term strategy can be developed avoiding inbreeding depression, and achieving considerable genetic gain per generation and per year. The key to rapid gain is turning over the generations rapidly as Meskimen and Franklin did with *E.grandis* in Florida (a 4 year cycle). The operations for this strategy are relatively cheap as controlled pollination is not required, nor is identification and mapping of plants in a progeny test. After several generations the separate sublines could be mixed and a new start made with the resulting outcrossed progeny, again in several separate lines. This strategy was commenced for a number of species in Zimbabwe in 1980, and is receiving serious consideration in several other countries.

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Appendices

APPENDIX 1. List of Participants

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David Gwaze, Research Forester - F.R.C.; Workshop Secretary

Ms. Sally Bleakley, Tree Breeding Technician, F.R.C.; Workshop Secretary

Martin Armour, Deputy Director, Zimbabwe Forestry Commission, Harare

James Sinclair, Chairman, Z.F.C.; Harare

Ralph Cant, Research Forester, F.R.C.; Participant

Benjamin Munyamba, Forest Ranger, F.R.C.; Participant

John Wiltshire,Projects Co-ordinator, Zimbabwe Forestry Commission, Harare

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Gert Rode, Senior Forest Research Officer, German Agency for Technical Co-operation (G.T.Z.), P.O.Box 41607, Nairobi, Kenya

APPENDIX 2. Workshop Agenda

REGIONAL SEED CENTRE WORKSHOP
ON THE
TAXONOMY AND SEED HANDLING OF AUSTRALIAN FOREST TREES IN EAST AFRICA

Forest Research Centre, Harare, Zimbabwe: 8-12 July, 1985

Workshop Chairman:	Dr. R.D.Ayling, Program Officer, Forest Sciences, IDRC, Nairobi.
Workshop Secretary:	Mr. D.P.Gwaze, Research Officer, Forest Research Centre, Harare.
Workshop P.R.O.:	Miss Sally Bleakley, Forest Research Centre, Harare.
ACIAR speakers:	Mr. D.J.Boland, CSIRO Division of Forest Research, Canberra. Mr. M.I.H.Brooker, CSIRO Division of Forest Research, Perth. Dr. K.G.Eldridge, CSIRO Division of Forest Research, Canberra.

AGENDA

SUNDAY, 7 JULY

1800 - 1930	Icebreaker at Jameson Hotel (Campbell Room)

MONDAY, 8 JULY

0800	Buses depart Jameson Hotel for conference centre.
0830 - 0900	WELCOME TO PARTICIPANTS (Workshop Chairman) OPENING ADDRESS (Mr. J.M.Sinclair, Chairman of the Forestry Commission, Zimbabwe).
0900 - 1200	COUNTRY REPORTS - Australian tree species in African plantations: existing role and potential.
0900 - 0920	Ethiopia
0920 - 0940	Kenya
0940 - 1000	Malawi
1000 - 1045	Tea/coffee break
1045 - 1100	Swaziland
1100 - 1115	Tanzania
1115 - 1130	Uganda
1130 - 1145	Zambia
1145 - 1200	Zimbabwe
1210	Buses depart for Jameson Hotel.

1230 - 1330	Lunch at Jameson Hotel
1345	Buses depart for conference centre.
1400 - 1515	PRINCIPLES OF SPECIES SELECTION (D.J.Boland)
1515 - 1535	Tea/coffee break
1535 - 1630	Video - "Curious and Diverse Flora of Australia"
1630 - 1700	Inspection of new Regional Seed Centre building site and some of the equipment that has been obtained for it (hopefully building operations will be well advanced by the time of the workshop). (Dr. R.D.Ayling and B.R.T. Seward)
1705	Buses return to Jameson Hotel.

TUESDAY, 9 JULY

0800	Buses depart for conference centre.
0830 - 1000	SEED COLLECTION TECHNIQUES (D.J.Boland, B.R.T.Seward) Film - "In a Nutshell" Video - "Seed Extraction of Acacias"
1000 - 1020	Tea/coffee break
1020 - 1200	Demonstration of seed collection equipment. (R.T.Cant, D.P.Gwaze)
1200 - 1300	Lunch at conference centre.
1300 - 1440	SEED STORAGE AND TESTING (D.J.Boland, B.R.T.Seward) Video - "Towards 2000" Video - "French work on Eucalyptus"
1440 - 1500	Tea/coffee break
1500 - 1530	AN OVERVIEW OF THE TAXONOMY OF AUSTRALIAN ACACIAS (M.I.H.Brooker)
1530 - 1630	Practical use of seed processing equipment (B.R.T.Seward)
1645	Buses return to Jameson Hotel.

WEDNESDAY, 10 JULY

0800	Buses depart for conference centre.
0830 - 0945	PRINCIPLES OF FOREST GENETICS (Dr.K.G.Eldridge)
0945 - 1000	Tea/coffee break
1000 - 1200	Visit to seed testing laboratories, Department of Research and Specialist Services.
1200 - 1345	Lunch at Red Fox Hotel.
1400	Buses depart for conference centre.
1415 - 1530	MANAGED SEED PRODUCTION - IMPROVED SOURCES (Dr.K.G.Eldridge)
1530 - 1550	Tea/coffee break

1550 - 1605	Eucalypt Resource Conservation Stands in Zimbabwe (B.R.T.Seward and L.J.Mullin)
1605 - 1630	Some thoughts on the certification of eucalypt stands for seed collection (D.J.Boland and M.I.H.Brooker).
1645	Buses return to Jameson Hotel.

THURSDAY, 11 JULY

0800	Buses depart for conference centre.
(0830 - 1010)	COUNTRY REPORTS - Promising indigenous tree species for planting.
0830 - 0845	Ethiopia
0845 - 0900	Kenya
0900 - 0910	Malawi
0910 - 0920	Mozambique
0920 - 0930	Swaziland
0930 - 0940	Tanzania
0940 - 0950	Uganda
0950 - 1000	Zambia
1000 - 1010	Zimbabwe
1010 - 1030	Tea/coffee break
1030 - 1100	TAXONOMY OF AUSTRALIAN BI-PINNATE ACACIAS - SECTION BOTRYCEPHALAE (D.J.Boland)
1100 - 1230	EUCALYPT TAXONOMY (M.I.H.Brooker) - Australian perspective - Overseas situation
1230 - 1330	Lunch at conference centre.
1330 - 1400	TAXONOMY OF CASUARINA (D.J.Boland)
1400 -1515	Field examination of eucalypts and casuarinas at the Forest Research Centre.
1515 - 1535	Tea/coffee break
1535 - 1615	Summing up (Dr.R.D.Ayling)
1625	Buses return to Jameson Hotel.
1815	Buses depart for Red Fox Hotel.
1830 - 2030	Informal social function at Red Fox Hotel.
2040	Buses return to Jameson Hotel.

FRIDAY, 12 JULY

0700	Buses depart for field day on identification of eucalypts at Mtao Forest.
1600	Buses leave Mtao for Harare.

Appendix 3

Australian Species in African Plantations

Country Reports *

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* No report available from Mozambique

AUSTRALIAN SPECIES IN ETHIOPIA

by Ms. H. Ibrahim

Ethiopia lies in East Africa where the longitudinal range is from 33°E to 48°E and the latitudinal range is from 3°N to 18°N. Although the entire country lies within the tropics, only the lowlands have a hot climate; on the highlands of the plateaus the nearness of the equator is counterbalanced by the elevation of the land producing moderate conditions. The high mountains are characterized by a cold, alpine climate. In Ethiopia places located at different latitudes and similar altitudes tend to have the same annual temperatures.

Regarding the amount of rainfall, all highlands in the south-west and above the elevation of about 1 000 m.a.s.l. receive an annual rainfall of between 1 400 and 2 200mm. Rainfall decreases in all directions from the south-western highlands but is modified by elevation. Highlands over 2 500m receive between 1 400 and 1 800mm annual rainfall; those which lie between 600 and 2 500m receive 1 000 and 1 400mm. Rainfall decreases to less than 200mm along the coast, in the Danakil depression, the lower Awash Basin and in Eastern Ogaden.

There are five climatic regions, each associated with distinct types of native vegetation or climax phase communities. This relationship is summarized in Table 1.

Table 1.

Relationships with Vegetation and Altitude

(Elevation in metres)

	Arid	Semi-arid	Dry subhumid	Moist subhumid	Humid
Steppe	Below 300	-	-	-	-
Open woodland	300-1100	Below 500	-	-	-
Savanna	1100-1400	500-1100	300-700	-	-
Deciduous woodlands	-	1100-1500	700-1200	600-1000	-
Evergreen woodlands	-	1500-1700	1200-1600	1000-1400	1400-1600
Lowland Forest	-	-	1600-1700	1400-1600	Below 1600

	Arid	Semi-arid	Dry subhumid	Moist subhumid	Humid
Highland Forest	-	-	1700-2300	1600-2400	1600-2500
Mountain Woodland	-	-	2300-2600	2400-2800	2500-3000
Mountain savanna	-	-	2600-3100	2800-3600	-
Alpine	-	-	Over 3100	-	-

Existing Role and Potential of Australian Tree Species in Ethiopia Plantations

The first Australian tree species were introduced in 1895 to solve the problem of the severe shortage of fuelwood and poles around the capital city, Addis Ababa. Mondonvidallet, a French philologist, is credited with the introduction of 15 eucalypt and acacia species. These included Eucalyptus amygdalina, E.bicolor, E.camaldulensis, E.cladocalyx, E.cornuta, E.diversicolor, E.globulus, E.leucoxylon, E.melliodora, E.patens, E.resinifera, E.rudis, E.salubris and E.tereticornis. Of these species, E.globulus has done remarkably well and has been extensively planted about towns and villages on the western plateau. At lower elevations, E.camaldulensis plays a similar role.

Eucalyptus globulus is an extremely adaptable species which grows well on a variety of soils and in a variety of climates. In Ethiopia it succeeds everywhere in the Highlands, and does best at altitudes from 1800-2600m on loamy soils. It is not successful in the hot lowlands and in depressions. On calcareous soils establishment is more difficult and the plants require more cultivation. Stands established from seedlings may grow within 8-10 years to a height of 10-15m and a diameter of 15cm. Volumes produced on average in such plantations are 350m^3 per hectare. After cutting, the stands are allowed to coppice, usually on a rotation of 5-7 years. This species is used mainly for building poles, fencing posts, tool handles, telegraph posts and wood fuel. It is also grown for logs for the production of plywood veneer and, to a lesser extent, for sawn timber.

Eucalyptus camaldulensis grows well over a wide range of soils in rainfalls varying from 550 to 2 200mm and is more suited to lower elevations. Stands of this species are planted about towns in the Rift valley and in the wetter areas to the south-west. It is also planted along river banks and on alluvial flats where it is capable of withstanding floods. The growth rate is slower than that of *Eucalyptus globulus* but it is also used for telegraph posts, piles and bridge building.

The next large-scale introduction of species was made between 1956 and 1961 when trial plots and an arboretum were established. The introduction included 35 eucalypts, 2 acacias and 2 casuarinas. Following this, the Forestry Research Section of the Chilalo Agricultural Development Unit aided by the Swedish International Development Agency began trials in 1967 introducing 24 eucalypts. By 1975 further trials had been established in 3 different areas with 18 eucalypts with 2 or more provenances, 1 acacia and 3 casuarinas (all species are listed in Appendix I).

Most of the introduced species are obviously well adapted to the climatic and edaphic features of the country. Data on growth rates at different sites are shown in Appendix II. Among the species examined the following show good growth and are promising for future plantations:

Acacia decurrens
A.melanoxylon
A.mollissima
Casuarina equisetifolia
Eucalyptus camaldulensis
E.citriodora
E.cladocalyx
E.deanei
E.delegatensis
E.fastigata
E.globulus
E.grandis
E.maculata
E.maidenii
E.nitens
E.obliqua
E.regnans
E.robusta
E.saligna
E.viminalis
Grevillea robusta

The demand for forest products is increasing because of increases in population and in the standard of living. Consequently, larger and larger proportions of the forest areas are devoted to intensively managed fast-growing species of eucalypts, acacias and casuarinas. Between 1974/75 and 1983/84 increasing areas of Australian species were planted for fuelwood, poles and pulp and paper on 200 000ha of which 130 000ha were peasant wood lots and 70 000ha government plantations. Regions where eucalypts are planted may be divided into the four climatic zones shown in Table 2.

Table 2

Planting Zones of Ethiopia

Zone	Elevation (m)	Mean annual rainfall (mm)
Moist montane	1750-3000	1000-2000 +
Dry montane	1750-3000	450-1000
Moist highland	1000-1750	1000-1800
Dry highland	1000-1750	600-1000

Main soil types are:

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

b) Black or dark brown clays and clay-loam 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 some extent on calcareous soils.

The utilization of eucalypts has increased rapidly. Between 1978/79 and 1983/84, fuelwood was approximately 860 000m^3, for construction 191 000m^3 and 200 000m^3 for transmission poles.

The potential of eucalypt plantations is immense. For fuelwood, 35 000ha was allocated to be planted around Addis-Ababa in the coming 10 years; for pulp and paper an appropriate site was chosen and since 1980 a total area of 260ha has been planted. The major species planted for pulp and paper are Eucalyptus dalrympleana, E.deanei and E.viminalis.

Forest destruction due to fire, clearing for agriculture, grazing, cutting for fuelwood and other causes expose the soil to sun, wind and rain over large areas of the country. To control these, acacias and casuarinas were planted as windbreaks, shade and shelter, and for soil improvement and erosion control.

Appendix I

Introduced Australian Species

Eucalypts

Eucalyptus alba
" amygdalina
" bicolor
" bicostata
" bosistoana
" botryoides
" brockwayi
" camaldulensis
" citriodora
" cladocalyx
" cloeziana
" cornuta
" crebra
" dalrympleana
" deanei
" delegatensis
" dives
" diversicolor
" dundasii
" dunnii
" fastigata
" ficifolia
" globulus
" gomphocephala
" grandis
" gunnii

E.johnstoni
E.largiflorens
E.leucoxylon
E.maculata
E.maidenii
E.melliodora
E.microcorys
E.microtheca
E.nitens
E.obliqua
E.occidentalis
E.paniculata
E.patens
E.pauciflora
E.pilularis
E.regnans
E.resinifera
E.robusta
E.rudis
E.saligna
E.salmonophloia
E.salubris
E.sargentii
E.sideroxylon
E.tereticornis
E.torelliana
E.viminalis
E.wandoo

Acacias

Acacia cyanophylla
A.decurrens
A.melanoxylon
A.pycnantha

Casuarinas

Casuarina equisetifolia
C.cunninghamiana
C.stricta

Appendix II

Growth Rates at Different Sites

Assela

Soil type: Acidic (ph 5.6)
Elevation: 2450 - 2500m
Mean annual rainfall: 1200mm

Species	age (year)	mean height (m)	Dbh (cm)	mai (H) m	mai (Dbh) cm
E.deanei	8	14.75	13.10	1.84	1.64
E.delegatsensis	14	17.69	18.47	1.26	1.32
E.dalrympleana	8	15.17	14.24	1.9	1.79

Munessa forest

Soil type: well-drained forest soils and swampy grasslands with black claysoils
Elevation: 2000 - 2350m
Mean annual rainfall: 1040mm

Species	age (year)	mean height (m)	Dbh (cm)	mai (H) m	mai (Dbh) cm
E.grandis	9	23.4	17	2.6	1.89

Alemaya College of Agriculture

Soil type: alkaline (ph 7.8)
Elevation: 2070m
Mean annual rainfall: 855mm

Species	age (year)	mean height (m)	Dbh (cm)	mai (H) m	mai (Dbh) cm
E.cladocalyx	11	18	25	1.6	2.3
E.citriodora	11	12	18	1.1	1.6
E.camaldulensis	11	12	20	1.1	1.8
E.globulus	11	15	30	1.4	2.7
E.grandis	11	25	30	2.3	2.7
E.robusta	11	11	15	1.0	1.4
E.saligna	11	25	28	2.3	2.7
E.tereticornis	11	21	22	1.9	2.0

Holleta Agricultural Experiment Station

Soil type:	acidic
Elevation:	2400m
Mean annual rainfall:	1100mm

Species	age (year)	mean height (m)	Dbh (cm)	mai (H) m	mai (Dbh) cm
E.globulus	24	37	33.4	1.5	1.4

Menagesha

Soil type:	acidic soil (ph 6.0)
Elevation:	2400m
Mean annual rainfall:	100mm

Species	age (year)	mean height (M)	Dbh (cm)	mai (H) m	mai (Dbh) cm
Acacia melanoxylon	5.25	9	8.49	1. 71	1.62
A.mollisima	5.25	13	10.9	2.48	1.94
E.camaldulensis	"	13	9.47	2.48	1.8
(106590)					
E.globulus	"	20	11.84	3.08	2.26
(1075)					
(11171)	"	18	12.25	3.43	2.33
E.grandis (11319)	"	17	10.04	3.24	1.91
E.maculata					
(11181)	"	11	9.51	2.1	1.81
(10728)	"	8	9.3	1.52	1.77
E.obliqua					
(11295)	"	19	10.94	3.62	2.08
E.regnans(10967)	"	15	10.29	2.85	1.96
E.saligna(1100)	"	8	7	1.52	1.33
(11248)	"	14	10.23	2.67	1.95
(10994)	"	13	10.17	2.48	1.95
E.viminalis					
(11175)	"	15	10.41	2.86	1.98
(1120)	"	13	9.57	2.48	1.62
Grevillea robusta	"	8	5.76	1.52	1.1

Shashemene

Soil type: acidic
Elevation: 1890m
Mean annual rainfall: 97mm

Species	age (year)	mean height (m)	Dbh (cm)	mai (H) m	mai (Dbh) cm
A.melanoxylon	5.3	16	12.03	3.06	2.27
A.mollissima	4	18	12.8	3.36	2.42
E.globulus(1075)	"	26	15.64	4.91	2.95
(11171)	"	27	15.7	5.09	2.96
E.grandis(11319)	"	20	13.7	3.77	2.58
E.maculata(11181)	"	15	12.6	2.83	2.38
E.obliqua(11295)	"	22	16.21	4.15	3.06
E.saligna(1100)	"	14	19	2.64	3.58
(11248)	"	22	14.7	4.15	2.77
E.viminalis(11175)	"	21	14.4	3.96	2.72
(1120)	"	19	13.6	3.6	2.56
Grevillea robusta	"	10	9	1.48	1.7

Belete

Soil type: acidic (5.7 - 6.0)
Elevation: 2000m
Mean annual rainfall: 1550mm

Species	age (year)	mean height (m)	Dbh (cm)	mai (H) m	mai (Dbh) cm
A.melanoxylon	5.8	15	12.31	2.59	2.12
A.mollissima	"	22	14.75	3.79	2.54
E.camaldulensis (10659)	"	20	12.28	3.45	2.11
E.globulus(1075)	"	24	14	4.14	2.41
(11171)	"	28	13.85	4.82	2.39
E.grandis (11319)	"	28	16.91	4.83	2.92
E.maculata(11181)	"	17	14.06	2.93	2.42
(10728)	"	20	13.39	3.55	2.34
E.obliqua(11295)	"	17	12.33	2.93	2.13
E.regnans(10967)	"	22	17.78	3.79	3.07
(762)	"	24	16.22	4.14	2.78

Belete (continued)

Species	age (year)	mean height (m)	Dbh (cm)	mai (H) m	mai (Dbh) cm
E.saligna (1100)	5.8	26	16.41	4.48	2.83
(11248)	"	29	17.84	5.00	3.08
(10994)	"	31	16.59	5.34	2.86
E.viminalis					
(11175)	"	25	15.65	4.3	2.7
(1120)	"	25	16.22	4.3	2.8
Grevillea robusta	"	12	8.88	2.07	1.53

AUSTRALIAN SPECIES IN KENYAN PLANTATIONS

by P. Oballa and D. K. Musya

Kenya has a total area of 582646 km^2 of which 11200km^2 is water surface. It is divided by the equator and has a latitudinal range from 4^o north to 4^o south. The country displays a wide range of sites and climates from the snow-capped peak of Mount Kenya (5 199 m.a.s.l.), the humid tropical coast, and the harsh arid areas of the north. Rainfall varies from 220mm in the semi-desert areas to 2 300mm or more in the highlands. This variation in climate and relief is reflected in the vegetation. It is within these different ecological regions that several Australian tree species have been planted in localities that if not similar, can be likened to their area of origin.

Existing role

Australian species were introduced at the beginning of this century and at present they occupy more than 39 000 hectares. About 150 species of Australian origin are found in Kenya. These include species of Eucalyptus, Acacia, Grevillea, and a few other less planted genera (1). About 130 species of eucalypts have been introduced into the country (2), out of which only a few species have been established in plantations. A larger number still exists in arboreta, experimental plots or as ornamentals where their performance is being studied.

Eucalyptus saligna is the most widely planted species and it is mainly used for domestic and industrial fuelwood. The plantations were established in 1903 to provide firewood for railway transport. Management of the fuelwood plantations was through coppice where cutting was undertaken every 10 years until the stumps began to deteriorate at age 30. With the decline in the use of fuelwood for locomotives in 1948, plantation management was directed to the production of power and telecommunication poles (3). Of the total area of 12 000 hectares planted to eucalypts, E.saligna covers an area of 4 000 hectares. The other widely-planted species of eucalypts include E.grandis, E.microcorys, E.paniculata, and E.crebra. Eucalyptus globulus was widely-planted but leaf damage by Gonipterus scuteliatus has led to plantings of it being reduced.

At present most of the eucalypt produce is used for power and communication poles, posts for domestic construction, and firewood. In the industrial sector, increasing amounts of E.microcorys is being utilized by the Pan African Pulp Mill for pulp and paper production. E.regnans is used for fibre board and plywood. Owing to an increase in population, there has been a greater demand for more agricultural land. This pressure has resulted in the development of marginal lands for afforestation. It is these drier regions that E.camaldulensis and E.tereticornis have proved to be more successful than other species.

Other industrial uses of eucalypts include fuel for the processing of tobacco, coffee and tea.

Apart from eucalypts, about 30 Australian acacias have been introduced, the most common being Acacia mearnsii. The species was originally introduced as a source of fuel for railway transport and later became important for tannin extract from its bark. Due to economic reasons, the species has lost that importance to other agricultural activities that have shorter rotations. This has caused the area planted to decrease from 36 000ha in 1957 to about 12 000ha in 1983 (6,7). The East African Tannin Extract Company (EATEC) is the major grower of this species and in addition to tannin they produce charcoal, poles for domestic construction, and firewood. Experiments are under way to utilize the fibre residue of the extraction process as mulch for mushroom culture.

A.melanoxylon covers about 200 hectares and is used for making furniture. Other acacias such as A.aneura and A.mangium are in trials in dry zones and humid coastal areas.

Other Australian genera include Agathis, Angophora, Araucaria, Brachychiton, Callistemon, Callitris, Casuarina, Grevillea, Leptospermum, Macadamia, Syncarpia and Tristania (1). Macadamia intergrifolia is grown on farms for its nuts in Central Province and Western Kenya. The nuts are mainly processed for export.

Grevillea robusta plantation covers about 300ha. Its timber is primarily used for furniture, but the major use of Grevillea robusta is on farms as boundary plantings and windbreaks.

The Casuarinas are represented by three main species, C.cunninghamiana, *C.equisetifolia* and *C.montana*. *C.cunninghamiana* is planted in pilot plantations in both the highlands and coastal areas. *C.equisetifolia* has become naturalized along coastal sands. Its poles are straight and durable and are very much valued for domestic construction. The species has been successfully used to rehabilitate waste lands at the Bamburi Cement Factory near Mombasa.

At the demonstration centre for agroforestry at Machakos, started by International Council for Research in Agroforestry (ICRAF), seven species of Australian origin are included, namely: *Acacia saligna*, *A.holosericea*, *A.victoriae*, *Atriplex nummularia*, *Cassia sturtii*, *Casuarina equisetifolia* and *Grevillea robusta*. (4) These woody components of agroforestry systems fix nitrogen, produce dry season fodder and compete minimumly with agricultural crops.

Potential of Australian species in Kenya

Little has been done on the selection and improvement of the existing Australian tree species. This has been attributed to such factors as lack of suitable base population in some species for selection, shortage in seed supply to continue species and provenance trials, improper identification of some species (it is believed that the Kenyan strain of *Eucalyptus saligna* is either a hybrid of *E.grandis* or is *E.grandis*) and inadequate number of researchers.

Most of the Australian species in their homeland are grown to produce sawn timber of different applications. They are also the source of raw material for pulp and paper making (5). In Kenya some species have been successfully established and have replaced most indigenous species, but due to lack of proper technology to process the produce, the industrial uses have been limited. The introduction of the right technology will help to improve the present situation, so that these species can serve as alternatives to indigenous species.

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AUSTRALIAN SPECIES IN MALAWI

by E.Kananji and M.Chamba

Malawi's land area is 94 276 sq km, and the estimated population is 6.5 million people, growing at an average rate of 2.6% per annum. The population comprises 92% rural dwellers and 8% urban residents. It lies between 9°45'S and I7°35'S latitudes, or latitudinal range of only about eight degrees.

Although a small country, the topography is so varied and the altitudinal range so wide that climatic conditions are complex with many gradations between dry and wet and between hot and cold. The mean annual rainfall ranges from less than 820mm to over 2050mm with wide fluctuations from year to year. The rainy season lasts from November to March which is also the warmest part of the year. Rainfall is light and humidity low in other months.

The soil types include the acidic latosols of freely drained sites on gently sloping plains, the weakly acidic to weakly alkaline calcimorphic soils which are waterlogged for all or part of the year, lithosols which are shallow or stony and regosols which are immature soils developed from sands.

The country is divided into 11 principal silvicultural zones, based mainly on climate.

Background

Among the Australian species in this country such as Grevillia robusta, Acacia species and Eucalyptus it is the Eucalyptus species which are most important and have a proper record of earliest introductions.

The first recorded introduction of a species of eucalypt by the Scientific Department was in 1898, and that was E.pilularis. However, some relics of E.globulus and E.citriodora around Blantyre may have been planted when Blantyre Mission was established in 1875 (Anon. 1958). It is suspected that during the same period E.grandis was planted near the prison stone quarry, E.saligna near the mountain road on the way up the plateau while E.camaldulensis on the golf course, all in Zomba.

The bulk of Malawi's forest reserves were created primarily for catchment protection purposes. Therefore, most are located in upland and hill areas and along the rift valley scarps. The distribution of the population and the demand for forest products led to timber and pole production being concentrated around Blantyre, Zomba and Dedza.

The demand for forest produce in rural areas, until then, 1970, was met from indigenous forests. However, the ever-increasing permanence of settlement, the development of industrial agriculture (principally tobacco) and opening up of large agricultural schemes created demand for forest products which could not be met from the rapidly dwindling indigenous forest.

A bias towards Australian species, mainly *Eucalypts* started in the late sixties when small plot species trials were established at Chisasira and Mazamba and included *Eucalyptus grandis*, *E.robusta*, *E.camaldulensis*, *E.saligna*, *E.deglupta*, *E.tereticornis*, *E.citriodora*, *E.maculata*, *E.cloeziana*. These small trials gave an impression of how much potential these eucalypts had. *E.grandis* and *E.camaldulensis* were singled out as good for high altitudes, more rainfall areas and lower altitudes, drier areas respectively (Anon 1976). Similar results were reported by Nkaonja (1978) for the Lilongwe area.

From 1966 to 1976, eucalypts trial areas covered only 64 hectares.

No trials for *Acacia*, *Casuarina* or *Grevillia robusta* were recorded. *Grevillia robusta* present was for tea shade in the tea estates while the casuarinas were for mainly amenity reasons.

Present Situation

Following from these earlier results, the interest in Australian species increased tremendously. The arrival of Pryor of Australia in 1976 added more weight to the need to test more Australian species and provenances for Malawi's varied climate. As a result, by 1983 research trials on eucalypts occupied a total area of 4943.36 hectares. Three large trials were prominent. The Viphya Forest Industrial Trials (VFIT) at Chintheche were set up to investigate suitable species and provenances that were adaptable to the area with the purpose of providing fuelwood and mixed pulp for a proposed Pulp and Paper Mill. Next was the trial in Kasungu to find suitable and adaptable species and provenances that could provide fuelwood for tobacco curing purposes at the Kasungu Flue Cured Tobacco Authority.

At VFIT, promising species appeared to be *E.pellita*, *E.tereticornis* and

E.camaldulensis for the drier sites, while *E.grandis* remained superior for the wetter sites. As regards trials at Kasungu, *E.tereticornis*, *E.camaldulensis* from the northern territory and *E.punctata* were the promising species with *E.camaldulensis* being very exacting on soil types and soil depth (Ingram 1984)

The third large research project in the period was the fuelwood and polewood project sponsored by IDRC and geared toward the rural population of Malawi. The aim of the project was to obtain basic information on afforestation in the dry silvicultural zones of limited rainfall (600-1 000mm) and a dry season of six to eight months duration. The importance of this project can be seen in the light of 90% of the country's population in the dry zones. Of the Australian species tried, the best adapted and most productive were *E.camaldulensis* (excluding the Matchbox Creek provenance) and *E.tereticornis* followed by *Melia azedarach*, *E.maidenii*, *E.pellita* and *E. grandis* which grew best on hydromorphic soils (Nkaonja 1985). *Acacia mangium* also showed promise in several areas in the north (Nkaonja 1984). However, *Acacia pilotica*, *A. compylacantha* and *A.tortilis* which are bushy and thorny were poorest in performance but showed best potential as hedge plants. The *Acacias* were however, not represented at all sites, therefore there is scope for more research.

This increase in research activities on Australian species has been reflected by a complementary increase in rural and urban afforestation of eucalypts to a record high of 23 359.17 hectares excluding private estate and individual plantations, for the purpose of providing fuelwood and polewood for both urban and rural dwellers. Out of Malawi's total land area of 9 427 600ha, 0.25% of it is covered with *Eucalyptus* species.

Seed Orchards and Seed Services

Presently Malawi is self-sufficient in seeds of *E.grandis* from seedling seed orchards. Seed stands of *E.camaldulensis* and *E.tereticornis* have been established and will be ready to provide seed by 1987. *E.pellita* seed stands in the northern part of the country already provide sufficient seeds to meet the national requirements.

Attempts are being made to establish seed orchards of *Grevillia robusta*.

The Forestry Research Institute of Malawi, based in Zomba, has a seed collection team which uses equipment such as ladders and tree bicycles in seed collection work.

The Institute also carries out seed viability tests of eucalypts using the Jacobsen germination tank in the laboratory augmented by open nursery tests. Seed storage is done in a $27m^3$ coldroom at temperatures between 10^oC and 5^oC for all seed types.

Role

Woodfuel is the dominant source of energy in Malawi and this accounts for 98% of jobs by the rural dwellers and for 84-94% of the urban household tasks. Taking all wood-users in Malawi's economy, in 1983 wood energy constituted 85% of the total primary energy consumed in the country, followed by agricultural crop residues (6%), petroleum products (5%), hydroelectric power (3%) and coal (1%).

By 1983, the demand for woodfuel had grown steadily, reaching approximately 9 million m^3 solid wood which was consumed by the four categories of wood users as shown in Table 1 below.

Table 1 Consumption (%) By Wood Users

WOOD USER	CONSUMPTION		REMARKS
	m^3 (solid) millions	% of total effective demand	
Households	5.1	56.7	For cooking, fish smoking, construction
Urban	1.3	14.4	Cooking, charcoal, building, house construction.
Tobacco Industry	2.0	22.2	Shade construction, tobacco curing.
Other Industries	0.5		Brick-making, beer brewing, lime making pottery, tea processing, peeler logs

Knowing that 0.25% of Malawi's total land area is covered with Eucalyptus species planted by the Government, the role played by the Australian species cannot be over emphasised.

Potential Future

In 1983, the fuelwood supply was 7.0 million m^3 of solid wood, and the sources were the natural woodlands on customary land, the gazetted forest reserves and the plantations. The aggregate biomass mean annual increments from the existing natural forest and woodlands are $0.8m^3$/ha/year on customary land, $1.2m^3$/ha/year in gazetted forest reserves, and $10-15m^3$/ha/year from plantations and $8-10m^3$/ha/year from woodlots. The current demand for fuelwood exceeds the sustained supply by 2-3 million m^3/year and the consequences of deforestation are becoming apparent. The decline in sustained woodfuel supplies began in 1977 and has gone on annually ever since.

It would appear therefore that Australian species will still have great potential for the future of this country, in particular for the supply of fuelwood and polewood to the rural people. The substitution of plantation-grown eucalypts for indigenous species for charcoal making for urban dwellers will relieve the pressure on indigenous forests to a considerable extent.

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AUSTRALIAN TREE SPECIES IN SWAZILAND PLANTATIONS

by Gideon M.Dlamini

Existing Role and Potential

The Kingdom of Swaziland has an area of 17 365 sq km and is divided into four distinct topographical areas. These areas, from east to west are: the Lubombo Plateau with an area of 1 320 sq km, rainfall of 625-1000mm a year, altitude of 200-500m and a subtropical climate; the Lowveld with an area of 6 415 sq km, rainfall of 500-750mm a year, altitude of 200-700m, a slope of 3% and a near tropical climate; the Middleveld of 4 590 sq km, rainfall of 750-1 125mm a year and altitude of 700-1 300m and a gradient of 12%; and the Highveld of 5 030 sq km, rainfall of 1125-2250mm a year, an altitude of 1 300-1850m, a slope of 18% (although areas of 50% slope are common), and a temperate climate.

Commercial forests are concentrated in the Highveld and comprise about ninety (90) privately owned plantations totalling one hundred and one thousand (101 000) hectares. However, only four plantations are large (more than 1 000ha each) and of these, two take up 72% of commercial forest areas.

Most commercial forests are softwood (mainly pine) while 26% are *Eucalyptus* and *Acacia*.

Seeds are obtained from South Africa.

The role of Australian species in Swaziland is:

a) wood and wood products
b) *Eucalyptus* oil
c) tannin extract
d) soil stabilization

(A) Sources of Wood and Wood Products

Eucalyptus grandis and *E.saligna* (21 565ha) are used for poles, pulpwood, sawlogs and firewood, the products grown on 13 690, 3565, 1 110, 270 and 80ha respectively. Other species (*E.cloeziana*, *E.smithii*) are used for poles, mining timber and firewood.

Acacia species A.decurrens, A.mearnsii, are used for timber (720ha), fuelwood (510ha) and poles (90ha).

(B) Sources of Tannin Extract

A.mearnsii supplies tannin and bark is exported to South Africa where the tannin is extracted.

(C) Sources of Eucalyptus Oil

The leaves of E. smithii are used in the manufacturing of Eucalyptus oil. About 1 000kg of leaves gives 30-35 litres of oil (one hectare produces 210 litres).

The oil is used in sweets, medicines and in paint-remover. In 1982 approximately sixty metric tonnes of Eucalyptus oil were produced, 10 m-tonnes sold to the Republic of South Africa and the rest exported to other countries (Australia, Europe).

(D) Job Suppliers

In times of high unemployment, one appreciates the role of forests in supplying jobs to several hundreds of people. About 6 000 people are employed in forest and forest industries in Swaziland, making up 20% of the work force of the private sector.

(E) Sources of Income

In 1982 approximately USD 125 000 was earned from the sale of Eucalyptus oil. Charcoal production was approximately 7 260kg and earned USD400. A total of USD 2.7 x 10^6 was earned from roundwood production.

(F) Erosion Control

Overgrazing and wild fires are a serious problem in the country and there are advantages to the growing of trees.

Future Plans

The forestry section of the Ministry of Agriculture is working on a management program to improve Acacia production from six to more than fifteen tonnes of bark per hectare. This will necessitate establishing a tannin extracting factory and will provide jobs and tannin extract for export or local use.

EUCALYPTS IN TANZANIA

by S.S.Madoffe and I.M.Shehaghilo

Fuelwood accounts for 94% of the total energy used in Tanzania including energy for commercial purposes and about 98% of the population rely upon fuelwood as their source of domestic energy (Openshaw, 1978). The current fuelwood consumption is estimated at 35 million m^3 and is expected to rise to about 62 million m^3 by year 2000 when the population will have almost doubled, 35,7 million people (Mnzava,1983). Natural forests from which most of the wood is collected, can only supply about 19 million m^3. Thus, there is a supply-demand gap of almost 16 million m^3. Forests are substantially over-exploited and because of this, fuelwood collection is becoming a formidable task. In semi-arid areas, time spent to obtain fuelwood per household may be as much as 250-300 mandays per year (Mnzava, 1980).

Production from natural forests and exotic plantations

The projected wood demand can hardly be met from the natural forests because most of them take a long time to regenerate after harvesting. In savanna areas, the production is of the order 2-4m^3/ha/yr while in the high rain forests it is between 5-10m^3/ha/yr. Thus there are good reasons for establishing plantations of exotic tree species in Tanzania. This was noted as early as the German colonial rule in Tanganyika 1891-1914. Several advantages are associated with exotic plantations, the most important being the possibility of high yield of volume. Production figures of the order 15-25m^3/ha/yr can be achieved on good sites while on better sites the production can go up to 35m^3/ha/yr. Therefore with plantations of fast growing exotic tree species, the country should be able to meet fuelwood demand.

Eucalypts in Tanzania

The date of the first eucalypt plantings in Tanzania is rather obscure. German foresters reported at the beginning of this century that they saw old trees near coastal towns which had been planted by Arabs. From the year 1893, Germans planted various *Eucalyptus* species in different parts of Tanzania, including *E.camaldulensis*, *E.globulus*, *E.robusta*, *E.saligna*, *E.viminalis* etc. (Borota, 1969).

Tanzania has more than 80 *Eucalyptus* species (Lushoto arboretum alone has 65) from the coastal areas to the highlands. It is difficult to estimate the area covered by this genus, however research plots 0.25ha to 10ha are estimated to total 160ha (Mathias, 1984). Eucalyptus species and provenance research has covered at least all the soils and climatic conditions (500mm rainfall/year and above) of Tanzania and the results have been evaluated by Borota, 1969, Borota and Persson, 1971, Mushi, 1978 and 1981 and Madoffe, 1984.

Those eucalypts which have high forestry potential have been included in a village afforestation programme, most of them thrive in a variety of soils and tolerate prolonged dry seasons. They grow well, coppice readily and seed regularly with good germination capacity. Seedlings are easily raised in the nursery, hence costs are low, ideal conditions for village afforestation purposes.

Seed supply

Seed demand for various afforestation purposes is covered by local collections and by importation. Local seeds are collected from seed orchards, and unregisted seed sources such as trees in forest plantations or woodlots. Collection guidelines are set by the seed section of the Silviculture Research Centre and the collection is organized by the research staff in outstations, forest project managers and regional and district forest officers. Successful collection involves proper knowledge of the species, seed source, and the best time and method for seed collection.

There are no registered Eucalyptus seed stands. The bulk of seed is not pure, due to possible hybridization. Occasionally incorrect species or provenances have been supplied by seed brokers. The need to obtain quality seed is a challenge to researchers. Tanzania, in collaboration with DANIDA (Denmark) has initiated two Eucalyptus seed stands at Kwamarukanga and Tabora to increase the quality and quantity of the seed crop.

The species here are provenance conservation stands of E.camaldulensis at Urumwa and E.tereticornis and E.camaldulensis at Kwamarukanga. The Kwamarukanga trial is part of the gazetted Korogwe Forest Reserve (about 800ha) along the Tanga-Moshi main road about 400km from Dar-es-Salaam. The trial is located at $5^{o}12'$S, $38^{o}29'$E and 305 m.a.s.l. Mean annual rainfall is about 1070mm, falling mainly from November to May. Temperatures range from 23^{o}C in July to 28^{o}C in March. The land is gently undulating and the soil is a heavy clay loam. The previous vegetation was predominantly Miombo woodland.

The Urumwa site is located in Urumwa Forest Reserve about 18km from Tabora at $5^o08'S$ and $32^o45'E$ and 1220 m.a.s.l. Mean annual rainfall is about 1066mm, falling mainly from November to April but in some years, rainfall is erratic. The land is flat and the soil is red sandy loam. The vegetation prior to clearing was Miombo woodland.

Both trials were established in 1981, however about 80% of the Urumwa trial was accidentally burnt and replanted in March, 1985. Buffering and isolation are taken care of in these trials to minimize hybridization. Species and provenances are given in Table 1.

Table 1 Eucalyptus provenances used in experiments at Kwamarukanga and Urumwa.

Locality	Species	Batch No.	Origin	Area (ha)	Site Description
Kwamarukanga	E.tereticornis	S 12944	Helenvale QLD Australia	8.0	Lat $15^{o}46'$S,Long $145^{o}14'$E Alt 120 m.a.s.l.
		S 12189	Mt Garnet QLD Australia	8.0	Lat $18^{o}30'$S, Long $144^{o}45'$E Alt 875 m.a.s.l.
	E.camaldulensis	12181	Katherine NT Australia	8.0	Lat $14^{o}30'$S, Long $132^{o}15'$E Alt 110 m.a.s.l.
Urumwa	E.camadulensis	12186	Petford QLD Australia	8.0	Lat $17^{o}20'$S, Long $144^{o}58'$E Alt 460 m.a.s.l.

Other trials for seed collection

These are mainly planted for purposes other than seed production but they might be given intensive management for early production of seed. Table 2 lists the species

Table 2 Eucalyptus species by climatic zones (suggested) for seed collection.

Locality	Species	Altitude (m)	Rainfall (mm)
Lushoto	E.saligna E.maidenii E.botryoides E.grandis E.citriodora E.microcorys	1450	1060

Locality	Species	Altitude (m)	Rainfall (mm)
Olmotonyi	*E.saligna* *E.maidenii* *E.regnans* *E.citriodora* *E.globulus* *E.microcorys* *E.grandis* *E.maculata* *E.paniculata*	1610	970
Kihanga	*E.saligna* *E.viminalis* *E.maidenii* *E.globulus* *E.paniculata* *E.cloeziana* *E.macarthurii*	1830	1077
Kawetire	*E.saligna* *E.citriodora* *E.globulus* *E.macarthurii*	2250	1652
Kiwira	*E.macarthurii*	1660	2151
Kwamarukanga	*E.citriodora* *E.tereticornis* *E.camaldulensis*	350	997
Mbulu	*E.regnans* *E.paniculata* *E.maculata*	1260	950
Geita	*E.citriodora* *E.paniculata*	1280	982

Locality	Species	Altitude (m)	Rainfall (mm)
Rongai	E.maculata E.cloeziana	2012	914
Malya	E.camaldulensis E.microtheca E.alba E.melanophloia	1250	805
Singida	E.camaldulensis E.microtheca E.tereticornis	1500	661
Tabora	E.camaldulensis	1219	889
Dodoma	E.camaldulensis E.microtheca E.papuana E.tereticornis E.alba E.melanophloia	1120	568
Ruvu	E.alba E.camaldulensis E.tereticornis E.grandis E.robusta E.melliodora E.paniculata	90	1140

Future plans

The need for species diversification in our afforestation programmes, high cost of importing seeds and delays in procuring seeds call for efforts in establishing seed stands. These will receive intensive management to produce abundant seed to meet local demand and, possibly, surplus seed for export.

Future efforts will entail establishing seed stands in different climatic zones of the most successful Eucalyptus species and provenances. Management of the existing trials will be directed towards improving the seed crop and in this programme, the following will be considered:

Arid/semi-arid: E.alba, E.camaldulensis, E.microtheca and E.papuana.
Coastal areas: E.alba, E.camaldulensis, E.tereticornis.
Highlands: E.maidenii, E.grandis, E.regnans and E.saligna.

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AUSTRALIAN EUCALYPTS IN UGANDA

by Ms. R. Musoke

Introduction

The forest estate consists of a 1.5 million hectare reserve, 8% of the land and swamp area. Out of this, 732 000ha is closed forest, 768 000ha savannah woodland and 28 000ha of plantations. There is approximately 200 000ha of private forests. However the forest estate has been seriously affected by encroachment and illegal cutting which prevailed in the 1970's. Consequently there has been no large-scale plantation program by the department of forestry due to lack of resources. Tending and assessment operations have also lagged behind.

A number of industries in the country (tobacco, tea, sugar, fish smoking, bricks/tiles and pottery industries) depend on wood energy. Consumption has increased by 2.8% per annum, dominated by the non-commercial use of woodfuel in urban and rural areas.

As far as the commercial energy for the whole country is concerned, an average forest contributes 53% in the form of woodfuel and 14.2% in the form of charcoal. Regarding the total energy requirements including household, woodfuel and charcoal together contribute 96%. Urban areas are switching from charcoal and electricity to fuelwood due to the recent increase of 220% and 150% respectively.

Eucalyptus plantations and woodlots are the major source of fuelwood for the country, and in addition, provide building, telegraph and electric poles and fencing posts. Charcoal is mainly obtained from indigenous hardwood species that are left behind after felling a tropical high forest or savannah woodland.

A number of different species have been introduced into the country and some have been evaluated. Early assessment singled out 10 species with their lines of best production and location. Eight other species are also recommended for comparison studies. The ten species are presented overleaf.

Species	(1)	(2)	(3)	(4)	(5)	(6)
E.camaldulensis	✓	✓				
E.tereticornis	✓	✓				
E.citriodora	✓	✓				
E.paniculata	✓	✓	✓	✓	✓	✓
E.grandis	✓	✓	✓	✓	✓	✓
E.cloeziana	✓	✓	✓			✓
E.deglupta			✓	✓		✓
E.microcorys			✓	✓	✓	✓
E.maculata				✓		✓
E.regnans				✓	✓	✓

Key

1. fuel and pole species in savanna areas
2. saw timber species in savanna areas
3. saw timber species in high forest areas at lower altitudes
4. saw timber species in high forest areas at medium altitudes
5. saw timber species at high altitudes
6. species of importance for charcoal production or raw material for pulp and paper.

Potential of Eucalyptus

The right species established in correct locations gives Eucalyptus a high potential for fuel, poles, sawntimber and charcoal production.

Majority of fuelwood users prefer Eucalyptus wood to indigenous wood because of its high calorific content and frequently straight timber for poles and fencing posts.

Sawntimber is often easy to work and has a wide range of uses. The major problem with sawntimber is cracking and checking.

Charcoal produced from Eucalyptus species has a higher density (40kg/bag) compared to that of most indigenous Ugandan hardwoods (25-30kg/bag).

AUSTRALIAN SPECIES IN ZAMBIA

by A. Mubita and F. Mwanza

Some sixty species of Eucalyptus have been investigated in trials in Zambia since 1934 (Appendix 1). The trials have covered 330 plots in various regions of the country.

Only nine species have so far been investigated at the provenance level (incorporating more than five seedlots), the rest having been relegated to further observation due to their poor survival, growth and stem quality. Conclusions based on species trials in which some species were represented by one seedlot may not be valid because the seedlot involved could have been an unsuitable provenance. In most cases specific information on seedlots was scarce as to the number of trees and provenances represented.

The major limiting factors to the successful establishment of most eucalypts in Zambia, given that the standard establishment techniques are followed, are rainfall and to a lesser extent, soil fertility. It is not clear to what extent the absence of mycorhizal associations have contributed to the failure of some species in Zambia. In general, the Northern and Lake basin regions receiving fairly abundant rainfall (1212 to 1380mm/year) have provided good survival and growth of most species. The Southern and Zambezi Valley regions (726 to 850mm/year) have been found to be harsh habitats for most eucalypts except drought hardy ones such as E.tereticornis, E.camaldulensis and E.maculata. Due to their fast growth, eucalypts are important to the economy for fuelwood and other wood-based products. There are about 20 000ha of eucalypt plantations started since 1964.

Examples of soil types and climatic features of the major regions of the country are presented in Appendix 2.

Promising Species

E.grandis

This species was introduced into the country in 1959. Most of the stock numbers were of Queensland, Australia and Eastern Transvaal origin. E.grandis has been tested in nearly all climatic zones and its best performance is in the Northern Plateau on sandy soils.

Subsequently fourteen stock numbers, most of which were from New South Wales, Australia, were tested in a provenance trial at Chati in 1967. Results of this trial revealed little differentiation among provenances and probably led to the creation of mixed provenance seed orchards.

The species has potential for fuelwood, poles and posts, sawntimber, wood-based panels, pulp and other uses. It is attacked by Phoracantha when under drought stress and splits upon seasoning (10 to 15 percent moisture content). Other problems include rot of green timber, and generally poor stem form.

E.tereticornis

This was introduced in 1958 and has been tested in all major regions. Three provenance trials were set up on the Southern and Northern plateau. Results showed little differentiation among provenances. Tree seed of the species is derived from two seed orchards and two seed stands in the country.

The species is acknowledged to be highly drought resistant, but its poor form has prevented its wide use as a plantation species. It is not attacked by Phoracantha.

"Hybrid"

A hybrid between E.grandis and E.tereticornis was first spotted at Mochipapa on the Southern plateau. Since then the two species have been interplanted to encourage the natural production of "hybrid" seed.

The hybrid has been planted in various regions but particularly on the Central and Southern plateau where it performs as well as E.grandis and with the good stem form and drought resistance of E.tereticornis. In the Central plateau 64ha are under hybrid plantation.

E.cloeziana

This species was introduced into Zambia at Dola Hill in 1960 and since then it has been tested in the Northern, Central and Southern plateau. Further trials involved provenance research in 1972 and 1974 at Chati.

The species produces good quality timber for electricity poles due to its good stem form. The timber is stronger and has a higher wood density than

E.grandis, probably due to its slower growth. It coppices easily and is ideal for pole production. Sawntimber recovery is better than of E.grandis.

E.camaldulensis

This was introduced in 1958 at Dola Hill and Magoye on the Northern and Southern plateaus and further trials were conducted in the Lake Basin region. Twenty stock numbers were established as a provenance trial in 1967.

Early results showed poor growth and stem form but promising provenances were Albacutya, Victoria; Petford, Queensland; and Bland Crane, New South Wales. Currently, a 3.6ha seedstand of Congo origin supplies all the seed needs of the country. Clonal seed orchards may be established of promising provenances.

Seed Orchards

There are more than 40ha of Eucalyptus seed orchards consisting of five species and a natural hybrid. Most local eucalypt seed requirements are of E.grandis, E.tereticornis, E.cloeziana and the hybrid. Seed is abundantly produced but due to little demand, seed of some species is not harvested regularly.

The major problem in seed harvesting is the difficulty of reaching into the crowns of fully grown trees. Tree climbing for this purpose is dangerous and expensive and relies on experienced tree climbers. The practice of felling mother trees for seed is not favoured.

The full list of Eucalyptus seed orchards is given in Table 1.

Table 1 Eucalyptus Seed Orchards in Zambia

Species and Year of Establishment		Provenance		Seed Orchard	Type	Hectares
E.camaldulensis	1963	1644	Congo	SI-9	Seedling	2.3
E.cloeziana	1968	1872	Australia	SII-11	Clonal	3.6
E.grandis	1965	1560	S.Africa	SII-4	Clonal	3.6
E.grandis	1968	1560) 1744) 1560) 1566)	S.Africa	SIII-1B	Clonal	3.6
E.grandis	1968	0532) 0539) 0535)	Zambia	SIII-6	Seedling	7.2
Hybrid	1968	1645) 1646)	Siamambo	Compt 119 ABC	Seedling	3.6
Hybrid	1968	0566	Siamambo	Plot 5	Seedling	0.75
Hybrid	1968	-	Zambia	SII-18	Seedling	3.6
E.resinifera	1966	1705	Australia	SII-2	Clonal	3.6
E.tereticornis	1965	1528	-	SII-6	Clonal	3.6
E.tereticornis	1966	1528	-	SII-9	Seedling	3.6
E.tereticornis	?	2214	Siamambo	Compt 204	Seedling	-
E.tereticornis	?	1528	Tara	-	Seedling	-
						(39.0,5)

Appendix 1 Species Trials Since 1934

SPECIES	STOCK No.	LOCATION	PLOT No.	YEAR OF PLANTING
E.acmenioides	2396	Chati	1	1973
E.alba	1507	Magoye		1958
	1559	Dola Hill	353	1959
	1559	Magoye		1958
	1569	Kamaila	30, 34	1957
	1694	Dola Hill	443	1960
	1569	Samfya	193	1959
	1694	Samfya	213	1960
E.andrewsii	2083	Siamambo	7	1970
	2083	Chati	11	1975
E.astringens	2501	Chati		1975
E.bicostata	2397	Chati	4	1973
	2397	Ichimpe	77	1963
E.bleeseri	1662	Siamambo		1959
E.bosistoana	-	Dola Hill		1934
E.botryoides	SA.13709	Chichele	32	1952
	SA.13709	Siamambo		1952
	SA.13709	Ichimpe	78	1963
E.bridgesiana	-	Siamambo		1950
E.brockwayi	_	Chati	14	1973
E.camaldulensis	1284	Samfya	174	1959
	1284		168	
	1394	Chichele	7	1958
	0808	Siamambo	8	1973
	1644	Dola Hill	440	1960
	-	Dola Hill	242	1961
	-	Chichele	51	1963
	-	Sikalongo		1961
	-	Kamaila	141, 147	1960
	-	Magoye	16	1958
	-	Chichele	484	1962
	1644	Kasempa	C.SE	1965
	1741	Chati	4, 14	1962

Twenty provenances were established in 1967 at Chati.

E.campanulata	1361	Siamambo	401	1956
E.citriodora	0284	Kamaila	18	1958

SPECIES	STOCK No.	LOCATION	PLOT No.	YEAR OF PLANTING
E.citriodora	0284	Chati	A and C	1962
	0329	Masese	3	1962
	1379	Samfya	196	1959
	1379	Dola Hill	362	1959
	1549	Samfya	308 A	1959
	1573	Siamambo	604	1964
	1587	Choma		1962
	1587	Samfya	242	1960
	-	Chichele	15	1939
	-	Chichele		1947
	-	Chichele		1951
	1587	Chati		1962
	-	Dola Hill		1960
	1462	Chati		1968
	1897	Dola Hill	37/A	1964
	-	Dola Hill	38	1934
	-	Nkolemfumu	1C	1957
	-	Serenje	4 /11	1964
E.cladocalyx		Chati		1973
E.cloeziana	1417	Chichele	45	1963
	1462	Chati C		1962
	1462	Chati		1968
	-	Solwezi	1E	1964
	1481	Sikalongo		1961
	1589	Dola Hill	462, 355	1960
	1877	Chati	45	1962
	1877	Choma	488	1968
	-	Serenje	4/6	1964
	1399	Ichimpe	75	1962
	1462	Kasempa	5C	1965
	0643 ex 1589	Chipata		1968
	2046	Chati		

The first provenance trial of 13 seedlots were established in 1972 at Chati; further in 1974, six provenances of E.cloeziana were established at Chati again.

E.crebra	1508	Magoye	6	1958
	1508	Siamambo	406	1957
	1585	Siamambo	427	1960
E.deanei	1979	Chati		1967

Six provenances of E.deanei were established in 1973 at Chati.

SPECIES	STOCK No.	LOCATION	PLOT No.	YEAR OF PLANTING
E.decepta	1750 under	E.paniculata		
E.deglupta	1638	Dola Hill	403	1960
	1638	Dola Hill	325	1959
E.delegatensis	2481	Chati		1975
E.diversicolor	2393	Chati	11	1973
E.drepanophylla	1529	Kamaila	36, 42	1958
	1529	Dola Hill	374	1959
	1330	Siamambo	93	1957
E.dunnii	2004	Chati		1967
	2003	Chati		1967
	0550	Siamambo		1970
Six provenances of E.dunnii were established in 1973 at Chati.				
E.dundasii	2150	Siamambo		1970
E.exserta	2147	Siamambo		1970
E.fastigata	2084	Chati	3	1970
	2084	Chati		1971
E.fraxinoides	2394	Chati	13	1973
E.globulus	2477	Chati		1975
E.gomphocephala	1078	Chati	8	1973
	1078	Ichimpe	83	1963
E.grandis	1312	Dola Hill	372	1959
	1312	Samfya	230, 192	1959
	1428	Chati	D	1964
	1428	Magoye	36	1964
	1528	Chichele	30	1963
	1566	Chati	ABC	1961
	1744	Chati		1962
	1744	Dola Hill	503, 501	1960
	1744	Sikalongo		1961
	1744	Choma		1962
	1861	Dola Hill	33	1964
	-	Kamaila		1963
	1978	Chati		1967
	1982	Chati		1967
	-	Luwingu	6A	1965
	0440	Mbala		1966
	1298	Kasama		1963

SPECIES	STOCK No.	LOCATION	PLOT No.	YEAR OF PLANTING
	1861	Kasama		1964
	-	Serenje	12	1965
	-	Serenje	11	1968
	-	Serenje	10	1966
E.gummifera	2392	Chati	7	1973
	1441	Siamambo	82	1957

Fourteen provenances were established in 1967 at Chati.

E.hemiphloia	1697	Samfya	228	1961
	1697	Chati	C	1962
	1697	Dola Hill	147A	1960
	1697	Kamaila	35, 40	1960
	1434	Magoye	3	1958
E.intermedia	1703	Magoye	56	1961
	1703	Chichele	52	1964
E.intertexta	2478	Chati		1975
E.laevopinea	1360	Siamambo	402	1956
	1360	Siamambo	417	1958
	2097	Chati	6	1970
E.maculata	1903	Siamambo	605A	1964
	1903	Chichele	32	1963
	1903	Chati	D	1964
	1903	Chati		1963
	-	Chichele	10	1942
	-	Chichele	39	1951
	-	Luwingu	5	1958
	1847	Ichimpe	73	1962

Six provenances of E.maculata were established in 1974 at Chati.

E.maidenii	1639	Chati		1973
	-	Chichele	358	1952
	-	Lusaka N.	6A	1958
E.melliodora	1687	Chati		1973
E.microcorys	1417	Chichele	44	1963
	1671	Dola Hill	398A	1961
	1671	Kamaila	106, 51	1961
E.miniata	2142	Siamambo	C314	1970
E.muellerana	2479	Chati		1975
E.notabilis	1705	under E.resinifera suspected to be E.notabilis		

SPECIES	STOCK No.	LOCATION	PLOT No.	YEAR OF PLANTING
E.obliqua	-	Chati		1974
E.paniculata	0390	Samfya	253	1961
	0390	Dola Hill	409	1961
	0390	Kamaila	60	1960
	0390	Sikalongo		1961
	0354	Magoye	59, 60	1961
	0354	Kamaila		1960
	0354	Dola Hill	397	1960
	1723	Chichele	36	1963
	1723	Kamaila		1963
	7123	Dola Hill	411A	1961
	1723	Kamaila	54A	1961
	1865	Sikalongo		1962
	1865	Chati		1962
	1865	Choma		1963
(suspected to be E.decepta)	1750	Chati	A, B	1961
	1750	Chati	C	1962
	1968	Serenje	4/12	1964
	1968	Katete	2 a	1962
E.pellita	1362	Siamambo	403	1956
	1362	Siamambo	411	1957
	1362	Siamambo	18, 208	1971
	1362	Chati	34, 36	1971
	1436	Siamambo	418	1958
E.phaeotricha	1704	Kamaila	65	1961
	1704	Chati		1962
	0391	Sikalongo		1961
	1492	Dola Hill	426	1960
	1866	Choma		1966
	2094	Chati	1	1970
E.pilularis	1596	Kamaila	70, 74	1961
	1596	Chati		1967
	1596	Sikalongo		1961
	1596	Siamambo	762	1960
	1596	Samfya	252	1962
	1426	Dola Hill	351A	1961
	1863	Chati		1962
	1863	Masese	10	1962
	1894	Chichele	33	1963
		Serenje	4/45	1964

Twenty-two provenances established in 1967 at Chati were followed by a further trial at Chati in 1971.

SPECIES	STOCK No.	LOCATION	PLOT No.	YEAR OF PLANTING
E.planchoniana	2095	Siamambo	9	1970
	2095	Chati	5	1970
E.polycarpa	2144	Siamambo		1970
E.populnea	2149	Siamambo	6	1970
	2149	Chati		1970
E.propinqua	2217	Siamambo		1970
	-	Chati	32	1971
	0929	Chati		1975
E.punctata	1924	Chati	8	1965
	1237	Siamambo	404	1956
E.raveretiana	1998	Chati		1967
E.resinifera	1429	Kamaila	99, 71	1960
	1429	Dola Hill	381	1959
	1429	Siamambo	C.150	1956
	1429	Siamambo	408	1952
	1429	Siamambo	759	1959
	1705	Sikalongo		1961
	1705	Choma		1962
	1705	Masese		1962
	1705	Chati		1962
	1705	Chati	A, B	1962
	1705	Kamaila	4(a)	1963
	-	Katete	4	1964
	1706	Siamambo	611 A	1964
	1706	Chati	'D	1961
	1706	Samfya	254	1964
	-	Solwezi	1 D	1963
	1859	Kamaila	4/6) 4(c)	1963
	1860	Chichele	38	1965
	1925	Chati		1965
		Mbala	2	1960
Suspected to be E.notabilis	1705	Lusaka	25 B	1967
	1860	Serenje	4/8	1964

SPECIES	STOCK No.	LOCATION	PLOT No.	YEAR OF PLANTING
E.robusta	1500	Sikalongo		1961
	1876	Chati		1962
	1876	Choma		1962
	1876	Chichele	49	1963
	-	Chichele	14	1939
	-	Chichele	34	1958
E.saligna	0286 ex 13065	Kamaila		1962
	0286 ex 13065	Samfya		1959
Positively identified as E.saligna	1601	Dola Hill	410 A 331	1961 1958
	-	Choma	C, 28	1962
	-	Samfya	217	1960
	1601	Kamaila	78, 82	1960
	1602	Chati		1962
	1602	Choma		1962
	1690	Chichele	46	1963
	-	Masese	2, 4	1962
	-	Samfya	cat. B	1962
	-	Kamaila		1963
	-	Sikalongo		1961
	-	Choma		1963

In 1971, 14 provenances of E.saligna were established at Chati.

SPECIES	STOCK No.	LOCATION	PLOT No.	YEAR OF PLANTING
E.salmonophloia	2151	Siamambo	8	1970
	2151	Chati	8	1970
E.siderophloia	1606	Magoye	5	1958
E.sideroxylon	1702	Magoye	61	1961
E.sieberana	2480	Chati		1975
E.smithii	1698	Dola Hill	387	1961
	1698	Kamaila	130, 135	1961
	1698	Sikalongo	255	1961
	1698	Samfya	255	1961
	1414	Siamambo	90	1956
E.tereticornis	0705	Choma	Compt. 24	1962
	1373	Magoye	9	1958
	1528	Lundazi	1 A	1967
	1528	Siamambo	4	1970
	1528	Dola Hill	542	1960

SPECIES	STOCK No.	LOCATION	PLOT No.	YEAR OF PLANTING
E.tereticornis	1528	Kamaila	80, 84	1960
	1528	Magoye	37 A	1964
	1528	Chichele	50	1963
	1528	Masese	1	1964
	-	Katete	9	1968/70
	1645	Dola Hill	380	1959
	-	Siamambo	758	1959
	1710	Magoye		1958
	-	Lundazi	2 D	1968
	1710	Dola Hill	389	
	1710	Kamaila	88, 92	1960
	1710	Sikalongo		1961
	1710	Samfya	256	1961
	1710	Katete	8	1968/69
	1739	Chati	B and C	1962

Two provenances trials were established in 1967 (six provenances) and 1971 (twenty provenances) at Chati. In 1974 six provenances were established at Siamambo.

E.tessellaris	1651	Siamambo	429	1960
	1651	Siamambo	416	1958
	1651	Dola Hill	324	1958
	1651	Kamaila	26	1958
	1651	Kamaila	45, 96	1959
	1651	Magoye	20, 21	1960
	1651	Samfya	216	1960
	1651	Siamambo		1970
E.tetrodonta	1707	Dola Hill	430	1960
	1707	Kamaila	58, 62	1960
	-	Siamambo	Compt. 314	1970
E.thozetiana	2148	Siamambo	2	1970
		Chati	10	1970
E.torelliana	1180	Siamambo	407	1952
	1647	Siamambo	424	1958
	1650	Dola Hill	323	1958
	1657	Dola Hill	345	1959
	1657	Kamaila	48	1959
	1657	Magoye	66	1961

SPECIES	STOCK No.	LOCATION	PLOT No.	YEAR OF PLANTING
E.trachyphloia	2145	Siamambo	Compt. 314	1970
E.triantha	1327	Siamambo	217	1956
E.viminalis	1194	Siamambo	121	1956
	1499	Chati	2	1973

Appendix 2 Soil Types and Climatic Features

1. NORTHERN PLATEAU

(Ndola) 13°00' S, 28°39' E, 1270 m.a.s.l.

Soil type: Mainly alluvial soil, heavily leached with low base status, low organic content and pH of 5 - 5.5. Often very sandy (70 - 80%) and usually boron deficient

Climate: Rainfall 1200mm

Raindays > 0.1mm 107

> 1.0mm 90

Mean max. temperature	31.6°C	October
Mean min. temperature	6.4°C	July
Absolute Min. temperature	-2.2°C	

Frost, 2 days

2. CENTRAL PLATEAU

(Lusaka) 15°19' S, 28°27' E, 1154 m.a.s.l.

Soil type: Similar to Northern Plateau, but soils at main research station, Kamaila, are heavy sandy clays with pH range 5 - 6 and higher base status

Climate: Rainfall 806mm

Raindays > 0.1mm 84

> 1.0mm 70

Mean max. temperature	32.0°C	October
Mean min. temperature	7.7°C	July
Absolute Min. temperature	0°C	

Frost, 1 day

3. SOUTHERN PLATEAU

(Choma) 16°51' S, 27°04' E, 1267 m.a.s.l.

Soil type: Very similar to Northern plateau

Climate: Rainfall 850mm

Rainy days > 0.1mm 81

> 1.0mm 71

Mean max. temperature	31.2°C	October
Mean min. temperature	3.3°C	July
Absolute Min. temperature	-6.1°C	

Frost, 4 days

4. LAKE BASIN

(Samfya) 11°21' S, 29°32' E, 1172 m.a.s.l.

Soil type: Leached, deep sandy loams, which are rather more acid than Northern Plateau, pH4.5 - 5.5. Soils have high base status.

Climate: Rainfall 1380mm

Raindays > 0.1mm 105
> 1.0mm 88

Mean max. temperature 30.1°C October
Mean min. temperature 10.4°C July
Absolute Min. temperature 3.9°C
Frost, none

5. ZAMBEZI VALLEY

(Sesheke) 17°28' S, 24°18' E, 915 m.a.s.l.

Soil type: Deep infertile sands of the Karoo-Kalahari type, 90% sand with pH 5 - 5.5

Climate: Rainfall 726mm

Raindays > 0.1mm 77
> 1.0mm 56

Mean max. temperature 35.1°C
Mean min. temperature 3.6°C
Absolute Min. temperature -4.9°C
Frost, 10 days

AUSTRALIAN SPECIES IN ZIMBABWE - EXISTING ROLE AND POTENTIAL

by Ms. S. Bleakley and R. T. Cant

Few of Zimbabwe's indigenous tree species are gregarious, most are slow growing and generally not amenable to sustained-yield management, nearly all are unsuitable for growing in plantations, and, particularly in monocultures, their productivity is very low per unit area of land (Barnes and Barrett, 1976). It has been necessary, therefore, to turn to plantations of fast-growing exotic trees to supply the needs of this country for industrial timber, poles and fuelwood. *Pinus* supplies all of Zimbabwe's softwood requirements while Australian tree species provide the industrial hardwood, poles, and fuel. *Eucalyptus* is the principal supplier of hardwood. A small amount is provided by the black wattle, *Acacia mearnsii*, which is currently grown primarily for its bark extracts and not for its wood.

Plantation areas in Zimbabwe at June, 1983 were:

Type of plantation	Areas of plantations in hectares				
	Conifers	Eucalypts	Wattle	Other Hardwoods	Total
Commercial and industrial	64 408	17 288	14 814	176	96 686
Non-commercial and non-industrial	653	10 428	167	20	11 268
Communal lands	47	1 426			1 473
TOTALS	65 108	29 142	14 981	196	109 427

The combined totals of eucalypt and wattle plantations constitute 33,2% of commercial and industrial plantations, 94% of non-commercial and non-industrial plantations, 96,8% of communal lands plantations, and 40,3% of all timber plantations in Zimbabwe.

Production by primary processors of exotic hardwood (eucalypt and wattle) products in 1982/83 amounted to:

Type of produce	Volume (m^3)	Mass (t)
Sawn timber		
Structural	1 617	-
Sleepers	744	-
Other	5 296	-
Treated wooden poles		
Powerline	6 483	-
Telephone	1 448	-
Other	7 577	-
Veneer	3 176	-
Mining timber	-	5 520
Charcoal	-	1 100
Firewood	23 721	-
TOTALS	50 062	6 620

The role of Australian species in the overall forest economy of Zimbabwe may thus be seen but, in addition to the utilization statistics quoted above, an unspecified volume of poles and fuelwood is removed annually from the nearly 12 000 hectares of eucalypt plantations on farms and communally owned lands.

Important Species

Eucalypts are grown over a wide range of conditions in Zimbabwe, from mountain grasslands at altitudes as high as 2 000m down to warmer areas at 900m above sea level, and in rainfall regimes of 2000mm or more per annum to as little as 600mm (Mullin *et al.*, 1981).

Many species have been tried but eucalypt plantations today are dominated by two species, *Eucalyptus grandis* on the more favourable sites and *E. camaldulensis* in the harsher areas. No statistics are available on the actual plantation areas occupied by these two species or to show how much each contributes to the overall forest economy but as a rough guide probably 95% of all commercial and industrial eucalypt plantations are *E.grandis*, while the non-commercial and communal lands plantations are more-or-less evenly divided between *E.grandis*, *E.camaldulensis*,and an indifferent mixture of several species.

The only other plantation hardwood of any consequence is *Acacia mearnsii* which is confined to the wetter parts of the eastern border region at altitudes around 1500m.

E.grandis

This species was introduced as E.saligna about 1894 and was already well established by the time the State Forest Service came into being in 1920. It is the fastest-growing exotic species in the country and is planted over a wide range of sites. Mean annual volume increment may exceed $40m^3$/ha/yr on exceptional sites but $30m^3$ would not be considered unusual in good conditions. At the other end of the scale, the marginal sites may produce no more than $7m^3$/ha/yr (Barrett *et al*., 1975).

E.grandis is the subject of an intensive breeding programme to extend its site tolerance, improve frost resistance, improve stem quality and branch shedding, and reduce the extreme variation in basic density. To this end, two major seed-collecting missions to Australia in recent years have brought back seed from more than 300 mother trees across the range of provenances in Australia, and the trials resulting from these collections will provide material for multiple-population breeding.

E.camaldulensis

The original introductions showed this species to be tolerant of harsh conditions and it soon became known as the safest tree for planting in the drier parts of the country. However, the original material produced trees of poor form that found little use except for rough poles and fuelwood. Nevertheless, it has been planted widely, even in localities where it is unable to make full use of improved soil and rainfall.

In 1965, rangewide provenance collections were received from Australia and the resultant trials soon demonstrated that seed sources from the northern parts of Australia were the most suitable for Zimbabwe. It was also shown that the original material in Zimbabwe was clearly of southern Australian origin.

As soon as practicable, selections for breeding were made in these provenance trials, particularly among the outstanding Petford (Queensland) and Katherine (Northern Territory) seedlots. This breeding programme is now into the third generation, and has been augmented by recent collections from 169 mother trees in northern Queensland for multiple-population breeding.

Zimbabwe's rural afforestation project is making E.camaldulensis an increasingly important species for reforestation of denuded woodlands and it is expected that this species will eventually become the main source of fuel and poles in the country's communal lands.

E.tereticornis

Although an old-established species in Zimbabwe, it has never been used to any great extent in pure plantations but is common in mixed stands throughout the country. E.tereticornis has been regarded as less hardy than E. camaldulensis but recent provenance research has demonstrated that certain northern Queensland seedlots, particularly from around Cooktown and Laura, will tolerate some of the harshest conditions in Zimbabwe.

Major provenance collections, covering 104 mother trees, have been made by Zimbabwean teams in Australia, and some 20ha of provenance/progeny trials have been established to initiate a multiple-population breeding programme.

E.tereticornis is a faster-growing tree than E.camaldulensis, better formed, and generally a better plantation prospect, and it is expected that it will come into increasing use in the areas that are too marginal for E. grandis.

E.cloeziana

This species is by far the straightest eucalypt in Zimbabwe and it has a good growth rate on favourable sites of the eastern border region. Mean annual volume increments of more than $30m^3$/ha/yr have been recorded at age 9 1/2 years. E.cloeziana has a strong, heavy wood and it is the pre-eminent species in Zimbabwe for telephone and power-line transmission poles. Its major shortcoming is its intolerance of drought and frost and there is a question mark against the quality of its coppice.

The Gympie provenance is well-known internationally but a wide range of seed sources in recent trials will indicate whether other provenances merit consideration.

Acacia mearnsii

The plantation area of black wattle has declined in the last 20 years from about 25 000ha to the present-day figure of 15 000. This is largely due to fluctuating markets and competition from synthetic tannins. The wattle plantations that once covered extensive areas north of Mutare have largely been converted to pines but wattle continues to be an important species in the Chimanimani district.

Wattle is grown for its bark, not for its wood, and after the bark has been stripped for processing the wood is burned. However, wattle timber is used extensively elsewhere as a hardwood mix in the kraft pulping process and any development of chemical pulping in Zimbabwe could lead to the situation where wattle is grown as much for its wood as for its bark.

Species of Potential Importance

E.pilularis

This eucalypt is the major species sawn along much of Australia's eastern seaboard. It has been tried in Zimbabwe and some old plantings have produced trees with diameters in excess of one metre. It grows in the same general climatic conditions as E.grandisand there is no reason why it should remain a neglected species, particularly as it produces a good saw and veneer timber in this country.

Provenance trials of E.pilularis (and the closely related E.pyrocarpa) have been established as a first step towards the more thorough testing of this important species.

E.nitens

This species has not yet been planted commercially but trials have shown it to be the outstanding eucalypt for the high, cold altitudes where frost and exposure are important factors. Provenances from northern New South Wales have done best in local conditions and they have the added advantage over the southern provenances by producing wood of lower basic density, which is preferred in this country for utility-type hardwoods.

E.botryoides

An old-established species, E.botryoides has grown to sizes almost as large as E.grandis in some parts of the country. Provenance trials have shown extreme variation in growth rate and stem form, but the type approaching

E.saligna in certain morphological characters has performed well and has produced good quality saw and veneer timber.

E.citriodora

This is an old introduction but a much-neglected one. It produces a good quality timber and an excellent fuel, and its tolerance of very dry conditions marks it down as a species that merits wider planting for fuel and poles in the communal lands. Provenance collections have recently been made in Australia.

E.saligna

Although the name is well known, very little true *E.saligna* was planted in Zimbabwe before 1967. Its performance has been good and there are authentic records of heights exceeding 30 metres in as little as five years. *E.saligna* has shown itself to be more frost hardy then *E.grandis* (Mullin and Barnes, 1977) and the species certainly appears to warrant consideration for commercial planting.

E.paniculata

Most stands of *E.paniculata* probably contain a 50:50 mixture of *E.siderophloia*. This mixture has been planted widely and has grown well in dry areas. The species are considered too slow-growing for commercial plantations but they do have potential for the communal areas where the heavy timber would provide very durable poles and excellent fuel.

Casuarina cunninghamiana

This has been used for windbreaks and as ornamentals for many years, but only recently has it been realized that it has a potential nitrogen-fixing role in agroforestry systems. Seed has been obtained for provenance testing and for research into the effectiveness of different strains of *Frankia* in inducing nodulation.

Conclusion

The eucalypts have had an important place in Zimbabwean plantations since the beginnings of formal forestry in the 1920's, and although they have been planted on a smaller scale than the pines, the growing needs of the communal lands will eventually lead to a greater area of eucalypt plantations in the future. The potential of the eucalypts has not been fully exploited.

Other genera and species have begun to attract attention too, including those suitable for multiple uses. Their contribution to the overall forest economy could be considerable, particularly if termite-resistant species can be found. Not least of their uses will be to relieve the severe pressure on Zimbabwe's slow-growing, rapidly dwindling indigenous woodlands which are generally not suitable for plantation use.

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Appendix 4

Indigenous Species Research

Country Reports *

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* No reports available from Swaziland and Uganda

PROMISING INDIGENOUS SPECIES IN ETHIOPIA

by Ms. H. Ibrahim

The principal habit-forms of the natural vegetation are well in accordance with the altitude and temperature. The lowlands are characterized by steppes, savannahs and woodlands while the highlands are occupied by forests which change in the higher mountains again to woodlands, savannahs and steppes.

The majority of the remaining forests are located in the south and western parts of the country. The vegetation types can be summarized as:

a. Coniferous
b. Montane mixed broadleaved/coniferous
c. Montane broadleaved
d. Lowland broadleaved

More than 86 species are found in Ethiopia which are used for timber. Among these species, 15 are widely exploited. There are also multipurpose species which are useful for fuelwood, charcoal, gum arabic and fodder.

The Forestry Research Service planted some indigenous species in 1975 and growth rate data are given in Appendix 1. Provenance trials were undertaken for Cordia africana and Hagenia abyssinica.

For major species, a summarized description follows on silvicultural characteristics, usage and nursery practices.

Acacia albida

This is a thorny species up to 18m in height and 1m in diameter and it grows where the annual rainfall is 300 - 500mm. It makes its best growth on sandy or silty soils. It is often seen in cultivated fields where it is grown for shade and to improve the soil. It comes into leaf at the end of the rainy season and remains green during the hot dry season.This peculiar habit makes it extremely valuable as a shade tree and producer of fodder for livestock in the dry period.

Acacia senegal

A thorny shrub or tree 3 - 5m tall with deep penetrating and wide spreading roots; it grows on poor soil, rocky hills and sand tracts, but is also found on black cotton soils.

It produces gum arabic which is used in medicine, the manufacture of chewing gum, and in the textile industry. The leaves are collected for fodder.

Albizia gummifera

A deciduous tree attaining a height of 35-40m, it grows in humid low highland forests at altitudes of 1600-2200m. It regenerates easily from seed. There are about 12 000 seeds/kg. Seeds are soaked in warm water till cool and germinate in 7-14 days. Seedlings reach plantable size in 4-5 months. The wood is suitable for boxes, crates, utility furniture and joinery. The tree is a principal shade tree for coffee plantations in south and south-western Ethiopia.

Aningeria adolfi-fredric

A tree attaining a height of 45-50m and a breast height diameter of 2-4m, the bole is heavily buttressed for 6-12m. It is found in wet montane forests at altitudes of 1600-2400m. Seeds are collected from the forest floor. Usually the seeds are attacked by insects and must be sown immediately. Seeds germinate in 4-5 days and seedlings reach plantable size in 8-9 months. The wood is useful for general carpentry and construction.

Cordia africana

This is the most widely used timber tree in Ethiopia and is a fast-growing deciduous species attaining heights of 30m in closed stands but much less and with crooked boles in the open. About 2 500 - 4 500 seed/kg are produced. The seed germinates within 21 days, the seedlings reaching plantable size between 5-7 months. The wood is used for furniture, plywood/veneer, boxes and for shade.

Ekebergia capensis

This is a deciduous species reaching heights of 30m, occasionally higher, and found in the upper and lower highland forests between 1 600 and 2 600 m.a.s.l. Seeds are small (35 000 - 40 000/kg) and are sown in pots in the nursery. Seeds germinate slowly and seedlings reach plantable size in 9-10 months. The wood is suitable for general carpentry.

Hagenia abyssinica

This species reaches 20m in height with a round or umbrella-shaped crown. It is found in semi-humid and humid mountain areas between 2 400 and 3 000 m.a.s.l. on well-drained soils.

Seeds are small (450 000-500 000/kg) and germinate within 14-30 days. Seedlings reach plantable size in 7-8 months.

The wood is used for furniture, interior joinery, light duty flooring and veneer.

Juniperus procera

This is the principal utility timber in Ethiopia, an evergreen tree, reported to reach 50m with a straight but sharply tapered bole. It grows on sand clays but also appears tolerant of widely varying soils. It is a slow growing tree with a rotation age of 60-80 years. Seeds are small (40 000-50 000/kg) and germinate very slowly. Seedlings reach plantable size in 12-16 months and require shade in the nursery. The wood is used for furniture, joinery, fence posts and transmission poles. The adaptability of this tree to less favourable site conditions at higher altitudes and the value of its timber justify its cultivation in spite of slow growth.

Olea africana

The species sometimes attains heights of 18m but 10m is average. It is common at altitudes between 15 000 to 25 000m and prefers well-drained sandy loams.

The tree produces **about** 7 000 seeds/kg. Germination capacity is very low. Seedlings reach plantable size within 12 months.

Podocarpus graciliot

This is an evergreen, dioecious species, attaining a height of 45m with a straight and cylindrical bole. It is dominant in semi-humid highland-forests between 1 700 and 2 200m on deep, fertile, well-drained soils.

The species produces about 2 100 seeds/kg but only 70 viable seeds/kg. Seeds germinate very slowly. Seedlings reach plantable size within 12-14 months.

It is a high quality softwood used for internal joinery, furniture and veneer panels. When treated with preservatives, it may also be used for outdoor construction.

Pygeum africanum

This species attains heights of 25-35m with a cylindrical, straight bole. It is found in humid and semi-humid highland forests above 1 800m and with a rainfall in excess of 1 000mm. It grows on fertile, sandy loams.

It grows slowly with a rotation age of 60-80 years. There are 3 000-5 000 seeds/kg which germinate slowly. Seedlings reach plantable size in 9-12 months. The timber is used for lorry bodies, railway trucks, bridge decking, heavy construction timber, coarse furniture and veneer. The leaves are a source of domestic fodder.

Appendix 1

No.	Species name	Menagesha (age 5.25yrs.)			Shashemene (age 5.3yrs.)			Belete (age 5.8yrs.)		
		height (m)	dbh (cm)	basal/area (m^2/ha)	height (m)	dbh (cm)	basal/area (m^2/ha)	height (m)	dbh (cm)	basal/area (m^2/ha)
1.	Cordia africana	5	3.1	1.1	-	-	-	6	5.6	2.1
2.	Hagenia abyssinica	8	6.6	7.4	11	8.4	13.1	7	9.1	6.2
3.	Juniperus procera	4	3.0	1.1	5	7.9	7.2	7	9.7	10.7
4.	Olea africana	3	2.0	0.4	-	-	-	3	2.8	1.2
5.	Podocarpus gracilior	-	-	-	-	-	-	5	4.5	2.0

Site Description

No.	Place	Soil ph	Elevation (m)	Mean annual rainfall (mm)
1.	Menagesha	6.0	2 400	1 100
2.	Shashemene	5.6	1 890	970
3.	Belete	5.8	2 000	1 550

INDIGENOUS SPECIES OF KENYA

by P. Oballa and D. K. Musya

Extensive areas of Kenya's indigenous forests have been exploited over the last 50 years for sawn-timber and other forest products such as charcoal. As a result, many species such as *Podocarpus* spp., *Juniperus procera*, and *Vitex keniensis* have been severely depleted and could be completely lost by the end of the century. Little importance was attached to the planting of these valuable species, mainly on account of their slow rate of growth. However, exotic species have failed to replace indigenous timber in places where high quality is needed for furniture and interior furnishings. If Kenya is to earn more foreign exchange from forest products, these indigenous species must not only be conserved but be improved and grown side by side with the exotics.

Promising species for planting

The indigenous species planted can be grouped into three categories: those planted for their valuable timber; multi-purpose species for agroforestry, and those planted as ornamentals. Timber species include *Afzelia quanzensis*, *Chlorophora excelsa*, *Fagaropsis angolensis*, *Cordia abyssinica*, *Prunus africana*, *Vitex keniensis*, *Ocotea usambarensis*, *Juniperus procera* and *Podocarpus* spp.

Vitex keniensis is widely planted on the eastern slopes of Mt. Kenya. Collection of seeds is from single trees or small natural groves. Germination is good and fairly uniform after 4 weeks. The species is grown in a rotation of 40-45 years. The timber works easily and polishes well and is used for furniture and panelling.

Chlorophora excelsa grows well in lowland rain forests and in wet regions of the coast. It prefers deep, fertile moist loams and avoids acid soils. Seeds germinate well between 16-20 days and maintain viability up to 9 months. Seedlings are liable to gall infestation from mvule gall fly (Phytolyma lata) until they have reached heights of 5m. The timber matures at the age of 60-80 years. The species is highly valued for furniture, panelling and domestic flooring, boats and wharf timber.

Ocotea usamberensis. This species produces seeds about every ten years and in the forest it suckers. It is distributed in the montane forests of south and east Mt. Kenya, on the eastern slopes of the Aberdare Ranges and Taita Hills. Germination of the seeds is sporadic often taking 2-3 months. The trees mature in 60-75 years and frequently have heart rot. Due to difficulties in seed supply, the species can be raised by lifting natural root-suckers which are produced near the stumps of felled trees. The timber is valuable for furniture, panelling, flooring and heavy construction work.

Other important timber species being raised in plantations are: Podocarpus milanjanus, P.gracilior and Juniperus procera. These thrive in montane coniferous forests above 2 200m. Podocarpus spp. seed well but germination is sporadic, taking 1-6 months. They may also be grown using wildings, and mature in 75 years. These have been the standard building and general joinery wood of East Africa. It is odourless and non-resinous and is the accepted standard boxwood for packing of foodstuffs.

Regeneration experiments of valuable hardwoods of Kakamega forest has been going on for sometime and results indicate that some species (Maesopsis eminii, Croton megalocarpus, Olea welwitschii, Prunus africana and Markhamia platycalyx) can be profitably grown under the "shamba" system. After felling the trees, young seedlings are taken care of by the shamba tenders and, at the same time, they bury more seeds which germinate. Cultivation of agricultural crops continues until the canopy closes. Pruning and thinning of the stand by the shamba owners is not permitted.

More indigenous species are being recognized for multipurpose use and have been included in experimental plots for agroforestry. These include *Acacia albida*, *A.tortilis*, *A. xanthophloea*, *Balanites aegyptiaca*, *Acacia senegal* and *Tamarindus indica*. These woody components of agroforestry systems are important for nitrogen fixation, produce dry season fodder and compete minimally with agricultural crops. In addition, species such as *Acacia arabica* is valued for tannin and gum arabic, and *Tamarindus indica* is planted for edible fruits. *Sesbania sesban* is important for firewood in swampy areas.

A *Euphorbia* project for the production of liquid fuel and charcoal briquets from *Euphorbia tirucalli* has started in Baringo District. *Euphorbia* is xerophytic and can produce excellent fuelwood in dry areas.

A number of indigenous species are grown as ornamentals and with increasing urbanization more will be planted. Ornamentals include *Terminalia* spp., *Calodendron capense*, *Acacia xanthophloea*, *Ficus* spp., *Spathodia nilotica*, *Warbugia ugandensis* and several *Euphorbia* spp.

The need to conserve the existing flora is a challenge to research-workers. Data must be collected on distribution, seed production, germination, tests and methods of vegetative propagation.

INDIGENOUS SPECIES RESEARCH IN MALAWI

by B. M. Chamba and E. Kananji

Indigenous species of Malawi are numerous but produce very insubstantial timber. Their main uses to date are to prevent soil erosion, flooding and maintain catchment areas. However, they do provide fuelwood and poles for domestic uses.

Indigenous species trials in arboretum form started in the late 1940's and early 1950's (Nkaonja 1982). A few species with valuable timber properties such as *Burtt-davya nyasica*, *Chlorophora excelsa*, *Khaya nyasica*, *Parkia folicoldea*, *Pterocarpus angolensis*, *P.stolzii* and *Widdringtonia nodiflora* were planted without any form of experimental design to permit meaningful statistical comparison.

The high demand of fuelwood and poles and the dwindling of forest resources prompted a sudden resurgence of interest in the 1970's in looking for fast-growing species. The Department of Forestry, with financial support from IDRC of Canada, embarked upon a rural fuelwood and polewood research project in September, 1978 and the indigenous species *Acacia albida*, *A.pylacantha* and *Albizia versicolor* were included in the trials. The choice of these species was based on their inherent multi-purpose values for fodder, soil improvement and fuelwood.

This paper discusses the silviculture of some of the 'arboretum' trial species and 1978 indigenous fuelwood and polewood trial species.

'Arboretum' trial species

Burtt-davya nyasica

This species occurs sporadically on alluvial grey-brown soils of the rift valley plains in southern Malawi.

The species produces mature fleshy fruit in abundance in April and May at the end of the rainy season. The species performance, in terms of growth, form and branching habit, is good. The timber is of high quality and used for structural construction.

Chlorophora excelsa

This occurs as a riverine species in small numbers bordering evergreen forests.

Establishment has been more successful from stump shoots than from root suckers. The use of seed has given high losses, particularly after pricking out into tubes (Nkaonja, 1982). In order to reduce losses, shade has to be provided at the nursery site.

In Malawi, there has been no report of gall-bug, (Phytolyma) which causes damage to C.excelsa. Interplanting C.excelsa with Terminalia combretum seems to reduce the propensity for insects to breed on C.excelsa, however this hypothesis needs to be tested. C.excelsa ia susceptible to fire and is only suitable for enrichment planting where complete fire protection is ensured.

The timber is hard and durable and used for cabinet work, building materials, canoes and boat construction.

Khaya nyasica

This is found along stream banks and moist areas of lower mountains and plateaus.

It is established easily from seed and has been planted in both single species plots and in mixtures with other species.

It is resistant to termite attack but is very susceptible to short-boxer attack (Hysipyla spp) which causes dieback and multiple leaders.

The timber has been used largely for furniture, cabinet work, framing and panelling.

Parkia folicoidea

This species occurs in forests along rives throughout the country but not in large numbers.

The timber is easily worked and is used for mortars, poles, firewood. The yellow sticky pulp around the black seeds is edible and the whole fruit is good fodder for domestic stock.

Pterocarpus angolensis

This occurs in several types of indigenous woodland in Malawi as scattered individual trees.

Establishment of *P.angolensis* can be achieved from seed and germination is usually very high. Collection is done in September and October and the seed requires pre-treatment before sowing to a depth of 15-20mm with light watering. The seedling may show annual dieback during the dry season and this may happen for a period of 8 to 12 years. Consequently, establishment from 'truncheons' or stem cuttings is preferred to seedlings although survival is usually low. A moderate compaction of the soil around the truncheons appears to improve the chance of survival.

The species is fire tolerant, a characteristic which makes it important for enrichment planting in areas where fire cannot be excluded completely.

It is used for quality furniture, joinery, boat building and other construction.

Widdringtonia nodiflora

This is an indigenous conifer which is found naturally on Mount Mulanje at altitudes over 1 500 m.a.s.l.

It has been established successfully from seed but grows more slowly than various exotic species. Interplanting of Mulanje cedar with pines has been carried out and 10 years after planting *W.nodiflora* was one half the height of *Pinus patula* and three-quarters the height of *P.elliottii*. Burning of seed on the ground also induces excellent germination and seedling growth is quite vigorous.

The species is highly resistant to fire damage and attacks by termites, borers and fungi.

It is used for various construction material.

1979 species trials

Acacia albida

This species occurs throughout the country, mainly below 600 m.a.s.l. in woodlands, savannas and along streams, often in pure stands where the water table is high.

It has been established successfully from seed and requires pre-treatment before sowing. It is a slow-growing species and exhibits dieback for some years until a deep tap-root develops. Because of its tendency to dieback during establishment, fire is not much of a hazard. The larvae of the butterfly, *Aphnalus hutchinsoni*, feed on the wood causing gum to exude from the bark.

The wood is used for handles, pestles, mortars and canoes. The fruit is valuable for livestock food.

Acacia pylacantha

This occurs in savannas and woodlands at low and medium altitudes in moist areas.

Establishment from seed has been quite successful and the seed requires pre-treatment before sowing. It is a fast-growing species. Moth caterpillars (*Gynamisa maia*) eat the leaves whereas butterfly caterpillars (*Aphnaeus hutchinsoni*) feed on the sap-wood. (Kitchin and Pullinger, 1982).

It yields a good gum exudate used for confectionery. The wood is used for building materials and tool handles. The root exudates are used for snake bite treatment and as part treatment for gonorrhea.

Albizia versicolor

The range of this species is widespread, from low to fairly high altitudes in woodlands and savannas.

It has been established from seed but growth is very slow.

The timber is used for doors, furniture, drums and mortars. Soap can be made from the roots. The pods, if eaten when young by stock or game are poisonous.

Table 1. Growth performance of some of the species mentioned.

Species	Age (years)	Stocking Stem/ha	D.B.H. (cm)	Ht (m)	Basal Area (m^2/ha)
Burtt-davya nyasica	19	-	36.0	16.0	-
Chlorophora excelsa	17	516	25.9	16.5	26.08
Khaya nyasica	17	277	23.7	16.9	12.16
Pterocarpus angolensis	17	239	15.3	12.3	4.34
Parkia folicodea	17	420	11.9	-	4.68
Widdringtonia nodiflora	9	2738	9.4	5.6	7.40
Acacia albida	1	-	-	2.7	-

REMARKS

From the preceeding discussion and Table 1, Burtt-davya nyasica, Chlorophora excelsa and Khaya nyasica show some potential, however these species required a lot of water. Research should be carried out to include provenance trials and examine silvicultural techniques (espacement,fertilizer application and thinning regimes) in order to improve their economy.

Pterocarpus angolensis, *Acacia albida* and *A.pylacantha* could be established from cuttings, but the cost of rooting hormones could be a constraint.

Although exotic species such as pines and eucalypts are fast-growing, a good number of indigenous species have their merits, medicinal values, soil improvement, fodder for stock, which may not be substituted by exotics. Research on indigenous species in Malawi, like other African countries, is lagging behind in favour of exotic species.

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PROMISING INDIGENOUS SPECIES IN MOZAMBIQUE

by Ms M. T. Alves

Trials with indigenous species started years ago in Mozambique in a somewhat unplanned way but by 1935, the programme had a more orderly and scientific basis. In spite of effort by interested individuals, budget difficulties slowed down the initial enthusiasm from 1945.

This accounts for the gaps in the available information which is scarce and scattered through low circulation publications and unpublished reports. As a result, in several instances no precise data can be extracted from the existing records and in a number of cases there are no records at all.

Early after independence (1975), the Ministry of Agriculture started a research programme dealing with the conservation of valuable species. The Research Centre was established in 1983 and initiated in Marrupa, Niassa Province a special programme dealing with native species.

Continuous exploitation of the most valuable components of the native forests and the role which they still play in the country's economy forced the Forestry Department to look into the matter again. As a result, new trials were established and although problems still make adequate follow-up difficult, in a few years time sound and reliable information should be obtained.

1. Trials : 1929-1945

i) Afzelia quanzensis

Two methods of propagation were used; seed and cuttings. Seed showed a germination rate of 100% but the growth of the seedlings was slow. Young plants seldom attained the height of 1.5m before the fifth year of age. The plants were kept in the nursery for 4-6 years to increase outplanting survival and growth.

Direct sowing in the field was abandoned at an early stage because of the high loss of seed bh insects and rodents and because of the strong competition from grasses.

The process which at the time proved to be the most successful was propagation by cuttings. Cuttings were 1.5-2.0m long and 5cm thick. They were either planted directly in the field or left in the nursery for one or two years in order to develop a good root system. Spacing adopted in the field was 5 x 5m. After a few years, thinning was done to a final spacing of 10 x 10m

Although both methods were used with Afzelia, only records of development for the stands originating from cuttings occur. These indicated an average annual increment of 16cm in height and 5mm in diameter.

ii) Pterocarpus angolensis

Pterocarpus seed is attacked by insects inside the pod, and when the fruit was buried, germination was seldom higher than 1%.

It was necessary therefore, to extract the seed and check its condition before sowing. The operation was difficult and time consuming and trials were set out using cutting 2m long x 8cm thick. These were left for one year in the nursery to develop a root system.

Results with cuttings (again the only records available) showed an annual increment of of 42cm in height and 6mm in diameter.

iii) Milletia stuhlmannii

Propagation by seed was found to be very easy and the majority of plants were raised in this way although it is known that cuttings were used to some extent.

Records available indicate a mean annual increment of 29cm in height and 5mm in diameter but whether this applies to seedlings or cuttings, is unknown.

Spacing for Milletia and Pterocarpus was the same as for Afzelia. These three species covered a total planted area of around 600 hectares. Most of it still remains and can be seen 20km from Maputo on the main road to the north of the country.

It is unfortunate that the lack of information prevents an accurate assessment of the development of these stands.

iv) Khaya nyasica

Small plantations, along roadsides and in urban parks are still common in the northern areas of the country. This species, from an early date, proved to be one of the fastest growing and easiest native species to raise from seed. Measurements available indicate a mean annual increment 90cm in height and a little more than 1cm in diameter.

v) Chlorophora excelsa

This was also a success and available records point to a mean annual diameter increment of 2.5cm. Annual height growth was around 30cm. Stock apparently was raised from seed.

vi) Trichilia emetica

This tree occurs throughout Mozambique, being particularly abundant in the southern areas. Although a

> native, the majority of specimens occurring along the coastal strip south of the Save River were probably planted and not a product of spontaneous regeneration.
>
> This may be explained by the socio-economic importance of the species. Besides eating the seed pulp, the population extracts from it a favourite cooking oil used from very early ages. The harder seed core yields another oil which is used in the preparation of soap. Other local uses of the species include the manufacture of pestles and wooden plates, bowls and spoons. Artists use the attractive light-coloured wood for carvings and it is also suitable for furniture.
>
> For all these reasons, it used to be an old habit for most countrymen in the provinces of Inhambane, Gaza and Maputo to plant a few Trichilia in their farms, frequently close to the family house for shade.
>
> Farmers either raised plants from seed or more commonly from buried root pieces. In both cases a good mother tree was selected beforehand, the important requirements being a high fruit yield and the sweetness of the seed pulp.
>
> No records are available but the impression is that the species is a fast grower. When raised from seed it can attain 5m in height and 5cm in diameter after 4 years.

According to past indications, at least Khaya and Chlorophora should be raised in plantations. Both yield good quality timber, suitable for a number of purposes. Khaya is reasonably well represented in the country but good sized Chlorophora are rare due to over-exploitation and also to the peculiar breeding difficulties of the plant itself.

Trichilia has been planted in the past but this will decrease due to the availability of industrial oils and soaps.

The rotation cycles for these species are not known but it is obvious that the quick returns which are characteristic of fast growing exotics are not to be expected.

2. *Trials* (1981 ff)

In 1981 a comprehensive set of trials were established in the Marrupa area (Niassa province) to study both development of the local native forests and the adaptability of fast growing exotics to the region.

Within the overall scheme of trials, a number of experiments examine the raising of native species. The greatest interest still lies with *Afzelia*, *Milletia* and *Pterocarpus*, but a good number of other species are also included.

The approach has changed in relation to past experiments in two ways:

i) Trees were raised from seed in order to try and achieve a better log height and quality than in previous experiments (past experience showed a marked tendency for trees to start branching heavily at the very top of the cutting).

ii) Some trials have pure stands of one single species but others were designed for species associations so as to reflect the natural composition and structure of the forest.

All trials were measured in 1983.

Early indications are that there are yet no reasons to rule out future commercial plantations of these species, at least on a moderate scale. Three new species have so far drawn attention in the trials: *Sterculia appendiculata*

Bombax rhodognaphalon and *Dalbergia melanoxylon* the precious "Blackwood".

INDIGENOUS SPECIES FOR PLANTING IN TANZANIA

by I. M. Shehaghilo and S. Madoffe

Tanzania is a large country (937 062 sq km) and conditions vary greatly from place to place, climate is one of the most important factors for tree growth.

The country can be classified into four broad ecological zones:

1. Coastal Zone: below 500 m.a.s.l., temperature over 20°C, humidity about 60% and rainfall of 700mm
2. Semi-arid Zone: elevation between 500-1 500 m.a.s.l., average rainfall below 700mm, humidity very low with an unfavourably long dry season
3. Interior Lowland Zone: elevation 500-1 500 m.a.s.l., rainfall 700mm, humidity lower than 60%, temperature about 20°C
4. Highland Zone: temperatures below 20°C, rainfall 700-1 000mm or more, humidity over 60%

With these varying conditions, one can expect a large variation in species composition, and in fact it is estimated to be over 1 500 different indigenous species (Redhead and Temu, 1983).

Many traditional timber species have been severely exploited and some species which were lesser known have become valuable substitutes. With the increasing population, forested land has been reduced considerably, thus reducing supply of fuelwood, Tanzania's main source (97%) of energy for the rural population. The government has intensified afforestation programmes in rural areas. Both indigenous and exotic species which offer multiple benefits have priority for planting. This paper gives a short list of indigenous species which have shown some promise in Tanzania (Table 1).

Table 1. Promising indigenous species for planting in Tanzania and their main uses.

Species	Main uses
Acacia albida	Soil improver, fodder - much used in agroforestry
Acacia tortilis	Firewood, charcoal, fodder
Albizia lebbek	Firewood, shade, soil improver
Albizia gummifera	Firewood, shade, implements
Cordia abyssinica (C.africana)	Firewood, shade, bees favour the tree for honey production, leaves used for mulch
Maesopsis eminii	Timber, crop shade
Markhamia platycalyx	Firewood, building poles
Rauvolfia caffra	Medicinal, firewood, small items like spoons and pipes used locally by villagers
Tamarindus indica	Edible fruit, firewood, charcoal, shade
Trema guineensis	Land reclamation, shade for crops, firewood
Trichilia roka (T.emetica)	Oil and soap production, shade for tree crops if properly spaced
Zizyphus mauritiana	Living fence, fodder, edible fruit

The Seed Situation

Afforestation with indigenous species was given less attention in the past because natural stands were abundant and after cutting, natural regeneration was either encouraged on site or sites were planted with exotics.

Little attention was directed to seed problems of indigenous species, even the traditionally valued and heavily exploited timber species. When the need to grow more indigenous species, both naturally and artificially, was realised, it became evident that seed availability had to be considered (Shehaghilo, 1980). Studies have started on some indigenous seeds from phenological observations to collection, processing and germination. The result of the studies together with the literature showing experience from other countries on few species is far from complete and there is a lot of information lacking in this area.

However, efforts are being made by the seed section at Lushoto Silviculture Research Centre to supply the seeds of the above-listed species and others as much as possible while studies go on.

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INDIGENOUS SPECIES OF IMPORTANCE IN ZAMBIA

by A. C. Mubita and F. Mwanza

There are some 2 000 woody indigenous species in Zambia and some of these have contributed significantly to the economic development of the country. Since the 1930's _Baikiaea plurijuga_ (mukusi) has been used for a variety of uses such as furniture, mining and railway sleepers and parquet flooring. The construction of the national railway line (1902-1906) from Victoria Falls, Livingstone, to the Copperbelt made extensive use of durable mukusi sleepers.

The development of mining on the Copperbelt made extensive use of native timbers for refinery and structural supports. Even today species of _Brachstegia_, _Julbernardia_, _Isoberlinia_ and _Marquesia_ are extensively used.

Mixed mutondo woodlands are of economic and social importance to the ordinary Zambian and provide fuelwood and charcoal. Some indigenous species produce dyes for leather manufacture whereas others may be of medicinal value.

Silvicultural research

The Teak Forests

There are some eighteen silvicultural investigations being carried out in teak forests some of which started in the 1960's. They are intended to provide basic information about phenology, regeneration and tending methods of mukusi and other timber species of economic importance (_Pterocarpus angolensis_, _P. antunesii_, _Guibourtia coleosperma_, and _Entandrophragma caudatum_.)

Below is a list of species raised from seed and field tested.

Species	Age (yrs)	Height (m)	DBH (cm)	End uses
Afzelia quanzensis	9	2.7	4.1	Furniture, parquet batterns, canoes, joinery poles and fence posts
Albizia adianthifolia	9	5.5	8.2	Furniture, parquet batterns, joinery, fence posts and tool handles
Baikiaea plurijuga	9	2.3	4.2	Construction timber, parquet batterns, railway sleepers
Erythrophleum africanum	9	4.7	6.3	Joinery, flooring, turnery, construction timbers
Parinari curatellifolia	9	3.9	6.2	Flooring, scaffolding poles, fruit is edible and suitable for wine
Pterocarpus angolensis	9	1.7	4.0	Furniture, construction timber, joinery, flooring, poles
Branchystegia spiciformis	6	1.0	0.6	Joinery, furniture, mining timber, sleepers, bark rope
Uapaca kirkiana	4	1.3	-	Joinery, furniture, charcoal, edible fruit and oil, wine

In addition, there have been long standing investigations on Pterocarpus angolensis in a number of trial plots at Dambwa and Katombola in Livingstone since 1958.

Following the successful first international conference on the Teak Forests of Southern Africa(18-24 March,1984 Livingstone) resolutions were passed to treat all problems of teak forest management and conservation as special projects requiring external funding. To this effect a number of project proposals were drawn up by the Forest Department in order to solicit external support from foreign governments.

Other Woodland Timbers

Mixed mutondo woodlands comprise various tree species which are some of the most productive in Zambia. These species provide fuelwood, charcoal and structural timbers for both rural and urban dwellers. Due to intensive exploitation these woodlands are severely exhausted and there is an urgent need to evolve effective regeneration methods and conservation strategies.

Prominent species in these woodlands are:

Anisophyllea pomifera
Brachystegia boehmii
B. bussei
B.floribunda
B.longifolia
B.spiciformis
B.taxifolia
Julbernardia gloiflora
J.paniculata
Marquesia macroura
Parinari curatellifolia
Pericopsis angolensis

Applied research on indigenous tree species was carried out by D.B.Fanshawe for many years and his interest and work resulted in more than 4 000 specimens and collections of references on the flora of Zambia as well as the delineation of some fifty Botanical Reserves (Appendix 1).

These investigations on the miombo woodlands are still being pursued and have become some of the most valuable research undertakings in the quest for the scientific understanding of the ecology and silviculture of Savanna woodland tree species at least in Zambia.

APPENDIX 1

Publications and manuscripts by D.P.Fanshawe

1960	Evergreen forest relics in Northern Rhodesia.
1965	Check list of vernacular names of the woody plants of Zambia.
1967	The vegetable ivory palm - *Hyphaene ventricosa* Kirk its ecology, silviculture and utilisation.
1968	Fifty common trees of Zambia. Forest Department Bulletin No.5. A further 6 volumes are in preparation.
1969	Vegetation of Zambia. Forest Research Bulletin No.7.
1972	The Bamboo - its ecology and silviculture. Kirkia 8 (2), 157.
1972	Useful trees of Zambia for the agriculturalist. Government Printers, Lusaka.
1973	Vegetation of ... District. Research pamphlets for a total of thirty-three districts.
1973	Check list of the woody plants of Zambia showing their distribution. Forest Research Bulletin No.22.

Manuscripts

1970	The biology of the mofu tree - *Entandrophragma delevoyi* De Wild.
1972	*Baikiaea plurijuga* Harms.

INDIGENOUS SPECIES FOR PLANTING IN ZIMBABWE

by D. P. Gwaze

Forestry research in Zimbabwe has concentrated on exotic tree species, mainly pines and eucalypts. Exotic species are widely planted in commercial plantations, urban streets and parks. Except for firewood, poles and high quality furniture wood, demand for other wood products is met from exotic commercial plantations (Table 1).

The question of whether an exotic or an indigenous species should be grown is important and has not been thoroughly investigated. The choice of species for planting should depend on the following: (1) suitability for the site, (2) survival and growth rate, (3) suitability of the species compared with other species for a particular use, (4) energy, labour and capital needed to grow the product. Indigenous species are not planted in commercial plantations because they are generally slow-growing, and many have short boles and/or spreading crowns. Productivity (volume) of pines and eucalypts is in the order of 10 to 100 times that of most productive indigenous species (Barnes and Barrett, 1976). Many indigenous species have spreading crowns which require them to be planted at wide spacing. This reduces productivity per unit area. Indigenous species are reported to be less adaptable on poor sites and require considerable cultural inputs (Midgley and Boland, 1983). This may not necessarily be entirely true as many indigenous species are resistant to termites and other insects.

Although exotic species may be fast-growing, there is still a strong case for planting indigenous species. Slow growth rates may be acceptable on the following basis: a) indigenous trees are more compatible than exotic trees with native fauna, b) indigenous species may have special properties or characteristics not possessed by exotic species, such as medicinal value, termite resistance, forage value, burning properties, excellent furniture timber, etc.

Potential species

The main prospects for the planting of indigenous species lie in their multipurpose uses and in production of highly prized furniture wood.

Acacia albida

This is one of the largest indigenous species. It is a riverine species but occasionally occurs in woodlands. The species is most promising for planting in agroforestry systems and has a characteristic of shedding its leaves at the start of the rainy season. This enables intercropping with agricultural crops and the fallen leaves will rapidly decompose, enriching the soil. The species has a deep taproot which does not compete with agricultural crops for water and nutrients. It also retains leaves in winter, thereby protecting the soil from wind and providing shade to animals. The species has pods and leaves which are high quality fodder. It is nitrogen fixing and can be used for fuel and tannin production. The growth rate of the species is good. A specimen planted in December 1981 at Lions Den (200km N.W. of Harare) was over 2m in height a year later (Haney, 1983). The species has a large natural range throughout Africa and probably possesses a large amount of genetic variability for characteristics such as growth rate. It will be worth testing the whole of the natural range in order to find the right provenance for our environment.

Acacia karoo

This species is frost and drought resistant and it can grow on harsh sites such as mine dumps (Haney, 1983). It is fairly fast-growing and is an ideal multipurpose tree. Its uses include fuelwood, furniture, honey production, glue (from gum), rope and tannin (from bark).

Baikiaea plurijuga and *Pterocarpus angolensis*

These are two of the most important commercial indigenous timbers in Zimbabwe. They grow on Kalahari sands in Matabeleland and produce high quality wood used in the production of sleepers, veneer, furniture and flooring. Their high quality warrants research into possible planting of the species to ensure that domestic demands will be met in the future.

Khaya nyasica

This is a large species attaining heights of up to 60m or more in its natural environment. It is distributed in high rainfall areas. Growth rate is average. A specimen planted at John Meikle Forest Research Station in the eastern districts in 1968 was nearly 5m in height6.7cm diameter at 4 years. This species is a true mahogany and is an excellent furniture timber.

Bivinia jalbertii

This is an ideal commercial plantation species. It has a long, straight bole and fine, horizontal branches. Growth rate is believed to be slow. It could be used as sawn timber, pole or firewood in areas of high rainfall.

Cordia abyssinica

This species is fast-growing and is excellent as a shade tree. It is already used as such in coffee plantations. The wood is durable and may be used for furniture.

Other Species

Other possibilities include Acacia abyssinica, Newtonia buchananii, Albizia schimperana, and Tamarindus indica.

Conclusion

Research into the planting of indigenous tree species should receive more consideration. Indigenous species, although reportedly slower growing than the common exotics, may have characteristics that are not possessed by the latter. These characteristics may be sufficiently important to compensate for slower growth rates. Many indigenous trees have a wide distribution and it will be important to test their genetic variability.

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Table 1. Estimated Wood Consumption in Zimbabwe 1978/79 (Banks,1980)

WOOD CATEGORY	SOURCE & AMOUNT, 000's m^3 u.b.				NOTES
	CONIF. PLANT/S	Euc.& Wattle	INDIG. W/LAND	TOTAL	
SAWLOGS(veneers & sleepers incl.)	230(i)	13(i)	81(ii)	324	(i) Mainly E.Dist.plantations (ii) Mainly State Forests & T.T.L.
Poles.piling & posts	-	20	665(iii)	685	(iii) Per capita basis - T.T.L. 0,16 m^3 u.b.
Round mining timber	-	12	31	43	
Pulpwood	63	29	-	92	
Other uses	1	26	-	27	
Indust.Wood	294	100	776	1 170	
FUELWOOD Comm.sales	-	91(iv)	-	91	(iv) Based on plantation returns
COMM.FARM.SECTOR(v)					(v) C.S.O. returns
(a)Dom.Fuelwood	-	124	555	679(vi)	(vi) Est.to be 70% of total of (v)
(b)Tobacco curing	-	54	238	292(vii)	(vii) Est.to be 30% of total of (v)
Tribal Trust Lands	-	-	3 500(viii)	3 500	(viii) Per capita consumption of 0,85 m^3 u.b.
Mining sector	-	-	131	131(ix)	(ix) Per capita basis
Urban areas	-	-	281	281(x)	(x) Per capita basis
Sub Total F/wood	-	269	4 705	4 974	
GRAND TOTALS	294	369	5 481	6 144	

Appendix 5

SEED STORAGE AND TESTING IN ZIMBABWE

By B.R.T.Seward

Introduction

Seed storage and testing are complex and specialist fields and it would not be possible to cover the many aspects of both subjects in one short paper. While there are a number of publications dealing with the storage and testing requirements of many important species used in commercial and industrial plantations throughout the world, there is a lack of information on some of the less well known species that are already, and could become, increasingly important in the future. Agroforestry and multipurpose species are two examples, particularly in an African context. There is therefore an urgent need to carry out more work into some of the basic testing and storage parameters of these lesser known species, and it is anticipated that the new Regional Seed Centre will have a useful role to play in this work.

Storage:

Excluding damaged seed, whose storage life is adversely affected regardless of storage facilities, there are a few basic principles that can be followed for extending the storage life of seed in the absence of equipment to carry out proven storage practices. For those species, such as pines and eucalypts, known to require low moisture contents (m.c's.) and temperatures for successful storage, it should not be too difficult to dry seed(without applying excessive heat that could damage the seed), thereby reducing m.c's. Once dried, it must be sealed and stored in a cool place. Seed kept in open containers and subjected to large temperature and moisture fluctuations is almost guaranteed to lose viability fairly rapidly. Providing seed has been well dried (and even treated with an insecticide/fungicide if deemed necessary), it can be sealed quite effectively in a variety of suitable containers, including plastic bags. If more than one plastic bag is used, several very tight knots can be tied in the necks of each bag, thus affording a reasonably airtight container. Sealing after drying ensures that the seed does not come into contact with the air and is therefore not affected by changes in the relative humidity of the atmosphere with which it strikes an equilibrium by mutual exchange of moisture. It is this fluctuation, interacting with high temperatures, that usually brings about a rapid deterioration of seed viability. Storing seed in a cool place is largely a matter of common sense, and there is little need to elaborate on this aspect.

Testing:

The purpose of conducting tests is to obtain essential information on the potential of seedlots to germinate and produce seedlings and, by extension, to calculate the amount of seed required to meet specific planting requirements. Tests involve using samples, which in most cases are only very small fractions of their respective seedlots, and unless the samples are truly representative, the time, effort and precision that go into testing the seed will have been wasted and the results largely meaningless. There are a number of acceptable sampling methods and, during the course of this workshop, you will be seeing at least three of them.

A simple and useful test that used to be conducted at the Forest Research Centre in Harare was a sandbox test, which is a modification of the "sand flat" technique used in the U.S.A. Although it is now largely discontinued, it was originally carried out as an adjunct to the formal germination tests carried out in the government seed testing laboratories. Results obtained from the sandbox and laboratory tests indicated that it was possible to establish meaningful comparisons, which were generally better for pines than for eucalypts. It is interesting to note that the results from sandbox tests are always consistently lower than those obtained in the laboratory, which is to be expected. Laboratory tests are performed under optimum conditions, whereas sandbox tests can be said to equate more closely to those obtained in the field under normal nursery conditions which, in itself, can be used to advantage. (See Tables 1 and 2).

The basic requirements for conducting sandbox tests are trays and a suitable medium for filling trays, and a structure that provides protection from the elements, birds and rodents. Asbestos-cement seedling boxes measuring 160mm x 100mm x 40mm deep have been found ideal, being more durable than plastic, while coarse gravel dust is used in preference to the finer germination media which are liable to compact and impede drainage. In the case of pine species and the larger-seeded eucalypts such as <u>E.maculata</u>, four replicates of 100 seeds per tray are sown for each seedlot using a template and dibble to control lateral spacing and sowing depth respectively. With smaller-seeded eucalypts, 0,5gms of seed are evenly broadcast-sown in each of the four containers. Watering is done using a fine rose with the object of keeping the medium moist at all times, as it must never be allowed to dry out. No nutrients are needed as the seed has enough food reserves to provide for the seedling's needs during germination. Germination counts can be performed at predetermined, convenient intervals and, once recorded, all germinants are removed from the containers with tweezers. The means of the four replicates can be plotted on a graph from which both germinative energy and germinative capacity can be assessed if required. Germinative energy is taken to be where the percentage germination is greatest in relation to elapsed time, while germinative capacity is usually regarded as the total number of germinated seeds at the end of the test run.

While accepting the limitations of sandbox tests, it is believed they can perform a useful seed-testing function where laboratory facilities are not available.

PROJECT E 107 (GERMINATION TESTS) FORM 1 1695

TABLE 1 SAMPLE FORM

TEST NO.______ SPECIES Pinus taeda S/N.__.__

No.of seeds per box: 100

Date sown 13.9.84 Date of last count 22.10.84

TABLE 1. SAMPLE FORM

TEST NO. ____________ SPECIES Pinus taeda S/N ____________

No. of seeds per box: 100

Date sown 13. 9. 84 Date of last count 22. 10. 84.

BOX NO. 14

DATE	No.	R/TOTAL
17/9	NIL	0
24/9	NIL	0
1/10	10	10
6/10	53	63
15/10	16	79
22/10	3	82

BOX NO. 23

DATE	No.	R/TOTAL
17/9	NIL	0
24/9	NIL	0
1/10	15	15
8/10	49	64
15/10	8	72
22/10	1	73

BOX NO. 75

DATE	No.	R/TOTAL
17/9	NIL	0
24/9	NIL	0
1/10	5	5
8/10	47	52
15/10	19	71
22/10	3	74

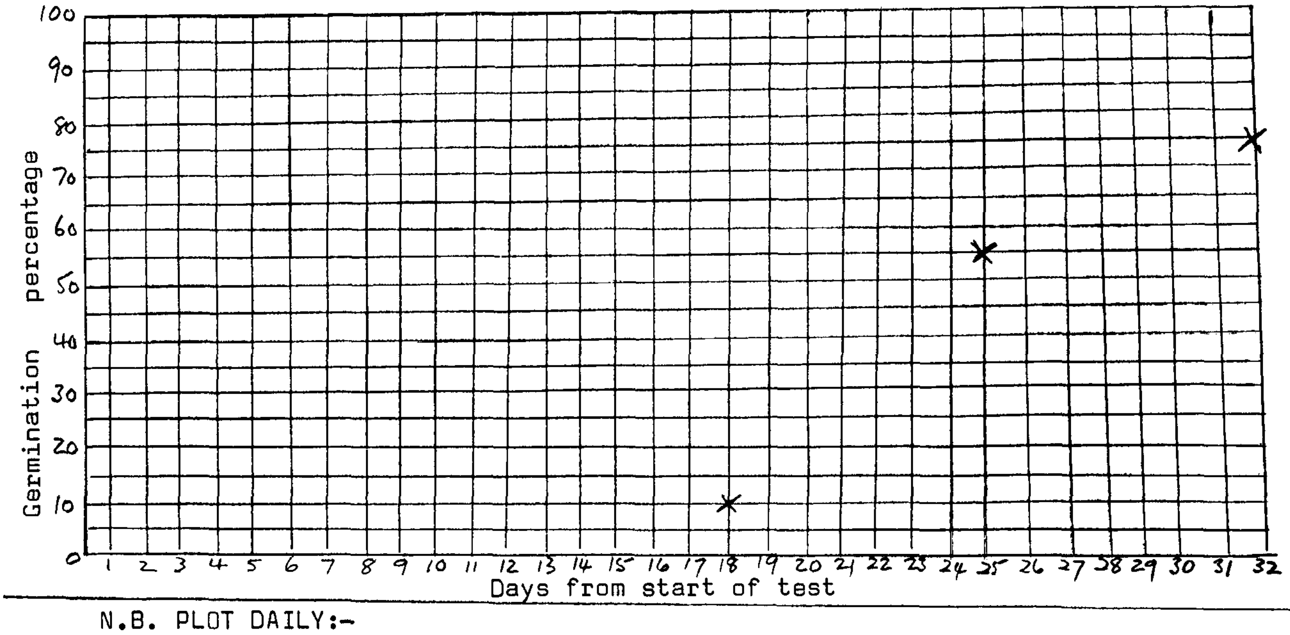
BOX NO. 76

DATE	No.	R/TOTAL
17/9	NIL	0
24/9	NIL	0
1/10	2	2
8/10	40	42
15/10	30	72
22/10	5	77

MEANS.

1/10	8
8/10	55
15/10	74
22/10	76

GERMINATION AT 40 DAYS 76,5 %



N.B. PLOT DAILY:-

1. Mean of all 4 Sub-samples as a percentage
2. On the second germination day & each successive day, additionally, plot the cumulative total daily percentages to date & against each point, enter the actual number germinated to date.

G.P. & S. 80391. TABLE 2 S.5

Phone: 20370, 28121.

Laboratory number MF170-432605

GOVERNMENT SEED TESTING LABORATORY,
MINISTRY OF AGRICULTURE,
P.O. BOX 8100,
CAUSEWAY,

/OTJ

SEED SERVICES
DEPT. OF AGRICULTURE
17 OCT 1984

SEED ANALYSIS CERTIFICATE

Kind and/or variety, as stated by sender. PNUS TAEDA (CLONE MXD) 12192 COLL 8/83 exJMFRS

Sample submitted by F.R.C.

Sample received 9 AUG 1984

PURITY ANALYSIS (percentage weight)				GERMINATION TEST (percentage number)					Pure live seed content
Pure seeds	Weed seeds	Other crop seeds	Inert matter	Germination	Abnormal seedlings	Hard seed	Fresh ungerminated seed	Dead seed	
				83,0				17,0	

Prohibited weed seeds	No. found	Other crop seeds	% by wt.
Weed seeds			
		Kind of inert matter	
Total number of weeds in	g.		

Remarks and recommendations:

Copies to

Senior Seeds Officer