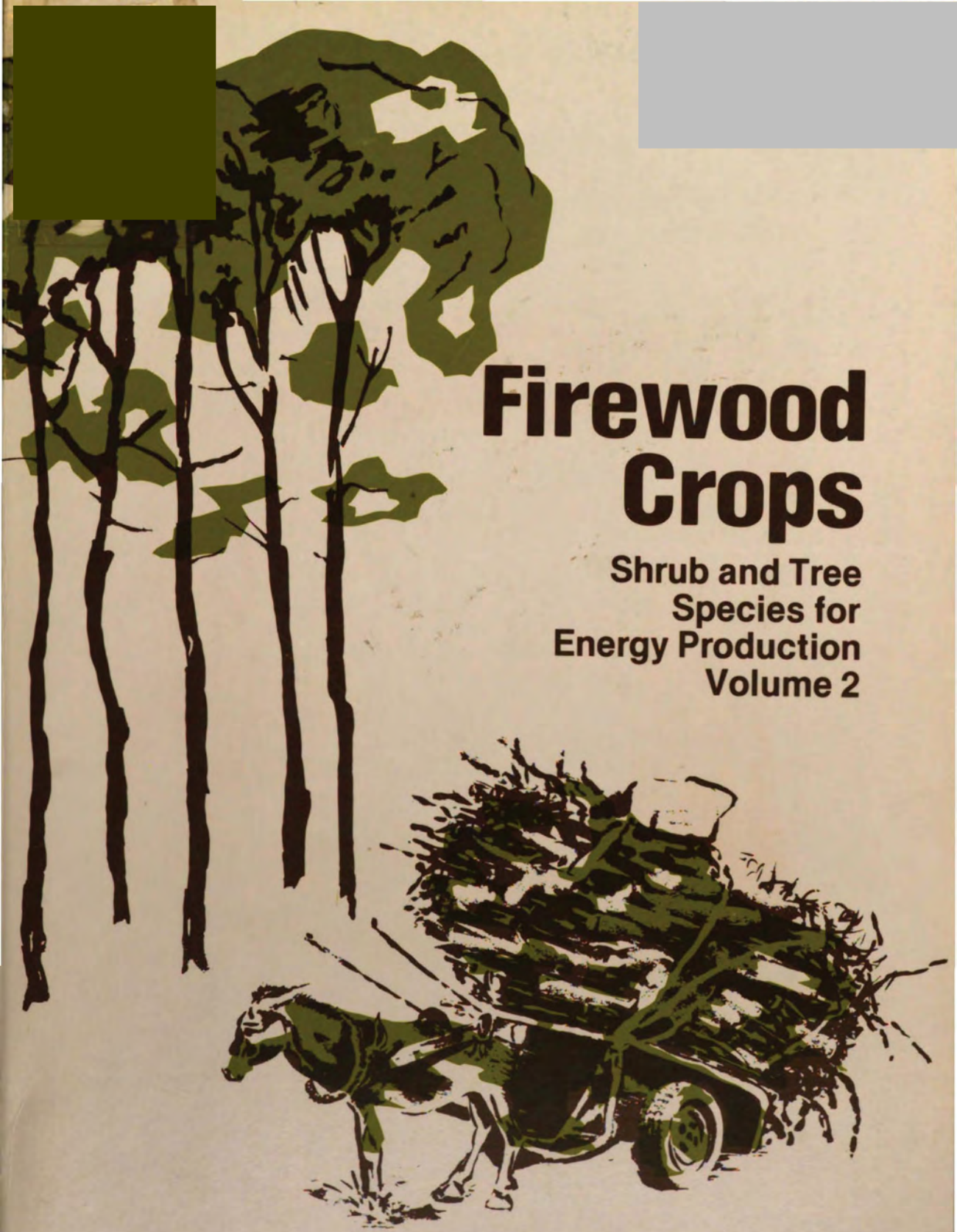

Firewood Crops

Shrub and Tree Species for Energy Production Volume 2

NATIONAL ACADEMY OF SCIENCES

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Shrub and Tree Species for Energy Production Volume 2

Report of an Ad Hoc Panel of the
Advisory Committee on Technology Innovation
Board on Science and Technology for International Development
Office of International Affairs

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This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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PANEL ON FIREWOOD CROPS

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Preface

In 1980 the National Academy of Sciences published *Firewood Crops: Shrub and Tree Species for Energy Production*, a report prepared by an ad hoc panel of the Advisory Committee on Technology Innovation (ACTI). It is one of a series of reports that propose unconventional scientific approaches to problems of developing countries.

The original book describes 60 tree species or groups of species with promise for cultivation around the home or village or in firewood plantations. It does not suggest a comprehensive solution to the firewood crisis, but it does examine one part of the solution: the selection of species suitable for cultivation in different climatic zones.

During the final preparation of the first report, information was received on other species that also seemed to have potential as firewood crops but could not be included because of time constraints and lack of information. After publication of the book, still more information on further species was received. It was decided that these additional species should be evaluated and described in a second volume.

The purpose of this report, as of its predecessor, is not to delineate strategies for growing and utilizing firewood in any given region of the world, but to provide some general concepts and methods for planners and technicians to consider.

Primary emphasis is on species suitable for growing firewood for individual family needs. However, species suited to plantation cultivation for fueling small industrial factories, electric generators, and crop driers are also discussed. Most of the plants are little known in traditional forest production. Some are woody shrubs rather than forest trees, but these many-branched, crooked, sometimes short-lived species may better meet requirements for small-scale village use.

We particularly looked for multipurpose plants that have uses in addition to providing fuel—plants that adapt well to different sites, establish easily, and require little care; plants that thrive in problem environments such as steep hillslopes, low-nutrient or toxic soils, arid zones, and tropical highlands; and plants that have characteristics such as nitrogen-fixing ability, rapid growth, ability to coppice, and high calorific value.

In addition to the first report, other ACTI publications in the series *Innovations in Tropical Reforestation* that contain information on some exceptionally promising firewood species and related technologies are:*

- *Sowing Forests from the Air* (1981)
- *Mangium and Other Fast-Growing Acacias of the Humid Tropics* (1983)
- *Calliandra: A Versatile Small Tree for the Humid Tropics* (1983)
- *Casuarinas: Nitrogen-Fixing Trees for Adverse Sites* (1984)
- *Leucaena: Promising Forage and Tree Crop for the Tropics* (Second edition in preparation)

*For information on how to order these and other reports, see page 90.

Information on promising, fast-growing trees is also contained in Report No. 25, *Tropical Legumes: Resources for the Future* (1979).

These publication activities are supported largely by the U.S. Agency for International Development (AID). This study was sponsored by AID's Office of the Science Advisor, which also made possible the free distribution of this report.

A related report was written by E. L. Little, Jr., under a contract funded by AID and administered by the Forest Service, U.S. Department of Agriculture (*Common Fuelwood Crops: A Handbook for Their Identification*. Communi-Tech Associates, Morgantown, West Virginia. Available for purchase from Communi-Tech Associates, Post Office Box 3170, Morgantown, West Virginia 26503, USA. Single copy price: $13.50 [softcover]). The main objective of the handbook is to aid in the identification of the common trees and shrubs grown as fuelwood crops in plantations and forests chiefly in tropical regions. It was prepared as a companion volume to *Firewood Crops: Shrub and Tree Species for Energy Production* (Report No. 27).

WARNING

This book, if misunderstood, is potentially dangerous. Because of the severity of the firewood crisis, the panel has selected trees and shrubs that are aggressive and grow rapidly. These seem appropriate for cultivation in areas of extreme fuel shortage, particularly where climates and soil conditions are harsh. However, in more equable environments, and where no fuelwood shortages exist, such potentially invasive plants should be introduced only with great care and with serious consideration for the threat posed by their weediness. **In any trials of fuelwood plantations, local species should always be given priority.**

Contents

Introduction

The problems of firewood shortages and the promise of firewood plantations were described extensively in the first volume.

No less than one-and-a-half billion people in developing countries derive at least 90 percent of their energy requirements from wood and charcoal. Another billion people meet at least 50 percent of their energy needs this way. Indeed, it has been estimated that at least half the timber cut in the world still serves its original role for mankind: as fuel for cooking and heating.*

This essential resource, however, is seriously threatened. The developing world is facing a critical firewood shortage. The growth in human population is far outpacing the growth of new trees—not surprising when the average user burns as much as a ton of firewood a year. The results are soaring prices for wood, a growing drain on incomes and physical energy expended to satisfy basic fuel needs, the wasteful burning of animal manures to cook food rather than help produce it, and an ecologically disastrous and potentially irreversible spread of treeless landscapes.

There is no single magical solution to the firewood scarcity, but some blend of fuel conservation, tree planting, and new technologies could certainly ease its severity in any country. The failure of many affected countries to meet the firewood challenge does not, in the final analysis, reflect an absence of suitable technologies, but rather a failure of political systems, of social organization.

Many of the species included in this book would not be appropriate under certain conditions for fuelwood; for example, some of them have much higher value for other uses. The advantage of *Albizia* and a number of pine species, for instance, is that they have multiple uses. Should fuel needs diminish, the species can be turned to these alternative uses. *Albizia* is used for pulp; it could at the same time serve as firewood if that were needed.

In the Korean fuelwood plantation program, 30 percent of the species planted were required to have commercial uses in addition to fuelwood. The idea was that if fuelwood demands turned out to be less than initially anticipated, the trees would still serve some useful purpose.

Setting up a dependable national supply of firewood seems an ideal project for combined action by a country's government and its people.

*E. Eckholm 1975. *The Other Energy Crisis: Firewood.* Worldwatch Paper 1. Worldwatch Institute, Washington, D.C., USA.

I Fuelwood Species for Humid Tropics

Of the one billion people in the humid tropics, perhaps a fifth live in or adjacent to forests. To provide fuelwood and charcoal for their daily needs, these 200 million people fell acres of trees each year. In addition, much fuelwood is cut for shipment to urban markets. Together with commercial timber logging and expansion of agriculture, the result is depletion of tropical forests at a rate that exceeds any present attempts to replenish them.

This study, the second of two volumes, is concerned with ways of establishing self-replenishing sources of fuelwood. In some countries trees are already being profitably cultivated in energy plantations, and the idea has become more attractive as the price of other fuels rises.

Conditions in the humid tropics promote the growth of many kinds of trees and shrubs, with the heat and dampness ensuring high rates of photosynthesis and short harvest cycles. The question is, which trees are the best candidates for deliberate cultivation?

The first volume of this report described the following species as worth testing for fuelwood crops in the humid tropics:

Acacia auriculiformis
Calliandra calothyrsus
Casuarina equisetifolia
Derris indica
Gliricidia sepium
Gmelina arborea
Guazuma ulmifolia
Leucaena leucocephala
Mangroves
Mimosa scabrella
Muntingia calabura
Sesbania bispinosa
Sesbania grandiflora
Syzygium cumini
Terminalia catappa
Trema spp

This section of the present volume describes further shrub and tree species that hold promise for cultivation in humid tropical regions both for profit and for staving off the threat of fuelwood depletion in developing tropical countries.

Species included in other sections of this volume that are worth testing in the humid tropics are *Melaleuca quinquenervia* and *Robinia pseudoacacia*.

Pinus caribaea (see page 22) 8 months old, intercropped with corn 1 month old in Turrialba, Costa Rica. (R. Salazar)

Albizia falcataria

Botanic Name *Albizia falcataria* (L.) Fosberg

Synonyms *Albizzia falcata* (L.) Backer, *A. moluccana* Miq.

Common Names Batai, Molucca albizzia, Moluccan sau, djeungjing, sengon, falcata, vaivai, puah, white albizzia, kayu macis, tamalini, mara, placata, plakata

Family Leguminosae (Mimosoidae)

Main Attributes Because of its rapid growth, vigorous coppicing, and usefulness when grown in combination with agricultural crops, it should be considered for firewood, notwithstanding its low specific gravity and low caloric value. In some regions like Western Samoa and Java the species is already used as fuelwood.

Description One of the fastest growing of all trees, *Albizia falcataria* reaches (under favorable conditions) 15 m in height in 3 years, 30 m in 10 years, and 44 m in 17 years. When grown in the open, its crown spreads to form a large umbrella-shaped canopy, but in plantations it has a narrow crown. Its flowers are creamy white and have a slight fragrance.

Distribution *Albizia falcataria* is native to Papua New Guinea, West Irian, the Solomon Islands, and the Moluccas. The species is grown in plantations, notably in the Philippines and elsewhere in Southeast Asia and in Fiji. It has also been used in variety trials in India, Sri Lanka, Taiwan, and Western Samoa. It is now naturalized in many urban areas of Sabah. On Java, especially west Java, it is planted in home gardens and gardens mixed with herbaceous and tree crops (for example fruit trees) as a source of timber and firewood. The practice is quite widespread in the area and can yield a substantial income for villagers.

Use as Firewood The wood is light, soft, and lacks strength (specific gravity 0.24-0.49). Tests performed in Java show that it makes good charcoal and that its caloric potential varies from 2,865-3,357 kcal per kg.

Yield On better soils growth can be up to 50 m^3 per ha per year, while average sites yield up to 39 m^3 per ha per year on a 10-year rotation. (Growth tends to culminate at or before 10 years.)

Other Uses

- Wood. The wood is excellent for fiber board and particle board. It is also used as veneer core stock and for pallets and crating, furniture components, matches, and boxes.
- Pulp. The species is most suitable for ground wood pulp because of its low density, pale color, and fiber length and qualities. In the Philippines it is successfully used for newsprint.
- Shade. *Albizia falcataria* is widely used as a shade tree for cattle and for cocoa, coffee, banana, and tea plantations.

Environmental Requirements

- Temperature. *Albizia falcataria* requires a temperature range of 22°-29°C.
- Altitude. Within its natural range, this species occurs up to 1,000 m elevation. It is grown at altitudes up to 1,500 m, but generally does best in plantations below 800 m.
- Rainfall. This tropical species thrives in humid tropical climates with no more than a slight dry season (0-2 months). The best Philippine growth has been achieved on sites with an annual rainfall of 4,500 mm and no dry period.
- Soil. *Albizia falcataria* does best on well-drained, deep soils with reasonably high fertility. Like some other legumes, it is likely to perform better on slightly alkaline than on acid soils.

Establishment The tree regenerates easily by natural seeding on any clearing. It produces seeds prolifically and regularly from an early age, usually from 3 to 4 years on.

- Seed treatment. Best germination occurs after mechanical scarification or treatment with sulfuric acid for 12 minutes followed by water for 15 minutes. Seed may also be placed in boiling water, removed from heat, and wrapped in wet cloth for 24 hours.
- Ability to compete with weeds. Remarkably fast initial growth is typical of *Albizia falcataria*; therefore, weeding normally can be limited to one complete weeding and three spot weedings during the first year after planting. Occasional elimination of vines may be necessary after that.

Pests and Diseases Various white and brown rots are the most serious diseases afflicting *Albizia falcataria* plantations. These diseases normally follow wind damage. Plantings in the Philippines are subject to attack by the fungus *Coiticum salmonicolor*, causing "albizia canker,"

Albizia falcataria growing on Mt. Vaea, near Apia, Western Samoa, where it is widely used for firewood. (B. Cahusac)

which can be devastating unless controlled with Bordeaux mixture or other fungicides. Harmful insects are *Eurema blanda, Eurema hecabe, Semiothise* spp., *Xystocera festiva* (wood borer), and *Penthicodes jarinosa.*

Limitations *Albizia falcataria* is extremely susceptible to uprooting and breakage of branches by high winds. Once exposed, the low-density wood is easily attacked by fungi, which bring about rotting of the trees. The tree has a massive root system that is known to contribute to soil erosion, and it should not be planted on steep hillsides. Large tree roots, rather than holding the soil, have an opposite effect. Grass and herbaceous plants are soil retainers.

Bursera simaruba

Botanic Name *Bursera simaruba* Sarg.

Synonyms *Bursera gummifera* L., *B. ovalifolia* Engler, *Elaphrium simaruba* Rose

Common Names Gumbo limbo, gum-elemi, gumtree, West Indian birch, red birch, almacigo, indio desnudo, palo mulato, galo de incienso, turpentine tree, and many others

Family Burseraceae

Main Attributes This handsome tree is esteemed for fuel and for living fence posts throughout Central America and the Caribbean. So far, however, it is virtually unknown elsewhere. It is easily propagated—green branches thrust into the ground take root quickly and grow vigorously. The trees regenerate swiftly after cutting. In fact, even trees blown down by winds send up shoots, which soon become trunks as big as the original.

Description The gumbo limbo as it grows in forests is an erect, straight, resinous tree reaching 20–30 m, with a stout trunk (to 75 cm) that is often forked about 2 m from the ground, forming thick vertical branches that fork again higher up. The bark, which peels off in thin flakes, is typically copper colored (sometimes silvery) and glossy. When growing in the open, the branches spread and form a broad crown. The tree is bare during the cool, dry season. The leaves are compound and have a turpentine odor when crushed.

Distribution This handsome tree is native to and esteemed in areas from central Florida through the Bahamas and West Indies and from southern Mexico to the northern parts of South America.

Use as Firewood The wood has a high moisture content, but when thoroughly dry it is commonly burned as firewood and charcoal. Because of its flammability, Indians of Yucatan use it for kindling. The wood has a specific gravity, green and oven dried, of 0.30–0.40.

Yield No studies have been made of the potential firewood yield. In Belize, surveys have shown populations of up to 57 trees per ha in the wild.

Other Uses

- Wood. The wood seasons well, with slight shrinkage; is easily worked; saws, planes, and polishes satisfactorily; holds nails firmly; and is used commercially for a veneer that resembles paper birch and for plywood for interior use. It is fairly strong, but is not durable for outside use, being attacked by borers, beetles, and termites. Locally, it is made into boxes and crates, soles for sandals, light furniture, and matchsticks and toothpicks.
- Beautification. The gumbo limbo is much used as an ornamental. In southern Florida it is planted as a landscape tree in new developments and along streets, mainly because of its quick growth, but also because of the newly awakened appreciation of native species. It has long been planted as a living fence throughout the Caribbean area.
- Resin. The aromatic resin, which oozes from an incision as a thick, amber gum, is concentrated and dried and the chips offered as tithes or burned as incense in South American churches.

Environmental Requirements

- Temperature. Gumbo limbo requires a subtropical or tropical climate. Fully grown trees stand occasional brief winter frosts.
- Altitude. It is found from sea level to 1,800 m elevation in Guatemala, but generally occurs below 1,000 m.
- Rainfall. The tree abounds where annual rainfall averages 500–1,400 mm.
- Soil. Gumbo limbo endures extreme soil types ranging from fertile, moist forest habitats to dry, barren limestone, but it grows best in rich lowlands. Under the severely arid conditions of some Caribbean islands it is rather stunted and crooked, but survives. It has a high degree of salt tolerance.

Establishment While the tree reseeds itself in its natural areas, it is seldom deliberately propagated by seed.

- Ability to compete with weeds. Being a forest tree, the gumbo limbo tolerates shade at all stages of growth. It is not retarded by the shade of competing vegetation even in the juvenile period.

Pests and Diseases The resin is a natural insect repellent, and no pests or diseases are reported in available literature.

Limitations Apart from cold sensitivity, the handicaps seem to be only the brittleness of branches, which may be snapped off by strong gusts of wind; the perishability of exposed wood; and the discoloration of the timber by the

Bursera simaruba. (From *500 Plants of South Florida* by J. Morton)

sap-stain fungi to which it is prone because of its high moisture content. (Such staining can be avoided by immediate kiln drying or by immediate spraying of the cut logs with a fungicide.)

Coccoloba uvifera

Botanic Name *Coccoloba uvifera* (L.) L.

Synonyms *Coccolobis uvifera* Jacq., *Polygonum uvifera* L.

Common Names Seagrape, seaside grape, bay grape, baya de praga, mangle de falda, raisin la mer, uva de mar, uva de playa, uva caleta, uvero, horsewood, hopwood

Family Polygonaceae

Main Attributes Seagrape is one of the first woody species to become established on sandy shores, being more hardy in these exposed places and more tolerant of salt than most trees.

Description Fully exposed on windswept seacoasts, the seagrape is dwarfed and bushy (to 2.5 m high) and forms dense colonies. On leeward shores and inland locations it becomes a round-topped, spreading, low-branching tree up to 15 m high, with thick, smooth branches and a stout trunk to 1 m in diameter. The stiff and leathery leaves are large, thick, and almost circular. They turn scarlet or yellow and drop off in the winter dry season, but they are soon replaced by silky new growth with a bronze hue. Small and fragrant white flowers are borne profusely in spring and develop into red-purple grapelike clusters of velvet-skinned edible fruits. Male and female flowers are borne on separate trees.

Distribution The seagrape is native to southern Florida, Bermuda, the Bahamas, and West Indies. It also grows from the northeast coast of Mexico along the Atlantic coast of Central America, reaching down both coasts of South America as far as Peru and Brazil. It is often planted as a seashore windbreak in the Hawaiian Islands. It was introduced into the Philippines and Zanzibar about 40 years ago.

Use as Firewood Throughout its range, the wood is commonly employed as firewood and for making charcoal. In Mexico the charcoal has been particularly prized by blacksmiths and silversmiths. In an ignition trial, small dry branches and twigs were lit with matches. The first flames gave off a little smoke; within 5 minutes there were red coals and only wisps of smoke; and in another 5 minutes there were bright, smokeless, even flames whose intense heat surpassed the maximum 204°C on a thermometer held 40 cm above the fire, proving the seagrape to be ideal for cooking. Its specific gravity is reported to be from 0.7 to 0.96.

Yield The seagrape is fast growing, multi-stemmed if pruned, and profusely branched. Yield should be exceptional, though no statistics are available.

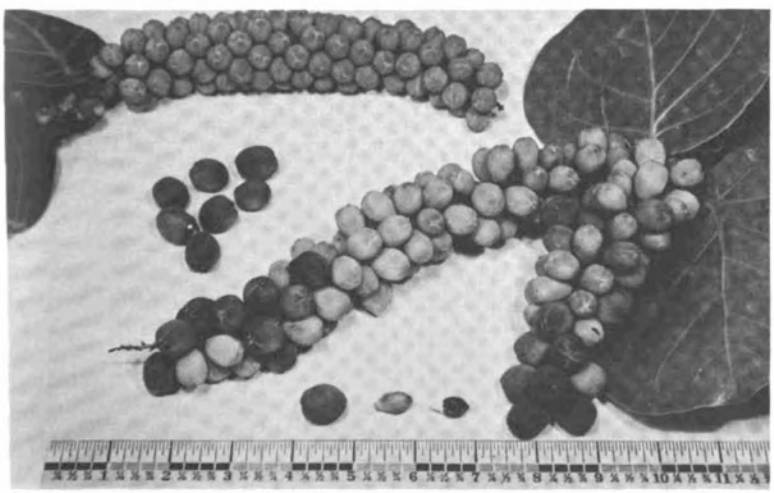
Other Uses

- Wood. The wood is fine grained, compact, heavy, and hard. It takes a high polish and is valued for furniture and cabinetwork, but is subject to dry-wood termites.
- Ornamental. The seagrape is widely grown as an ornamental tree and is a great favorite for Florida landscaping in even the most sophisticated sites, either free form or trimmed to a globular head. It is also close planted and trimmed as a hedge. It flourishes inland as well as in coastal locations and is long lived.
- Fruit. The fruits are popular in the Caribbean, where they are sold by street vendors and in local markets. They make excellent jelly.
- Honey. The flowers yield abundant nectar, and the honey, though high in moisture, is of good quality, light amber in color, and spicy.
- Bark. The bark is rich in tannin. In the past, the red-brown evaporated decoction of the wood and bark, called kino, was regularly exported to Europe for use in tanning and dyeing.

Environmental Requirements

- Temperature. The seagrape requires a subtropical or tropical, climate. It does need full sun.
- Altitude. In the Philippines the tree grows well from sea level to an elevation of 500 m. In Florida it occurs up to the central part of the peninsula, and it has withstood brief freezes that have killed mature mango trees.
- Rainfall. Throughout its range, the seagrape is subject to great variations in annual precipitation, from the 1,400-mm Florida average to the 500-mm average of the near-arid islands of the Caribbean.
- Soil. The seagrape is remarkable in its ability to thrive in nearly pure sand and on rocky coasts, as well as in marl, oolitic limestone, and diabase, dry or wet, but with good drainage. It is extremely tolerant of salt.

Establishment Seeds germinate readily, but a seedling seagrape may not fruit for 6–8 years. Vegetative propagation is preferred because it is



Coccoloba uvifera tree and fruit. (K. and J. Morton)

quicker and is the only way to assure reproduction of female trees or selected cultivars. Air layering, ground layering, and grafting are practiced, but mature wood cuttings are most commonly employed for mass multiplication.

- Seed treatment. None required.
- Ability to compete with weeds. The seagrape cannot tolerate shade; therefore, seedlings should be weeded until they outgrow competition. For this reason, cuttings are more practical because they become established quickly and outdistance the weeds.

Pests and Diseases In Hawaii, seagrapes planted inland are attacked by the rose beetle *Adoretus sinicus*. Generally, the seagrape is virtually free of pests and diseases, but occasionally, under adverse conditions, the leaves are affected by rust or fungal or algal leaf spots, and there have been reports of mushroom root rot.

Limitations The seagrape is not adapted to extremely hot and humid environments. It needs full sun, low altitudes, and mild winter weather where only brief frosts may occur. Leaf fall may be a nuisance in cold dry seasons.

Eucalyptus brassiana

Botanic Name *Eucalyptus brassiana* S. T. Blake

Common Names Cape York red gum, gum-topped peppermint (Queensland); karo (Papua New Guinea)

Family Myrtaceae

Main Attributes *Eucalyptus brassiana* is a hardy, fast-growing tree adapted to a variety of site conditions in the lowland tropics. It tolerates periodic flooding and readily coppices.

Description The tree often grows from 7 to 15 m high on infertile sites but reaches more than 30 m on better sites. The trunk may be moderately straight for half the tree's height, but is often badly shaped. Typically, it divides into several large ascending branches.

Distribution A tropical eucalypt, *Eucalyptus brassiana* occurs in southwestern Papua New Guinea and on Cape York Peninsula in Queensland, northern Australia, between latitudes 8° and 16° S. The best development is on lowland sites in Papua. It has recently been introduced to several subhumid to humid tropical areas.

Use as Firewood *Eucalyptus brassiana* is a fast-growing species with the capacity to produce coppice shoots. The wood is moderately dense, probably similar to that of *Eucalyptus camaldulensis*.

Yield Trees in experimental plots in Malaysia have reached as high as 7.6 m, with a diameter of 6.3 cm at 2.5 years of age. In Bangladesh the tree's growth rate is similar to that of *Eucalyptus camaldulensis*, while it has shown average-to-good growth rates in trial plots in Vietnam, parts of East and West Africa, and Brazil.

Other Uses

- Wood. The brown or pale reddish brown heartwood is hard, heavy, strong, and durable. Because the natural stands occur in areas of low population density, the timber has been used very little. On Daru Island, Papua New Guinea, it is regarded as an excellent building timber for general construction and posts.

Environmental Requirements

- Temperature. In Queensland and Papua New Guinea, the natural habitat of the species, the climate is tropical and humid to subhumid. The trees withstand high temperatures, since the mean maximum temperature of the hottest month is around 32°C. Frosts have not been recorded, and the seedlings are likely to be frost-sensitive.
- Altitude. The natural stands occur at low altitudes from sea level to 650 m.
- Rainfall. In its native habitat the tree tolerates a dry season lasting from 3 to 5 months; the minimum annual rainfall is 1,000 mm.
- Soil. The species grows from well-drained rocky slopes to undulating plains and on seasonally inundated flats and depressions. The soils are typically infertile. It has grown well on the margins of rice fields in Bangladesh.

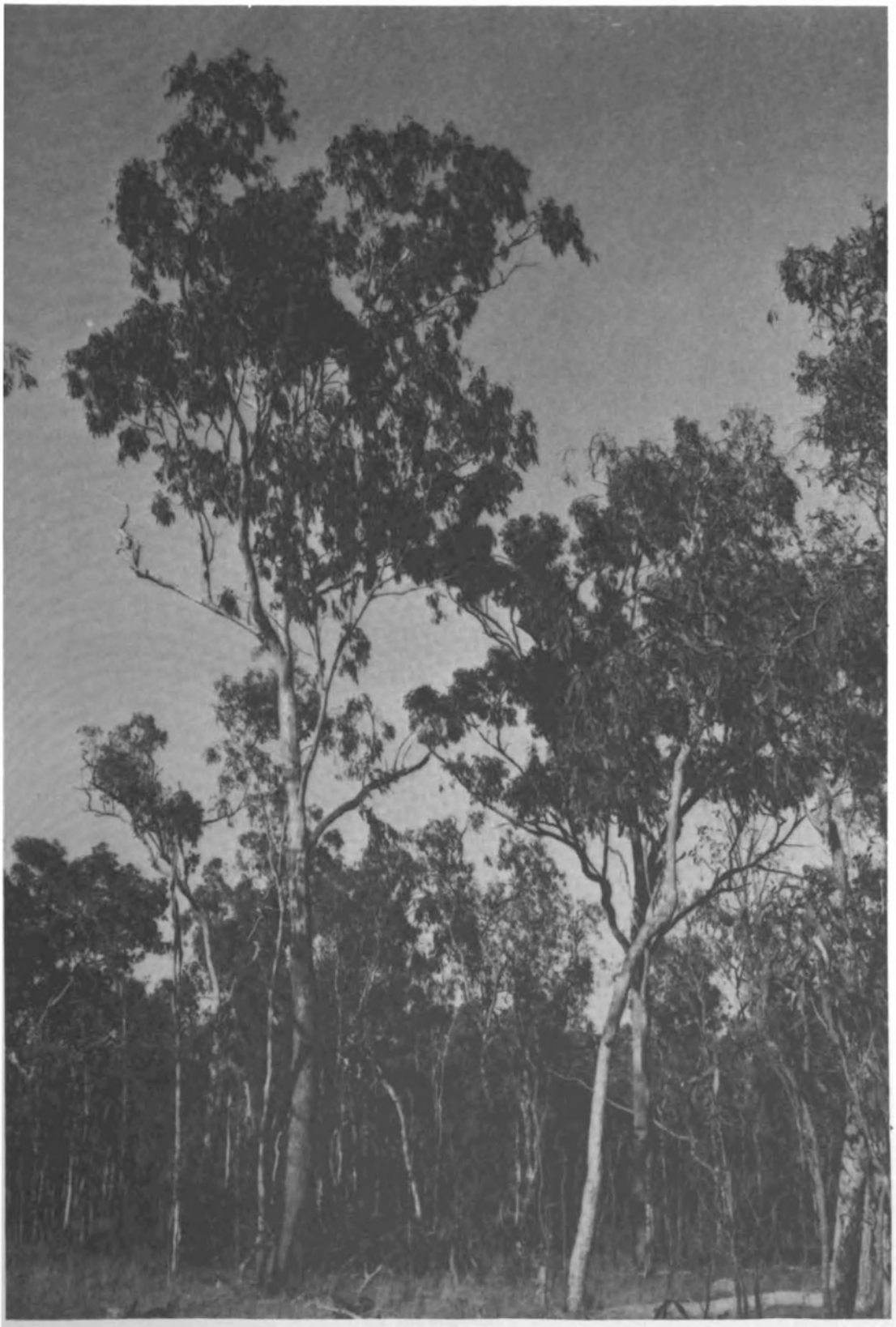
Establishment *Eucalyptus brassiana* regularly produces good seed crops. Seed germination is high, and the seeds are long lived when kept sealed and dry in cold storage. The plantable stock raised in the nursery is likely to be about 25 percent of the viable seeds sown. The seedlings can be raised in trays and transplanted into containers or sown directly in containers. Under favorable conditions, plantable seedlings can be produced within 6-10 weeks after sowing.

- Seed treatment. None required.
- Ability to compete with weeds. Poor. Rapid initial growth is dependent on complete weeding during the first year.

Limitations There is little experience with planting this species in large areas, and its silvicultural requirements are not well known, but it must be kept free of weeds during the establishment phase. Provenance trials are required to determine the optimum seed sources.

Related Species The tree is related to the well-known fuelwood species *Eucalyptus tereticornis* and *Eucalyptus camaldulensis*, and to *Eucalyptus exserta*, which is widely planted in the People's Republic of China.

Eucalyptus brassiana, Australia. (J. Doran)



Eucalyptus deglupta

Botanic Name *Eucalyptus deglupta* Blume

Synonym *E. naudiniana* F. Muell.

Common Names Kamarere (Papua New Guinea); bagras (Philippines); leda (Indonesia)

Family Myrtaceae

Main Attributes Kamarere is one of the world's fastest growing trees. It is capable of colonizing land eroded by landslides and areas of recent volcanic activity.

Description This is a large tree, generally reaching from 35 to 60 m high but occasionally reaching up to 75 m, with diameters of 0.5–2 m or greater. On unstable soils and river alluvia the tree often develops buttresses 3–4 m high. The trunk is one-half to two-thirds of the tree height and is typically straight.

Distribution A wholly tropical eucalypt, kamarere has a markedly discontinuous distribution that includes Mindanao in the Philippines; Sulawesi, Ceram, and Irian Jaya in Indonesia; and parts of the mainland and New Britain in Papua New Guinea. The best development occurs on riverine banks at altitudes mainly below 150 m in New Britain. The species has been introduced to many humid tropical areas.

Use as Firewood The main use of *Eucalyptus deglupta* is as a pulpwood. It is normally considered too valuable for use as firewood. However, it grows so quickly that in suitable fuel-short areas it could be considered for both uses. Its wood has a specific gravity of 0.40–0.80. Trees greater than 15 years of age yield good charcoal.

Yield Test plots in Papua New Guinea suggest that in 15 years' time it may reach 44 m in height, with a diameter at breast height of 54 cm. Yields of 20–40 m^3 per ha per year are common to that age in several countries.

Other Uses

- Wood. The wood from natural stands has been used for heavy construction, furniture, and flooring. Shrinkage and fibre collapse have been slight.
- Pulp. Pulps of good yield have been obtained using the sulfate process.

Environmental Requirements

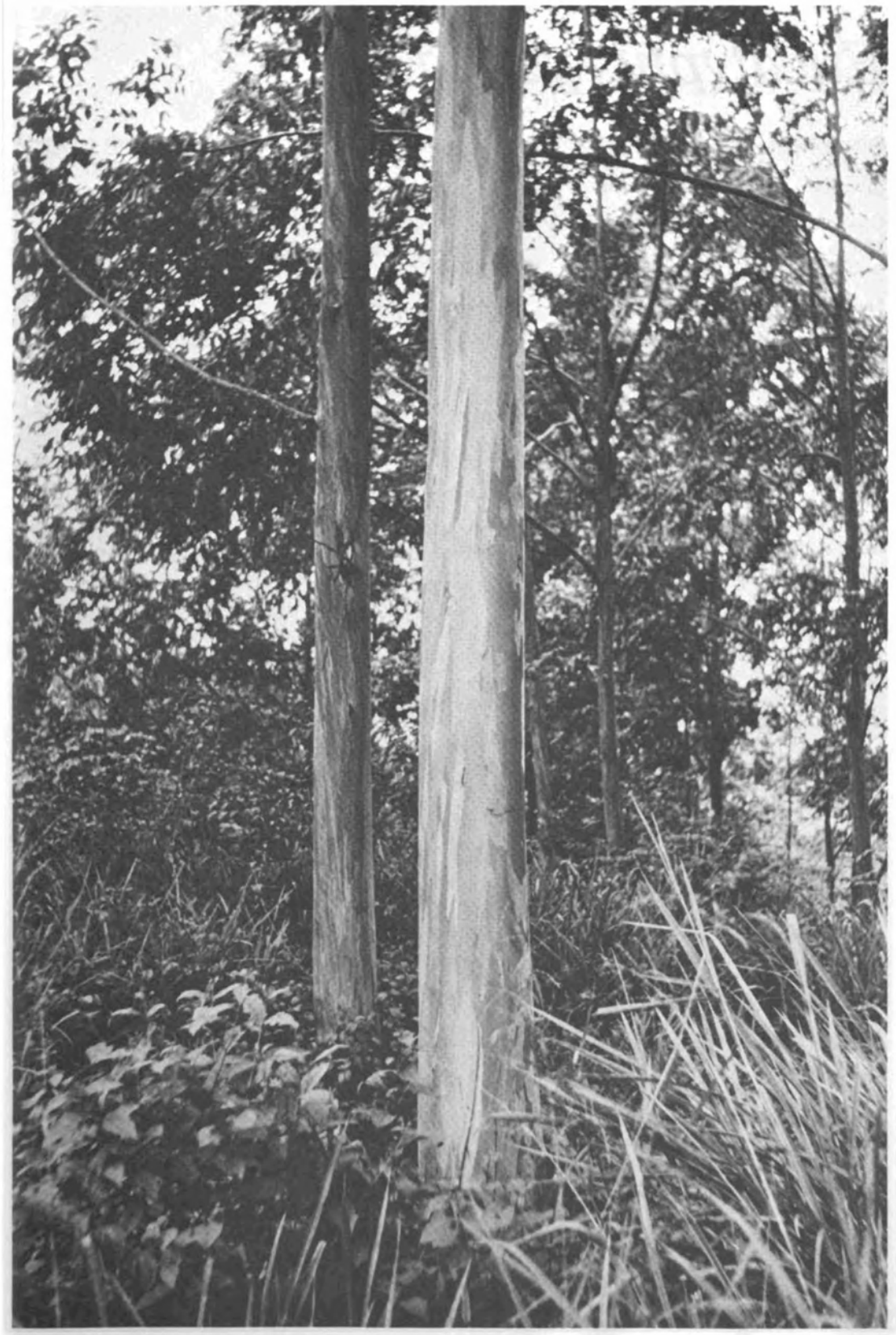
- Temperature. Kamarere's native climate is subequatorial in coastal areas and tropical elsewhere. Near sea level the mean maximum temperature of all months may be 30°–32°C, but at higher altitudes the mean maximum of the coolest month may be only 24°C.
- Altitude. It is found from sea level to about 1,800 m.
- Rainfall. The mean annual rainfall is mainly 2,500–3,500 mm in its native habitat, but there is no upper limit for planted stands on well-drained sites.
- Soil. The tree grows best on deep, moderately fertile sandy loams, but also occurs on soils derived from volcanic ash and pumice. Although most stands occur on alluvium along rivers, landslides and volcanic disturbances provide sites for small stands inland.

Establishment Under plantation conditions, kamarere flowers at an early age, usually by 3–4 years. Normally, the seedlings are field planted as tubed stock.

- Seed treatment. None required. The seed germinates quickly and subsequent seedling growth is usually fast.
- Ability to compete with weeds. The planting fields for kamarere must be weeded for the first 6 months and some weeding is necessary until the end of the second year.

Pests and Diseases In both natural stands and plantations, termites are the most serious pests of *Eucalyptus deglupta*. Young trees in Malaysia have been damaged severely by the cossid moth *Zeuzera coffeae* and a ring bark borer (family Hepialidae). Tip dieback of young trees in the Solomon Islands is caused by the coreid bug. Ant control must be continuous in Brazil. Trees of some provenances have been attacked by a stem and bark borer (*Agrilis* spp) in Papua New Guinea and the Philippines.

Limitations The bark is very thin and the tree is sensitive to fire, susceptible to frost damage, and intolerant of drought. Young trees in particular are brittle and easily damaged by strong winds, thereby decreasing the viability of seed. Kamarere usually does not coppice.



***Eucalyptus deglupta*. Four-year-old tree planted in Costa Rica by a small farmer on land used for agroforestry.**
(H. J. von Maydell)

Eucalyptus pellita

Botanic Name *Eucalyptus pellita* F. Muell.

Synonym *E. spectabilis* F. Muell.

Common Name Red mahogany, red stringybark, large-fruited red mahogany, Daintree stringybark

Family Myrtaceae

Main Attributes Red mahogany grows quickly in humid and subhumid tropical lowland regions. Good provenances from the Cape York Peninsula could provide the basis for important new eucalypt trials in tropical countries.

Description Red mahogany is a medium to large tree, usually 20–25 m in height but exceeding 35 m under favorable conditions. At its best its trunk grows straight up to half the tree height, with a large, heavily branched crown. On bare rock above beaches it may be reduced to a bushy shrub.

Distribution This eucalypt occurs on lower coastal slopes of Australia. Northern populations occur from near the top of Cape York Peninsula to between Cairns and Townsville (latitude 12°–18°S) and southern ones from near Brisbane to the Batemans Bay area in southern, coastal New South Wales (27°–36°S).

Use as Firewood The tree has a high density (990 kg per m^3) suitable for charcoal and fuelwood.

Yield In Espirito Santo, Brazil, a northern provenance reached a mean height of 13.7 m and a diameter of 12.6 cm in 3.5 years. In Minas Gerais State, the same provenance was 14.9 m tall with a diameter of 13.3 cm at the same age.

Other Uses

- Wood. The heartwood is moderately heavy, strong, and durable in and out of the ground. Although the grain is somewhat interlocked, the wood is not difficult to work. It has a wide range of uses for building and heavy ornamental work.
- Honey. The flowers are a minor source of thin, strong-flavored honey from January to February in Queensland. They provide large quantities of pollen for the bee colonies.

Environmental Requirements

- Temperature. Red mahogany is found mainly in the humid climatic zone. The mean maximum temperature of the hottest month varies from 24° to 33°C and the mean minimum of the coolest from 6° to 16°C; frosts are absent or occur less frequently than five times a year.
- Altitude. From sea level to about 750 m.
- Rainfall. The mean annual rainfall in the tree's natural Australian habitat is 900–2,300 mm.
- Soil. The tree grows mainly on gentle-to-moderate topography, though it is found to a limited extent on steep, well-drained slopes. It prefers moist sites—the lower slopes of large ridges and even alongside small streams in the drier and hotter parts of its occurrence. Soil types range from shallow sandy podsols derived from sandstone to deep forest loams. However, red mahogany is recommended for planting only in well-drained, sandy soil.

Establishment

- Seed treatment. No pretreatment is required. The seeds remain viable for many years under controlled storage conditions.
- Ability to compete with weeds. Once established, the tree forms a dense crown that shades out weeds at an early stage.

Pests and Diseases *Eucalyptus pellita* is moderately resistant to the stem canker *Cryphonectria cubensis* (Bruner) Hodges.

Limitations In areas other than Australia where it has been grown, *Eucalyptus pellita*'s growth rate has not been good enough to demonstrate an advantage over the better-known *Eucalyptus resinifera*. However, these results appear to be based largely on the southern provenances. Northern provenances have grown well in moist tropical areas, especially in Brazil.

Eucalyptus pellita, Australia. (R. D. Johnston)

Eucalyptus urophylla

Botanic Name *Eucalyptus urophylla* S. T. Blake

Synonyms *E. decaisneana*, also erroneously referred to as *E. alba*

Common Names Ampupu, Timor mountain gum

Family Myrtaceae

Main Attributes *Eucalyptus urophylla* shows promise in tropical or subtropical countries where the rainfall exceeds 1,000 mm annually. It is highly resistant to the stem canker *Cryophonectria cubensis* (Bruner) Hodges, which has caused serious losses to eucalypts in Latin America.

Description On favorable sites this species can exceed 50 m in height, with diameters of up to 2 m and straight clear boles for half or two-thirds of the tree height. There is considerable variation within the species in the degree of retention of rough bark, ranging from only a short stocking to boles fully clothed in rough fibrous bark.

Distribution *Eucalyptus urophylla* occurs in Timor and other Indonesian islands. It was introduced into Brazil in 1919 under the name *Eucalyptus alba*, and the progeny from this introduction were used to establish large areas of plantations. The progeny were mainly hybrid stock, and these trees have become known as "Brazil alba." The pure species has grown extremely well in Brazil, Cameroon, Ivory Coast, and the People's Republic of Congo and is showing considerable promise in areas in Southeast Asia and the Pacific where there is a distinct but not too severe dry period in the cool season.

Use as Firewood Although one of the less dense eucalypts, young trees make a satisfactory fuelwood. It coppices well.

Yield Yields of 20–30 m^3 per ha per year have been reported under favorable growing conditions. Low-altitude provenances have usually given the highest yields.

Other Uses

- Wood. The wood of older trees is used in heavy construction, building poles, and fence posts and gives a high pulp yield.

Environmental Requirements

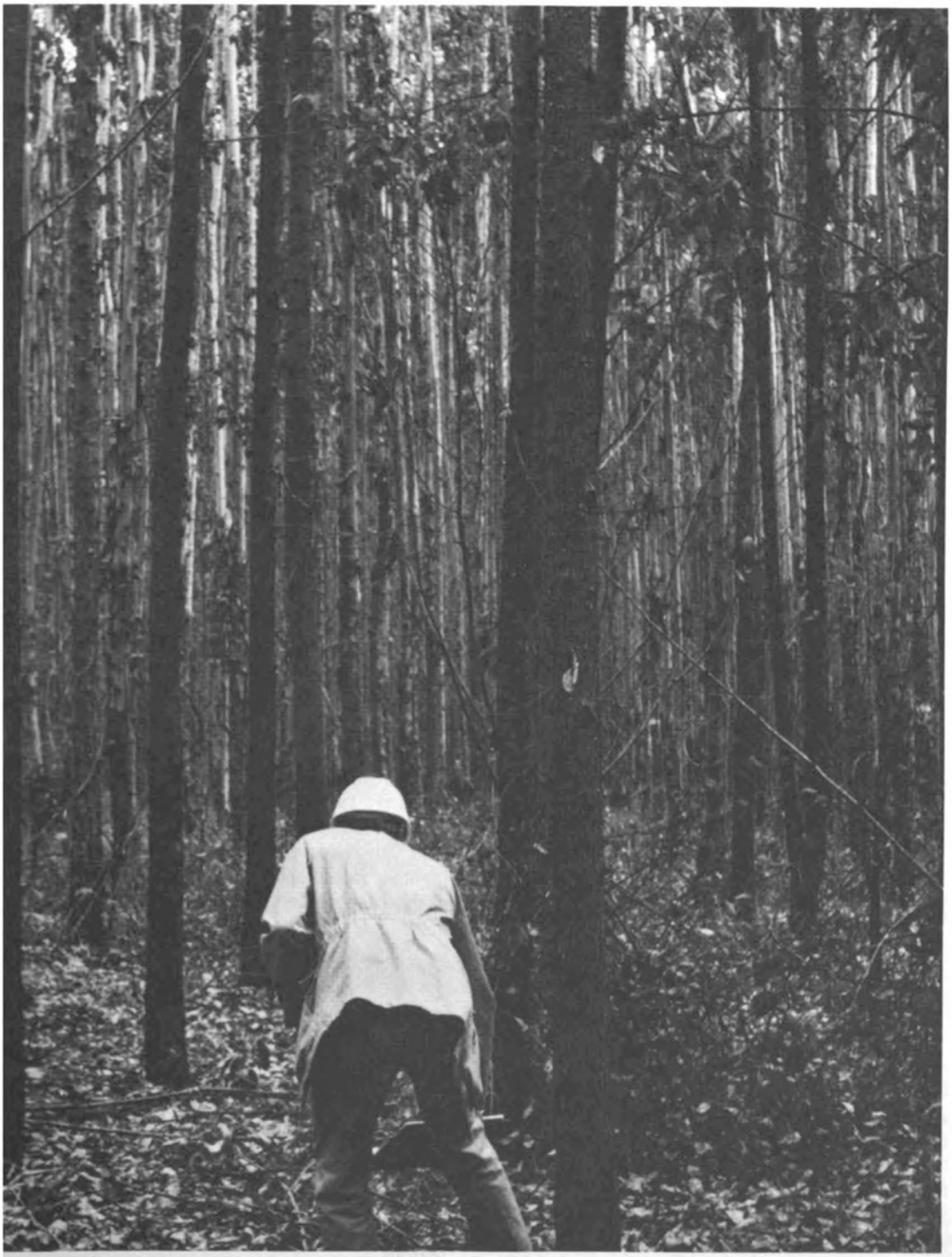
- Temperature. Mean monthly temperatures range from 18° to 28°C in *Eucalyptus urophylla*'s natural habitat.
- Altitude. This is primarily a mountainous species, growing at altitudes from 300 m to almost 3,000 m.
- Rainfall. The rainfall can be as low as 1,300–1,400 mm, but the tree does best with rainfall of 2,000–2,500 mm.
- Soil. This eucalypt grows best on deep, moist, free-draining, medium-to-heavy soils derived from noncalcareous rock.

Establishment The species seems to grow best under nursery conditions. In one trial in Costa Rica, seedlings were transplanted 55 days after sowing to polyethylene bags containing loam-sand mixture. In northeast Brazil the seedlings are grown in polyethylene bags in the nursery. They reach an optimum size of about 25 cm in 75 days. A technique to raise *Eucalyptus urophylla* and a hybrid of *Eucalyptus urophylla* × *Eucalyptus grandis* vegetatively by cuttings has been developed in Brazil and the Congo.

- Seed treatment. None required.
- Ability to compete with weeds. The tree is highly sensitive to competition in the early stages, and the plantation must be kept weed free for 6–12 months after planting. After that time, the dense crown inhibits competing weeds.

Pests and Diseases *Eucalyptus urophylla* is susceptible to termite attack. In Australia defoliation by a range of insects has reduced the growth considerably. The trees are resistant to the canker disease in Brazil. Leaf-cutting ants, *Atta* spp. and *Acromyrmex* spp., can be a problem in parts of South America; control measures are essential where the ants are present.

Limitations Seeds are not yet readily available from plantations or natural forests; however, a seed orchard has been planted in the Congo.



Eucalyptus urophylla, Brazil production stand. (CSIRO, Brisbane, Australia)

Hibiscus tiliaceus

Botanic Name *Hibiscus tiliaceus* L.

Synonyms *Pariti tiliaceum* Britton, *Paritium tiliaceum* St. Hil.

Common Names Mahoe, majagua, majagua de playa, sea hibiscus, seaside mahoe, emajagua, hau, among others

Family Malvaceae

Main Attributes The wood of this fast-growing tree is used chiefly for fuel, although the fibrous bark is much used for cordage. The trees sprout from stumps and, when cut back, produce long, vigorous shoots from which quantities of rope can be made.

Description The mahoe is an evergreen that may grow 12 m tall. Normally, it has a short trunk and a broad, rounded crown. In wetlands it is branched close to the ground, forming a low and sprawling massive mound. The lowest branches bend down, take root, and put forth new growth, thus forming extensive tangled thickets. The handsome leaves are somewhat heart shaped.

Distribution The mahoe is pantropic, growing just inshore of the mangroves on the coastal fringe and extending up estuaries and rivers.

Use as Firewood In Puerto Rico, India, and Malaya, the wood is used principally for fuel; it is also employed as firewood in Ghana. In Malaya, the tree is recommended for planting on poor soils as a firewood resource. In American Samoa and other Pacific islands, it is prized for making fire by friction because it ignites readily when a hardwood stick is twirled rapidly against it. In the past, in Hawaii, oiled sticks of mahoe wood were set afire and thrown from cliffs in quick succession as "fireworks." The wood has a specific gravity of 0.6.

Coppicing is remarkably swift and profuse, with multiple long stems arising from cut stumps.

Yield No systematic study has been made of the productivity of mahoe for firewood. Its rapid growth and spreading habit, however, augur well for high volume per hectare.

Other Uses

- Wood. The tree has been of such inestimable value to Pacific seafarers that it was formerly necessary to obtain permission before cutting a single branch. The heartwood is yellowish or purplish, light but firm, flexible, porous, close grained, easy to work, and takes a high polish. Durable in salt water, it is popular for fishing-net floats, floats for outriggers and for light boats, planking, and pilings for dwellings in wetlands. It is also used for laths for huts and for tool handles and cabinetwork. It has been pulped for papermaking, but the product is of low quality because of the wood's short fibers and is fit only for wrapping purposes.
- Bark. The bark has always been used for making rope and twine; for long, strong cables for hauling logs and ships; for harpoon lines and fish traps; and for mats, household strainers, tapa cloth, and hula skirts. Easily stripped from the branches in long ribbons, its rough outer surface is peeled off, leaving a smooth surface. When reduced to fiber, it is similar to jute. It is stronger wet than dry.
- Erosion control and dune fixation. The mahoe is ofen planted to stablize sand dunes and, on muddy shores, to trap soil to reinforce the coastline. In India it is planted to prevent erosion on the banks of rivers and reservoirs.
- Beautification. The mahoe is widely valued as an ornamental because of its lush foliage and attractive flowers. On high, well-drained land it becomes an elegant landscape plant with a symmetrical, rounded head and clear trunk, providing it is "raised up" by pruning the base when the tree is young. Enough space must be available for development of its form; this is not a tree for small gardens. It is sometimes close planted as a living fence.

Environmental Requirements

- Temperature. The species is adapted to warm, humid areas, from near-tropical (for example southern Florida) to ultratropical.
- Altitude. The mahoe grows from sea level to 500 m elevation.
- Rainfall. It thrives where there is annual precipitation of 1,400 mm. Some scattered specimens are found on the coasts of extremely dry regions.
- Soil. The tree has no particular soil requirements; it seems to grow equally well in mud, marl, sand, and limestone, assuming greater stature on high, dry sites inland than in its native habitat—shallow brackish swamps. It is highly salt tolerant.

Hibiscus tiliaceus. (From *500 Plants of South Florida* by J. Morton)

Establishment The seed capsules may float for months until they reach favorable shores, where the seeds readily germinate and colonize the area. In cultivation the tree is easily raised from seed or cuttings, or by air layering. Growth is rapid; in 2-3 years the tree is large enough to provide shade.

• Ability to compete with weeds. Seedlings should be weeded in the early stages if planted inland. If planted in swampy, saline sites, there will be little vegetative competition and they will be self-sustaining.

Pests and Diseases The mahoe is an extraordinarily healthy tree with few problems. Spring and summer wilting was observed at Lahore, India, and attributed to *Alternaria dianthi*, which is locally prevalent on other plants. The tree recovers by the following season without treatment. In Florida it is sometimes affected by leaf spot caused by *Gloeosporium* spp or *Phyllosticta hibiscina.*

Limitations The mahoe is limited to warm, humid, low elevations. It is intolerant of cold, though mature trees have not been seriously injured by brief frosts in southern Florida.

Maesopsis eminii

Botanic Name *Maesopsis eminii* Engl.

Common Names Musizi, ndunga, muhumula, esenge

Family Rhamnaceae

Main Attributes *Maesopsis eminii* is a quick-growing, short-lived species suggested for enrichment planting in the humid tropics where it grows well if the canopy opening is sufficient and there is no dense shade. It is also recommended for well-drained grassy areas of watercourses.

Description This fast-growing deciduous tree is cylindrical, straight, free of branches for 9–20 m, and has a wide-spreading crown. The size of the tree decreases across the African continent from east to west. In Nigeria it is seldom over 15 m high, while in Uganda it grows to 36 m.

Distribution The species is native to tropical Central Africa from Liberia to Tanzania, covering a range of latitudes from 8°N to 2°S. Plantations have been established or natural forests managed in Fiji, Indonesia, Malaysia, Kenya, Tanzania, Uganda, and Zaire. Trials have been established in other African countries and in Costa Rica, Hawaii, Western Samoa, and the Solomon Islands.

Use as Firewood Plantation wood of *Maesopsis eminii* is light and therefore is not an ideal fuelwood. Its specific gravity is 0.38–0.48.

Yield On good soils in Africa the tree may grow 2–3 m in height per year while it is young. In Uganda, musizi forest plantations are managed on a 30-year rotation, producing a final volume of 20–30 m^3 per ha per year. In many areas, yields of 8–20 m^3 per ha are common; on fertile volcanic soils of Malaysia and Indonesia annual yields even reached 20–30 m^3 per ha with a maximum of 33 m^3 and 40 m^3 per ha, respectively.

Other Uses

- Fruit. The fruits, which are often eaten by animals, contain an edible oil.
- Wood. The wood of *Maesopsis eminii* is open grained and light brown and, although light weight, is tough and easy to work. It tends to warp, split, or collapse during seasoning, but is used for general indoor construction, joinery, and veneers for matchboxes. It is also suitable for plywood and pulpwood. On Java, Indonesia, the species has been proposed as a substitute for *Albizia falcataria* because of its similar wood quality and its resistance to the *Xystrocera* woodborer, which damages the *Albizia*.
- Miscellaneous. In Zaire the trees are planted to shade coffee and cocoa plantations.

Environmental Requirements

- Temperature. *Maesopsis eminii* grows in an area of mean annual temperatures ranging from 22° to 27°C, while the mean minimal temperatures of the coldest months are 16°–24°C.
- Altitude. The tree is normally found between 100 m and 700 m elevation, but in several countries, including Uganda, it grows well up to 1,200 m.
- Rainfall. The species requires 1,200–3,000 mm of uniform summer rains.
- Soil. *Maesopsis eminii* is considered best suited to moderately fertile, well-drained, light-to medium-textured soils, with a neutral to acid pH.

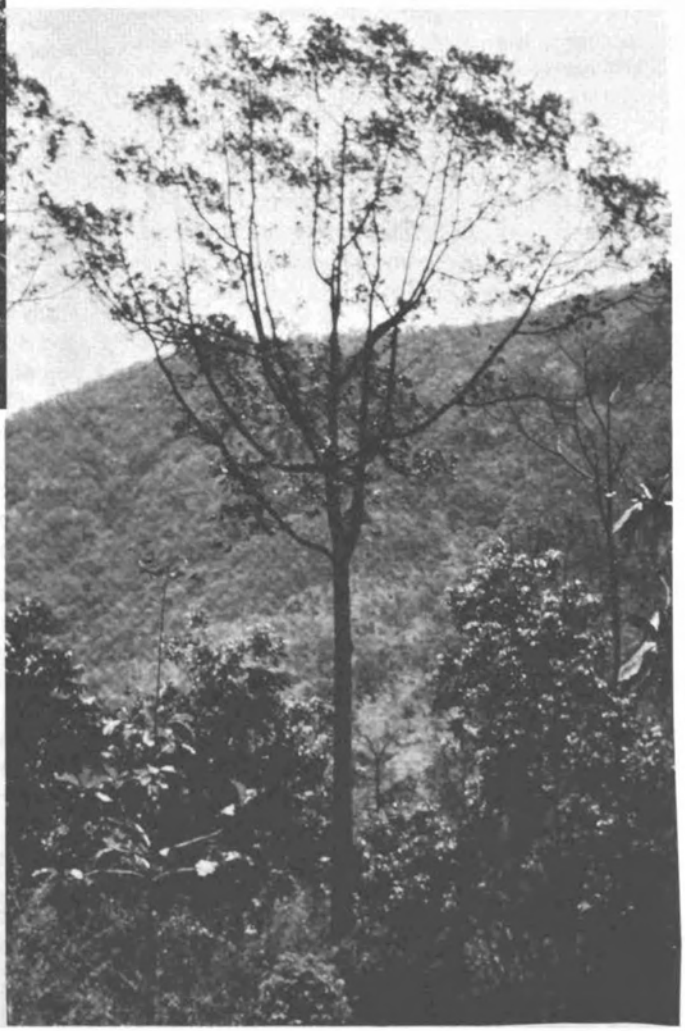
Establishment Natural regeneration is good; large quantities of seed are eaten and distributed by birds. The seeds number about 700 per kg. Artificial regeneration can be effected by direct seeding, but it is safer to raise seedlings in nurseries. Nursery stock should be planted out as pot plants at an early age, since the plants rapidly form long taproots. Stumps cannot be used.

- Seed treatment. Seeds must soak in cold water for 2-3 days.
- Ability to compete with weeds. The tree cannot tolerate *Imperata* grass competition during its early growth, but if it has been well tended during its early years, the rather dense umbrella crown rapidly suppresses competition. It is a light-demanding species that can be planted in pure plantations, but it can also be used for underplanting or enrichment planting in open woodlands.

Pests and Diseases Young trees are susceptible to cankers caused by *Fusarium solani* and other fungi. Bacterial wilt has been reported from a site in Malaysia with impeded drainage. In Zaire, damage by the *Monochamus scabiosus* borer has been reported.

Limitations The species cannot stand heavy weed competition or waterlogged soils. It is too wide crowned for use where maximum productivity per unit of land is the aim. It does not like

Maesopsis eminii, Sudan. Left: 2-year-old seedlings. Below: 25-year-old tree. (R. L. Plumptre)



grass competition. In the tropics, well-dried seeds can be stored, but not more than 3 months. Trees in poorly drained, infertile soil and on hillsides or in valleys are highly canker prone.

Pinus caribaea

Botanic Name *Pinus caribaea* Morelet*

Synonyms *Pinus bahamensis* Griseb., *Pinus hondurensis* Loock

Common Names Caribbean pine, pitch pine, pino de la costa, pino colorado, ocote blanco, pino caribaea de Honduras, pino macho

Family Pinaceae

Main Attributes Caribbean pine, which has fast initial growth, has become one of the more important pines for commercial timber plantations in tropical areas below 1,000 m. Because of the knowledge about the tree and its adaptability to equatorial lowlands or degraded lowland sites, it also deserves consideration as a fuelwood species.

Description *Pinus caribaea* is a large tree that under the best conditions may grow to 45 m in height and 135 cm in diameter. Generally the stem is straight and the branching is regular. However, there is great variation in tree form, particularly in the branching habits of natural stands.

Distribution Three geographic varieties of *Pinus caribaea* are distinguished. *Pinus caribaea* var *caribaea* (typical), or Caribbean pine, is found in western Cuba and the Isle of Pines. *Pinus caribaea* var *bahamensis*, Bahamas pine, is native to the Bahamas and Caicos Islands. *Pinus caribaea* var *hondurensis*, Honduran pine or pino hondureño, grows in the Atlantic lowland of Central America from northern Belize to northern Nicaragua.

Use as Firewood Young trees often grow rapidly, and both thinnings and branches from sawlog or pulp plantations could yield valuable fuel. The wood is soft, moderately lightweight (specific gravity, 0.4–0.66), and resinous.

Yield A mean annual increment of 21–40 m^3 per ha can be achieved on suitable sites up to the thirteenth year of growth.

Other Uses

- Pulp and papermaking. *Pinus caribaea* from natural forests is used in Nicaragua and Honduras for general-purpose pulpwood.
- Wood. The wood is excellent for particle board and noncompressed fiber board. It also is used for boat building, heavy construction, interior joinery and furniture components, and (form permitting) for veneer.

Environmental Requirements

- Temperature. The tree requires a warm, equable climate with no frost. In its native habitat, mean temperatures range from 22° to 28°C, with a maximum of 37°C and minimum of 5°C sometimes experienced.
- Altitude. In the equatorial zone, the species grows best at altitudes below 1,000 m, although it is planted up to 1,500 m.
- Rainfall. Throughout its natural habitat, *Pinus caribaea* grows in a climate with summer rainfall and a winter dry season. On the islands and on most inland areas, rainfall varies between 1,000 mm and 1,800 mm. In coastal areas rainfall may reach 3,900 mm, with poorly drained sites sometimes becoming waterlogged at the height of the rains. Some stands, however, grow on sites where annual rainfall may be as low as 660 mm.
- Soil. Soils are usually loams or sandy loams, sometimes with high amounts of gravel and generally well drained. The pH is usually between 5.0 and 5.5, although the very thin layer of soil on top of the coral platforms of the Bahamas has a pH of 8.4. In Cuba the soil is a deep, fine-grained clay that allows easy movement of air and water. In mainland coastal plains, *Pinus caribaea* occupies the well-aerated sands and silts and the levee banks where pH is between 4 and 5. Inland it can be found on a wide range of parent materials.

Establishment Easy germination and rapid early growth reduce costs of seedling production. It is essential to ensure that the correct mycorrhizae are available in the nursery soil to ensure root infection.

- Seed treatment. The seeds sometimes respond to moderate stratification, that is, a 24-hour water soak followed by 2–3 days of cold storage at 4°–5°C. They can be stored up to 10 years at 0°–5°C with moisture content below 10 percent.
- Ability to compete with weeds. *Pinus caribaea* can bear severe competition from shallow-rooted grasses, except when rainfall is below 1,000 mm. It is light demanding and cannot tolerate much overhead shade from tall grasses. Fast initial growth is typical of the species, and therefore weeding is often required for only one year after planting; weeding must

*This species was often confused with *Pinus elliottii* Engelm. Before 1950 it included *Pinus elliottii*.

Pinus caribaea, East Kalimantan, Indonesia. Two-year-old plantation growing in ultisol soil (R. L. Voss)

Pinus caribaea var *hondurensis* in Guatemala. (R. H. Kemp)

continue longer when the trees compete with climbing vines because of little shade production.

Pests and Diseases This species is susceptible to soil-borne pathogens that cause "damping off" and to various fungi that cause foliage blights, needle cast, dieback, stem and root damage, heart rot, and sap stain, depending on the location of the plantation. Serious insect pests are *Dendroctonus* (in Central American natural populations); *Ips* beetles; the pine aphid; leaf-cutting ants; termites; the Australian case moth, *Hyalarcta*; and the Nantucket tip moth, *Rhyacionia*. Damage to young plantations has been caused by squirrels, porcupines, and tree shrews feeding on the bark of stems and branches.

Limitations The great genetic variation existing within this species suggests abundant possibilities for genetic improvement in yield, stem form, growth, branching habit, and pest resistance. Indigenous seed of *Pinus caribaea* is available through commercial sources. However, in the short term, difficulties may be encountered in procuring seed for large plantations because the tree is so successful that seed is in high demand. In addition, outside its native habitat *Pinus caribaea* produces cones at low altitudes in the tropics, which reduces seed supplies.

Psidium guajava

Botanic Name *Psidium guajava* L.

Common Names Guava, guayaba

Family Myrtaceae

Main Attributes In high-population areas guava should be a good tree for use as firewood. It coppices readily and its growth rate is rapid at first and slower as the tree ages. Its ability to withstand repeated cutting should make it an exceptionally fine firewood, although the plant can be a problem weed and its wider planting should be encouraged only where enough utilization to keep it in check can be assured.

Description Guava is generally a shrub or low, wide-spreading evergreen tree 3-10 m high. It branches close to the ground and often produces suckers from roots near the base of the trunk. The small, fragrant white flowers are solitary or grow in small clusters on new axiliary shoots.

Distribution Guava is indigenous to the American tropics, where it occurs wild and cultivated. At an early date the Spanish took it to the Philippines and the Portuguese to India. It then spread throughout the tropics. It has been naturalized in many countries, being spread by birds; in some places it has become a troublesome weed in pastures and has been declared a noxious weed in Fiji.

Use as Firewood The hard, strong, heavy wood has a specific gravity of 0.8 and makes excellent firewood and charcoal. The gross calorific value per gram of dry matter (ash free) is 4,792 kcal with 0.85 percent ash.

Yield Firewood cutting causes the guava to spread by suckering, and it may become a pest in high-rainfall areas.

Other Uses

- Fruits. Guava fruits are made into preserves, jam, jelly, paste, juice, and nectar. They contain two to five times the vitamin C content of fresh orange juice, and red guavas are also a good source of vitamin A.
- Leaves. In some countries the tannin-rich leaves and green fruits are used for dyeing and tanning.
- Wood. Because of its strength the wood has been used for tool handles and implements.

Environmental Requirements

- Temperature. The trees are susceptible to frost, but if the freeze is not too severe they grow back quickly by suckering from below the soil. They require light.
- Altitude. Guava grows in the tropics from sea level to 1,500 m. However, it normally grows slowly at altitudes above 800 m.
- Rainfall. *Psidium guajava* does well in areas of 1,000 mm or more of well-distributed rainfall, and it can endure 4–5 months of drought.
- Soil. Guava does well on slightly to strongly acid soils. It flourishes in Florida on limestone and marl with a pH of 7.5–8.0. It grows relatively poorly in heavy clay soils; however, it is reported to tolerate flooding and to grow in areas where drainage is poor.

Establishment The tree can be propagated from seeds, cuttings, and suckers, or by inarching. In the past, most guavas have been grown from seed, but because of the great variability of guava fruits, vegetative propagation (for example, air layering) of superior clones is more common.

- Seed treatment. None required. The seeds remain viable for several months and will germinate in 3–5 weeks in the warm season.
- Ability to compete with weeds. Excellent. Guava is an aggressive plant that can withstand partial shading and can take over a site when it receives full sunlight.

Pests and Diseases Fruit flies, mealy bugs, scale insects, and thrips are reported to cause damage to the guava, mostly to the fruit. Wilt, the most serious enemy of the tree in India, reportedly occurs on soil above pH 7.5 and is usually fatal. Bark canker and dieback are diseases that kill branches. A bark-eating caterpillar and mealy scale may cause severe damage.

Limitations The trees can become serious pests, particularly with the root suckering induced by firewood cutting.

Related Species

- *Psidium littorale* is a native of Brazil that grows to a height of 8 m and can grow in dense shade as well as in the open. It is a good understory firewood in eucalyptus plantations in wet areas (5,000–6,000 mm rainfall). It also tolerates considerably lower temperatures and higher elevations than *Psidium guajava*.

Psidium guajava tree. (H. Y. Nakasone)

Eucalyptus robusta (see page 30) with a *Psidium cattleianum* understory on the island of Hawaii. (R. G. Skolmen)

II Fuelwood Species for Tropical Highlands

In the highlands (those areas above 1,000 m elevation) the problem of deforestation has become critical in many tropical developing countries. In part, the forests have been cut to make way for cultivation, but much of the denuded land results from the local population cutting trees and shrubs for fuelwood. The forests are receding rapidly up the hillsides as villages are forced to go higher in their constant search for fuel.

Only 10 percent of the population of tropical countries lives in the highlands, but the 40 percent living in the adjacent lowlands is also affected by the deforestation of hillsides that can no longer retain rainwater. The result is flash flooding, siltation, and drying up of streams needed for livestock and irrigation, all of which cut farmland productivity.

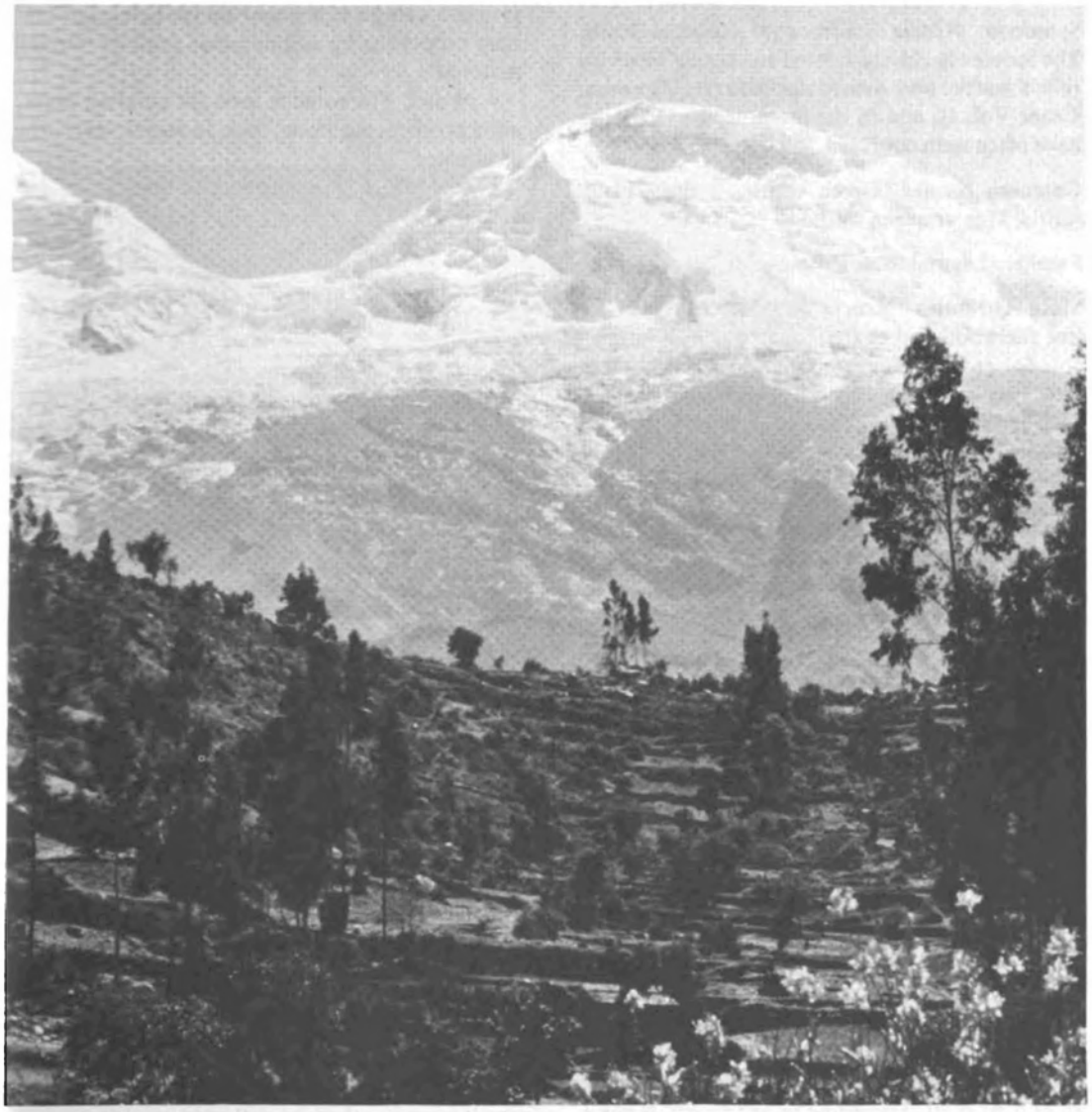
Reforestation of the highlands is official policy in many developing countries where subsistence farming is traditional, and efforts are under way to identify tree species best suited for these areas.

The first volume of this report described a number of species worth testing for highland fuelwood crops:

Acacia mearnsii
Ailanthus altissima
Alnus acuminata
Alnus nepalensis
Alnus rubra
Eucalyptus globulus
Eucalyptus grandis
Grevillea robusta
Inga vera

This section describes further species of trees and shrubs that merit testing in tropical highland areas.

Another species described in section III of this book that should be tested in the tropical highlands is *Dalbergia sissoo.*



Eucalyptus in Peru. (M. L. Barker)

Acacia decurrens

Botanic Name *Acacia decurrens* (Wendl.) Willd.

Synonym *Acacia decurrens* var *normalis* Benth. The species is closely related to *Acacia mearnsii* (black wattle) and *Acacia dealbata* (see *Firewood Crops* Vol. I), and in the literature these species have often been confused.

Common Names Green wattle, Sydney black wattle, king or queen wattle

Family Leguminosae (Mimosoideae)

Main Attributes *Acacia decurrens* yields excellent fuelwood and charcoal and has proved suitable for growing in many countries. The wood is little used for fuel except in Australia, but the bark is esteemed second only to that of *Acacia mearnsii* for tanning purposes. Like other acacias, green wattle fixes atmospheric nitrogen.

Description This is a beautiful tree with strong, upright growth, usually reaching 6–12 m in height. In the Nilgiris (India) it attains a height of 30 m and a diameter of 37 cm. It has a fern- or feather-like green foliage and in spring has a crowded head of fluffy, golden flowers. The slender seedpods, to 10 cm long, snap open when mature and throw the seeds a good distance.

Distribution This species is native to the coastal strip within 200 km of Sydney, Australia, and to adjacent lower montane valleys. It has been planted fairly widely on moist sites in southeastern Australia. It has also been introduced to Sri Lanka, Fiji, India, Kenya, South Africa, Hawaii, the Philippines, and parts of Central and South America.

Use as Firewood The wood is not suitable for sawtimber because of its small dimensions. It does make a good firewood, with a specific gravity of 0.50–0.70. According to one report, it has a caloric potential of 3,530–3,940 kcal per kg.

Yield A yield of 6–16 m^3 per ha per year has been reported, and in Sri Lanka the yield of firewood on a 15-year rotation averaged 25 m^3 per ha.

Other Uses

- Tanning. The bark of *Acacia decurrens* yields 35–40 percent good-quality tannin. However, it contains undesirable coloring matter, which reduces the value of the leather; planting was therefore stopped in favor of other acacias. Recent research, however, has shown that this problem can be eliminated by changing the tanning process or by adding other suitable tanning materials.
- Wood. The wood is used for building poles, mine props, fence posts, and, in recent years, for hardboard.
- Shelterbelt. The tree is used for shade and windbreaks. It has also been used as hedges on tea estates in Sri Lanka.

Environmental Requirements

- Temperature. *Acacia decurrens* thrives in a climate of 12°–25°C mean annual temperature. It is frost resistant and shade tolerant.
- Altitude. In its Australian home the tree grows in low valleys and on hillslopes (25–1,000 m), but mainly below 700 m. Elsewhere the tree may range up to 2,500 m.
- Rainfall. The mean annual rainfall for this species is 900–2,600 mm.
- Soil. *Acacia decurrens* prefers deep soils that are light to medium and free draining. It occurs naturally on soils of only moderate fertility: acid and neutral yellow earths, acid-bleached red duplex soils, podsols, and some brown friable earths derived principally from shales. The species also occurs on basalt-derived soils.

Establishment The species spreads rapidly by seed and root suckers and regenerates by coppicing. Seeds can be germinated after many years of storage in a cool, dry place. Seeds germinate in 7–14 days, and seedlings can be transplanted in 5–7 months.

- Seed treatment. The seeds are soaked 2 hours in acid or dipped in boiling water and left to cool and soak.
- Ability to compete with weeds. The tree spreads rapidly, forming solid stands too dense to permit grass or other vegetation to intrude.

Pests and Diseases *Acacia decurrens* is susceptible to the defoliator *Acanthopsyche junode*, but less so than *Acacia mearnsii*. Severe attacks by the rust fungus *Uromycladium* in the 1920s caused most plantations in New Zealand to be felled.

Limitations *Acacia decurrens*, introduced to Hawaii about 1890, has been declared noxious for state land leases because it spreads rapidly by seed and root suckers, crowding out other plants.

Acacia decurrens shelterbelt, South Africa. (A. P. G. Schönau)

Related species

• *Acacia dealbata* and *Acacia mearnsii* occur much more widely than *Acacia decurrens*. There are several species of relatively restricted distribution—for example, *Acacia parramattensis, Acacia sylvestris*, and *Acacia fulva*—with similar site requirements, but these have not yet been tested in cultivation.

Eucalyptus robusta

Botanic Name *Eucalyptus robusta* Sm.

Synonym *Eucalyptus multiflora* Poir.

Common Names Swamp mahogany, white mahogany, Australian brown mahogany, swamp messmate (Australia); robusta, beakpod eucalyptus (USA); brown gum, red gum (Sri Lanka and India)

Family Myrtaceae

Main Attributes Swamp mahogany is one of the most widely planted eucalypts. It grows well in plantations on good sites, but because of its ability to grow on both poorly drained and droughty locations, it is usually planted on adverse sites.

Description Swamp mahogany is a tree normally attaining heights of 25–30 m and diameters of 1–1.2 m (however, in Hawaii some giant specimens have reached 55 m with a 25-m trunk). The trunk is typically straight and branch free for about half the height of the tree. In open-grown trees the crown has long, spreading, irregular, and brittle branches, forming a dense canopy. In closely spaced plantations the branches are almost erect, so that little crown spread occurs. In plantations in humid climates a portion of the trees form aerial roots on the main trunk as far as 6 m above ground.

Distribution The species occurs naturally in a narrow coastal belt from Queensland to south of Bega, New South Wales, Australia. It grows from sea level to about 100 m. It has been planted in many other countries and adapts to varied conditions from equatorial regions to about latitude 35°, provided frosts are not severe. In Madagascar 150,000 ha have been planted.

Use as Firewood *Eucalyptus robusta* has been used as firewood in Madagascar, Uganda, Cameroon, Papua New Guinea, Sri Lanka, and Malaysia. It is also used for charcoal. The wood has a specific gravity of 0.70–0.80. The species coppices well up to age 25.

Yield Good yields have been reported from Brazil, Chile, Madagascar (10–35 m^3 per ha per year), Mauritius (10 m^3 per ha per year), Malawi, India, Malaysia, Papua New Guinea (21 m^3 per ha per year), Zaire (20-30 m^3 per ha per year), and Florida (16.8 m^3 per ha per year from 10-year-old trees). In Hawaii, 23- to 38-year-old plantations have a mean annual increment of 26 m^3 per ha.

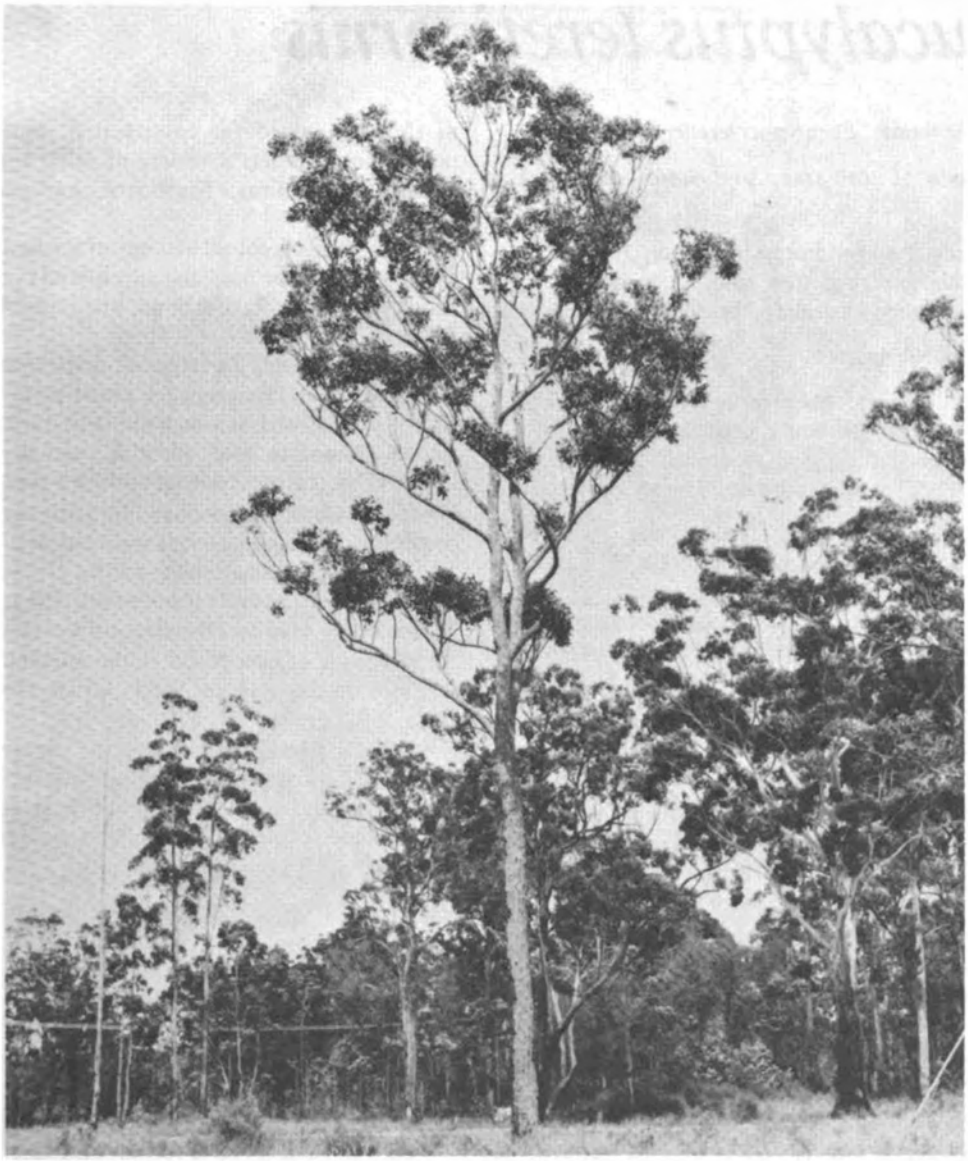
Other Uses

- Wood. The timber is used in the round and sawn for lumber, but there are limited supplies. In Hawaii, three companies were reported in 1961 to be making veneer and plywood of the timber. The wood can also be used for poles, fencing, wharf and bridge work, and general construction.
- Shelterbelt. This species is suitable for planting in coastal areas as shelterbelts, and it makes a good roadside shade tree. It is intolerant of salt spray but is quite wind firm and is used as a windbreak.
- Pulp. The timber is used for pulpwood, but the pulp is dark reddish brown and is not as good for this purpose as some other species of eucalypts. The bark must be removed from the stem before pulping.
- Tannin. The gum contains about 30 percent tannin.

Environmental Requirements

- Temperature. Mean minimum temperature in the coldest winter month is 3°–5°C. Winter frosts are rare, but 5 or 10 frosts may occur as long as they are not severe. Summer temperatures are warm, with a mean maximum of 30°–32°C. Humidity is high in all seasons of the year.
- Altitude. The tree grows on coastal sites from sea level to 1,600 m, depending on latitude.
- Rainfall. *Eucalyptus robusta* does best in areas with evenly distributed rainfall of more than 2,000 mm a year. It will grow reasonably well when there is rainfall of 1,000–1,500 mm with a 4-month dry season.
- Soil. In its natural habitat in Australia the tree occurs mainly on bottom slopes, in swamps, and on the edges of saltwater estuaries and lagoons. When artificially assisted, it grows much more vigorously in better soils if there is no competition from other eucalypts. It does relatively well in stiff clays and leached sandy loams, but has done poorly on droughty sands in northern Brazil.

Establishment *Eucalyptus robusta* is most commonly grown from seeds in containers in nurseries. Vegetative propagation by grafting and rooting of stem cuttings has been done with young trees, but it is not a common method of reproduction. Seedlings are best planted early in the



Eucalyptus robusta near Coffs Harbour, New South Wales, Australia. (Division of Forest Research, CSIRO, Australia)

rainy season. Natural regeneration on bare ground adjacent to plantations is common in many countries where the tree has been introduced.

- Seed treatment. None required.
- Ability to compete with weeds. Removal of vegetative cover before planting is essential. Planted seedlings are susceptible to competition and shading and generally require two weedings in the first 6 months.

Pests and Diseases In São Paulo, Brazil, *Eucalyptus robusta* has been attacked by the bacterium *Phytomonas tumifaciens*. This same organism has been detected in plants originating in the United States and Chile. The most common injuries in swamp plantations in Uganda are windthrow and root rot. The tree is also susceptible to attack by the *Gonipterus* beetle and to termites when it is young.

Limitations *Eucalyptus robusta* hybridizes with many other eucalypt species, which can make the collection of seed of true origin difficult. In California, USA, this tree has been abandoned for street planting because the tops break readily in strong winds.

Eucalyptus tereticornis

Botanic Name *Eucalyptus tereticornis* Sm.

Synonym *Eucalyptus umbellata* (Gaertn.) Domin.

Common Names Forest red gum, blue gum, mountain gum, red iron gum, Queensland blue gum, red gum (Australia); Mysore gum (India)

Family Myrtaceae

Main Attributes *Eucalyptus tereticornis* grows rapidly and withstands periodic flooding for short periods. It coppices vigorously and is one of the principal eucalypts grown as fuelwood.

Description A moderately large tree, *Eucalyptus tereticornis* attains a height of 30–45 m and a diameter of 1–2 m. The trunk is usually straight and at least half the total height. The crown is large and somewhat open. Small clusters of white flowers appear every year, but heavy blooming occurs only every 3 or 4 years in spring and summer.

Distribution This species occurs naturally in the widest latitudinal range of any eucalypt (6°-38°S) along the eastern Australian coast from southern Victoria to Queensland. It grows also in the savanna woodlands of Papua New Guinea's south coast. It is found in open forest or as scattered trees on alluvial flats and along stream banks, including brackish water. It has been introduced to many tropical and subtropical countries in Africa, Asia, and South America. More than 400,000 ha have been planted in India.

Use as Firewood The wood is hard, heavy, and strong (specific gravity 0.75 or higher). Density is lower in plantations in the tropics. The tree produces first-class fuelwood, which also makes good charcoal. Coppice regeneration has been widely used and it can be done three to four times on a 10-year rotation.

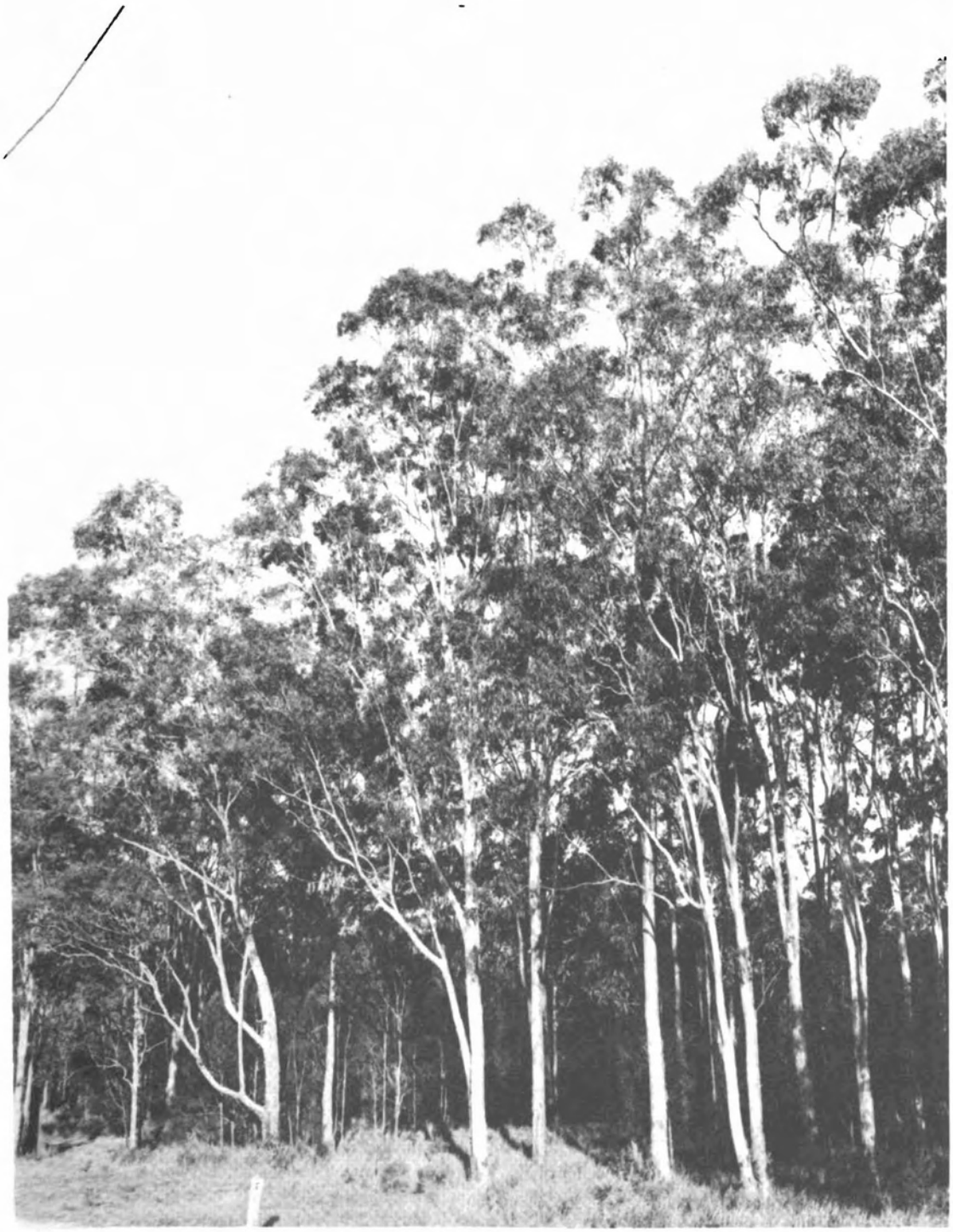
Yield The yield is very dependent on moisture. Higher yields are reported along canal banks and under irrigated conditions. In unirrigated plantations under good conditions in Africa the tree will yield 20–25 m^3 per ha per year for the first 15 years; thereafter, the yield drops to 10–15 m^3 per ha, unless the trees are coppiced.

Other Uses

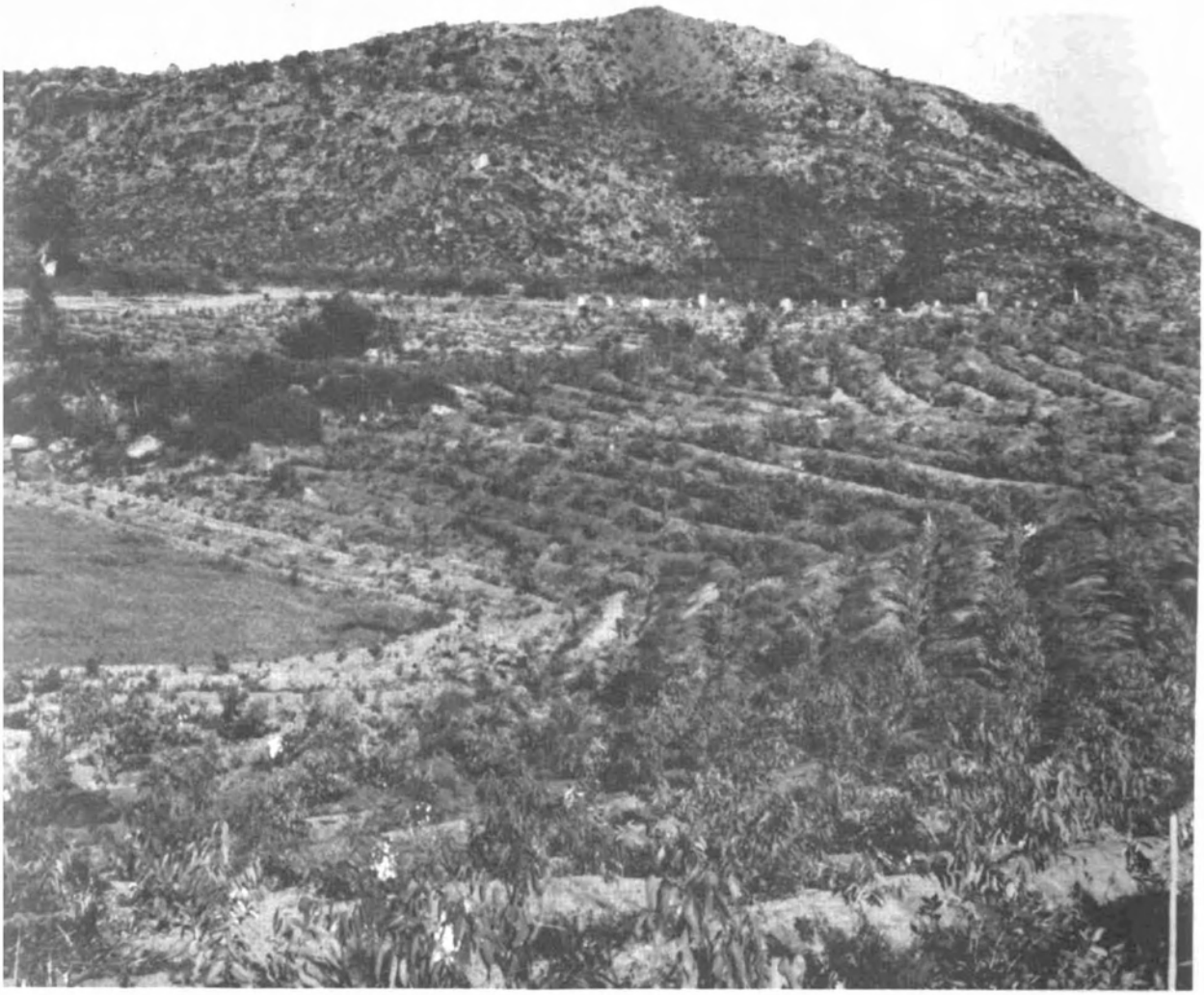
- Wood. The wood is immune to termites and dry rot and is therefore one of the most durable of timbers, valued for construction, especially underground. It has a variety of other uses including poles, posts, fiberboard, and particle board.
- Pulp. This is considered one of the best trees for fiber for paper pulp and rayon-grade pulp in India, Africa, the Pacific basin, and Latin America.
- Intercropping. *Eucalyptus tereticornis* has been used as an intercrop; for example, in Pakistan it is used with maize, especially during the first 6–12 months after planting, and in India with tapioca (cassava) during the first 2 years.
- Sand dune reclamation. In Uruguay and Costa Rica *Eucalyptus tereticornis* has been used for sand dune reclamation.
- Afforestation and reforestation. The species is extensively used in afforestation works in India, from the coastal plains to the mountains in the Himalayas, and in West Africa, notably Zaire.
- Oil. The leaves are among the commercial sources of eucalyptus oil.
- Honey and pollen. This species is an important provider of nectar and pollen for honeybee colonies.

Environmental Requirements

- Temperature. *Eucalyptus tereticornis* occurs within a wide climatic range with mean annual temperatures from 17°C to 38°C. This tree may withstand up to 15 frosts a year in the southern end of its natural range. In South China and Pakistan it is reported to survive temperatures down to −7°C.
- Altitude. In its natural habitat this species ranges from 600 m in Papua New Guinea to 1,000 m in Australia. As an exotic, it is planted from sea level (Zaire) to more than 1,000 m.
- Rainfall. The tree is widely planted in areas of summer rainfall with moderate to severe dry seasons. The optimum precipitation appears to be between 800 mm and 1,500 mm, but trees have been planted in areas with lower rainfall (400 mm in India, 550 mm in Israel, and 580 mm in Zimbabwe) and with considerably higher rainfall (2,180 mm in Colombia and 3,500 mm in Papua New Guinea).
- Soil. This species does best on deep, well-drained, light-textured soils that are neutral or slightly acid. It will tolerate some flooding, but not seasonal inundation. Outside its range it has



Eucalyptus tereticornis, northern Queensland, Australia. (Division of Forest Research, CSIRO, Australia)



Afforestation with *Eucalyptus tereticornis* in Karnataka, India. (K. A. Kushalappa)

been planted on a wide variety of sites that include alluvial soils, silts, and sandy clays.

Establishment For *Eucalyptus tereticornis* the site of the seed collection is important, and advice should be sought in selecting the most appropriate provenance in a new locality.

In most countries, seedlings 15–25 cm high are used as planting stock, and they can be produced in the nursery in 3–4 months.

- Seed treatment. None required; however, seeds from native stands in both Australia and Papua New Guinea may need cold, moist stratification.
- Ability to compete with weeds. Eucalypts are very sensitive to grass competition, and weeds should be removed until the canopy closes. Periodic soil working between rows by tractors has given good yield.

Pests and Diseases Most plantations have been free of pests and diseases. Termites will attack the young plants unless they are protected, and some countries have reported problems with varied fungi like *Cylindrocladium*, the climber *Merremia*, the snout beetle *Gonipterus*, and the mole cricket.

Limitations Because it is closely related to river red gum (*Eucalyptus camaldulensis*) and intermediate forms occur, care needs to be taken in assessing reports of growth.

Related Species

- *Eucalyptus rostricta* Schlecht. has similar wood that is used for the same purpose.

A 12-year-old seed stand of *Eucalyptus terreticornis* in Bangalore, India (K. A. Kushalappa)

- *Eucalyptus camaldulensis* Dehnh. is closely related, and intermediate forms occur commonly in Queensland.
- *Eucalyptus glaucina* (Blakely) L. Johnson, now regarded as a species, was formerly *Eucalyptus tereticornis* Sm. var *glaucina* (Blakely) Cameron. It occurs in northern coastal New South Wales.
- *Eucalyptus amplifolia* Naudin is a somewhat smaller tree that grows on clay soils (sometimes waterlogged) often at slightly higher altitudes than *Eucalyptus tereticornis* in eastern New South Wales.
- A number of land races, some of which were thought to be hybrids, occur. Some of these are:
  - "Mysore hybrid," Mysore gum, India
  - Eucalyptus "C," Zanzibar
  - Eucalyptus "12ABL," Madagascar, Zaire.

Gleditsia triacanthos

Botanic Name *Gleditsia triacanthos* L.

Synonym The genus name has also been spelled *Gleditschia*

Common Names Honeylocust, soetpeul, sweet locust, thorntree, three-thorned acacia

Family Leguminosae (Caesalpinioideae)

Main Attributes Honeylocust is widely planted as an ornamental and for windbreaks, fodder, and hedges. It is a moderately fast-growing tree with hard, strong wood that is quite resistant to decay. It is tolerant of low temperature, drought, and salt. The tree's pods are rich in sugar and are enjoyed by people, livestock, and wildlife.

Description A broad-crowned, flat-topped tree, the honeylocust typically attains a height of 24 m, with trunk diameters of 60–90 cm. Although some bisexual types are known, most specimens are either male (pollen producing) or female (fruit producing). Trunks and limbs of wild trees usually bear branching thorns, but a thornless form (f. *inermis* Schneid.) has been developed for cultivation; it has small, greenish, fragrant flowers in spring and flat, crooked pods in fall.

Distribution This valuable tree legume, well suited to cooler zones, can be found in North America from Ontario to Texas. It has also been naturalized in Europe and introduced into parts of Africa, Australia, New Zealand, and South America.

Use as Firewood Honeylocust has strong and durable wood of specific gravity 0.70-0.80. The trees coppice freely.

Yield Growth is fairly rapid on good sites under average conditions. Trees 18–35 years old in plantations in the Central Plains of the United States had an average increase in diameter of 4.6 cm each 10 years. Height growth in shelterbelts throughout the Central States has averaged 0.5 m per year for 7 years.

Other Uses

- Timber. The timber is hard, heavy, and strong, and the heartwood is durable in contact with the ground. The wood is used principally for posts, but on a smaller scale for furniture, structural work, and general utility purposes.
- Pods. The long pods, borne in profusion, have sweet-tasting pulp that is relished by people and animals alike, and so the tree is often planted for pasture shade. The pods make high-quality livestock feed, especially when crushed to make the high-protein seeds more digestible.
- Erosion control. A strong taproot, many-branched lateral roots, tolerance of alkaline and saline sites, and ease of reproduction make honeylocust a valuable erosion control species for temperate and subtropical areas. It provides light shade that encourages a grass cover.
- Ornamental and shade tree. In temperate areas of many countries such as South Africa, the United States, and Australia, the species is often planted for shade and beautification along roads and in towns. It is also used for hedges (the thorny kind makes impenetrable hedges) and windbreaks.

Environmental Requirements

- Temperature. Honeylocust is tolerant of low temperatures, and northern races are hardy to −34°C. Southern races are subject to frost damage when planted in cooler areas. The tree needs light.
- Altitude. This species can be grown up to altitudes of 1,500 m or more. A plantation in Colorado had good survival at 2,100 m, although the trees averaged only 2.4 m tall. The tree seems particularly worth testing as a new crop for tropical highlands such as those found in Nepal, northern Thailand, Central Africa, and Latin America.
- Rainfall. Honeylocust has deep roots and can make use of the moisture reserves of the subsoil, even if the surface is dry. In this way it is able to survive on all but the driest sites. Normal annual precipitation for good growth varies from 500 mm to more than 1,500 mm.
- Soil. The tree grows in most soil types, but occurs most commonly on rich alluvial floodplains of major rivers and on soils of limestone origin. The species tolerates both alkaline and acid soils, but develops best on those with a pH between 6.0 and 8.0.

Establishment Propagation by seedlings is easy and can be achieved by grafting, budding, or cuttings taken from hardwood, softwood, or the roots. Root cuttings and budding appear to be the best methods of reproducing desirable strains as fruit trees. Large seed crops are produced every 1–2 years, and the seeds will remain viable for up to 2 years when stored at room temperature and

Gleditsia triacanthos L. Honeylocust on Ohio State University campus, Columbus, Ohio, USA. (U.S. Forest Service)

for several years if stored in sealed containers at 0°–7°C.

- Seed treatment. Before germination can occur, the hard seedcoat must be made permeable, either by covering with hot water (88°C) until the seeds swell or by soaking in concentrated sulfuric acid for 1–2 hours and then washing in water. Treated seeds cannot be stored and must be sown promptly.
- Ability to compete with weeds. The tree needs weeding until it is well established.

Pests and Diseases Honeylocust is relatively disease free, but it is subject to a canker that can be fatal, and also to several wood rots. The leaves are eaten by mimosa webworm in some areas of North America.

Limitations Honeylocust may suffer some crown damage during high winds and is easily damaged by fire. Its extensive root system can block sewers and drains.

Melaleuca quinquenervia

Botanic Name *Melaleuca quinquenervia* (Cav.) S. T. Blake

Synonyms *Melaleuca quinquenervia* is one of a group of six closely related species (notably *Melaleuca leucadendron, Melaleuca cajuputi,* and *Melaleuca viridiflora*) that occur in Oceania and have been cultivated and naturalized in other areas. Their identities have been confused, and many references (both past and recent) must be treated with caution.

Common Names Broad-leaved tea tree, tea tree, paperbark tea tree, belbowrie (Australia); melaleuca, cajeput, paperbark, punktree (USA); niaouli (New Caledonia)

Family Myrtaceae

Main Attributes *Melaleuca quinquenervia* is a moderately fast-growing tree suitable for plantation cultivation on wet soils, including those subject to high rainfall and even inundation. It will grow at high planting densities, which quickly shade out competing vegetation. It survives fires, but has only slight resistance to freezes (although rootstocks survive and sprout). The species has shown promise in plantations in northern Nigeria.

Description The tree is usually medium sized, growing in Australia up to 25 m tall; the bole is short, 4–5 m high (and to 15 m in rare cases), and often crooked or twisted. However, if grown in dense stands it develops relatively straight, clear stems. It is easily recognized by its odd, whitish, thick, and spongy bark, which splits and peels in many cork-like layers and becomes rough and shaggy. The tree has narrow, stiff, aromatic leaves, 5–9 cm long, and "bottlebrush-shaped" clusters of fuzzy, white, malodorous flowers.

Distribution This species is native to Australia from Sydney north along the coast to the Cape York Peninsula in Papua New Guinea and to New Caledonia. It typically grows in almost pure stands or with only a few associates such as *Casuarina glauca, Eucalyptus robusta,* or *Eucalyptus tereticornis*. It has been planted and naturalized in many tropical regions. In southern Florida it escaped cultivation on seasonally wet sites and is constantly multiplying as a weed tree.

Use as Firewood The wood is an excellent fuel, but the thick bark of mature trees must be peeled off because only the outer layers will burn. The tree could be used as a woody biomass fuel; the problems of dust from the bark of mature trees and the low density of the bark can be overcome by properly engineered systems. Bark of young seedlings has a greater heating value per unit of oven-dry weight than the wood itself. The wood has a specific gravity of 0.60–0.74.

Yield In the Florida Everglades, unmanaged melaleuca stands that appear mature may have 7,000–20,000 stems per ha with an outside bark basal area up to 133 m^2 per ha and an outside bark volume of 792 m^3 per ha. Forty-year-old trees on good sites in Hawaiian plantations average 50 cm in diameter and 18 m in height at 6 m × 6 m spacing. The largest trees there reach a diameter of 90 cm and grow 24 m tall. Stumps sprout readily.

Other Uses

- Wood. The wood of paperbark is valued for wharf piling, boat knees, railway ties, mine braces, posts, fence rails, flooring, and rafters, and, if carefully seasoned, for gunstocks, cabinetwork, and carving. When the wood is well finished, some people consider it more beautiful than mahogany.
- Bark. The bark of paperbark is an effective insulator and was first used for packing the walls of cold storage rooms in Australia in 1861. It is mildew resistant and is long lasting under water, so that sheets of bark have been used for caulking boats. When chopped, it makes an excellent filler in nursery potting mixes.
- Honey. The tree blooms much of the year, providing abundant pollen and nectar. The honey is strongly flavored and dark and is not used as table honey. Because of its low cost, there is a strong demand for it by the baking industry and by natural health food dealers in Florida.
- Ornamental. Seedlings are transplanted from the wild (especially mature trees) for landscaping new developments in Florida because of their availability and low cost.
- Oil. Leaves, twigs, and seed capsules are crushed and distilled to produce niaouli oil, which together with cajeput oil from *Melaleuca cajeputi* has pharmaceutical and other specialty uses.

Environmental Requirements

- Temperature. Paperbark grows in areas with mean annual temepratures ranging from 18°C to 34°C.

A mature swamp stand of *Melaleuca quinquenervia* in southern Florida during the dry season. This was a *Taxodium distichum* forest that was killed by fire and invaded by paperbark. (T. F. Geary)

- Altitude. In Australia the tree occurs in low altitudes up to 500 m in the coastal belt, most commonly in seasonal swamps and the edges of tidal waters. In Hawaii it grows well in wet conditions up to 1,400 m altitude.
- Rainfall. The trees grow well in rainfall of as little as 1,000 mm at lower elevations and as much as 5,000 mm at higher elevations.
- Soil. In Australia paperbark can grow down to the sea's edge and is also found 40 km inland. It occurs on old and new alluvial soils, on shallow soils, and on degraded soils left after shifting cultivation. Trees grow to great size in oolitic limestone in Florida.

Establishment The seeds need wet soil for germination, and once established, seedlings can survive complete immersion for several weeks.

- Seed treatment. No pretreatment is necessary. The seeds are small (30,000 seeds per g).
- Ability to compete with weeds. The tree successfully competes with and outgrows other vegetation. The deep shade beneath a dense melaleuca canopy, combined with intense root competition and possible allelopathic influences, restricts the need for weed control to about the first 6 months.

Pests and Diseases None of importance has been reported.

Limitations Because of its high incidence of seeding, adaptability to a variety of growth conditions, rapid growth, and resistance to damage by disease, insects, flooding, and fire, the paperbark tree has spread rapidly throughout southern Florida. In wetlands it has crowded out native vegetation and destroyed wildlife habitats. Control by conventional means is difficult.

Volatile substances excreted by the flowers have been implicated as the cause of acute respiratory problems in Florida.

Related Species

In Thailand, *Melaleuca cajuputi* is the species cultivated; it occurs naturally from tropical Australia to Burma and Vietnam. *Melaleuca leucadendon* occurs in northern Australia, New Guinea, and northwestward to Amboina; *Melaleuca viridiflora* occurs in western and northern Australia and New Guinea.

Melia azedarach

Botanic Name *Melia azedarach* L.

Synonym *Melia orientalis* M. Roem.

Common Names Chinaberry, Persian lilac, alelaila, paraiso, pride of India, pride of China, bead tree, umbrella tree, bastard cedar, cape lilac, white cedar, drek

Family Meliaceae

Main Attributes The chinaberry is well known and has already been planted in many countries as an ornamental. Its quick growth and small dimensions make it a good choice for fast fuelwood production for household needs. In the Middle East the species has already been used for this purpose.

Description Chinaberry is a medium-sized deciduous tree, 6–30 m tall and 50–80 cm in diameter. It is popular for its showy clusters of pale purplish spreading flowers and for the shade of its dense, dark green foliage in summer. Its clusters of small, fragant flowers are succeeded by glossy, golden, berrylike fruits that remain long after the leaves fall. The tree is closely related to the neem tree, *Azadirachta indica* (see *Firewood Crops* Vol. I), which differs in having longer leaflets, white flowers, and a more spreading and open crown.

Distribution This native of Asia is probably from Baluchistan and Kashmir, but has long been cultivated throughout the Middle East and India and is now cultivated and naturalized in most tropical and subtropical countries. It is grown throughout the West Indies, southern United States and Mexico, Argentina and Brazil, West and East Africa, Southeast Asia, and Australia.

Use as Firewood The species is often planted for fuel supply in the Middle East as well as in Puerto Rico and Nigeria. It is planted in reforestation projects in Thailand for veneer and fuel, and in Assam (India) it is grown on tea estates for fuel. Its specific gravity is about 0.66 (calorific value 5,043–5,176 kcal per kg).

Yield Under good conditions the chinaberry grows fast. In Uganda it may grow 1.70 m in height each year. But growth slows down before large dimensions are attained, and trees of large girth are often hollow. Thus the trees are grown on short rotations. They regenerate readily from stump sprouts or root suckers.

Other Uses

- Wood. The wood is moderately soft and is weak, brittle, and susceptible to attack by drywood termites. Uses of wood include tool handles, cabinets, furniture, face veneer for plywood, cigar boxes, and the manufacture of writing and printing paper.
- Insecticide. Chinaberry, like neem, has insecticidal properties and its leaves and fruits are used to protect stored clothing and other articles against insects. Leaves, seeds, and fresh fruit contain substances that inhibit the feeding of the desert locust.
- Fodder. The leaves may be used for goat fodder.
- Seeds. Chinaberry seeds are often used for beads and rosaries.
- Ornamental. The tree is widely grown in warmer parts of the world for its scent and for shade. It is also used to shade coffee trees and to shelter cattle.

Environmental Requirements

- Temperature. The species grows in tropical, subtropical, and warm-temperature climates where mean annual temperatures are at least 18°C. Young trees are frost tender, but older trees resist frost (to a minimum of −15°C).
- Altitude. The tree grows up to 2,000 m in the Himalayas. In Africa the species has been recommended for lowlands and medium elevations.
- Rainfall. The species is drought hardy and can grow in areas with 600–1,000 mm annual precipitation. In drier climates it will perform well on wet soils along rivers or when irrigated, as is done in the Middle East for fuelwood production.
- Soil. The tree grows on a wide range of soils, but best growth is obtained on well-drained, deep, sandy loams.

Establishment Chinaberry is easily propagated from seed or cuttings. Fruits number 1,400–2,500 per kg and may be used directly or macerated to remove the pulp. Each fruit contains 1–5 seeds, which if not extracted may produce several seedlings. Seeds number 4,000–13,000 per kg. Average germination is about 65 percent. As planting stock, 1-year-old seedlings are preferred in temperate climates, while 6-month-old seedlings are used in the tropics.

- Seed treatment. To hasten germination, seeds should be soaked in water for a few days.

Melia azedarach. Fifteen-year-old tree in Pakistan. (M. I. Sheikh)

Seeds retain viability for a year, or for several years if kept in sealed cold storage.

Pests and Diseases The tree—especially if forced into fast growth—is susceptible to wind damage. From Jamaica, attacks of shootborers are reported. Several other pests and diseases have only been observed incidentally and are not particularly significant.

Limitations The tree is short-lived and its brittle limbs are easily broken by the wind. The fruits are bitter and have poisonous or narcotic properties.

Related species

- *Melia azedarach* L. var *australasica* (A. Juss.) C.DC. (white cedar, tulip cedar) from Australia (synonym *Melia dubia*). This species grows to a much larger size than *Melia azedarach* and is widely planted in Australia as a shade tree.
- *Melia a.* forma *umbraculiformis* Berckm. (Texas umbrella, chinaberry).

Robinia pseudoacacia

Botanic Name *Robinia pseudoacacia* L.

Common Names Black locust, false acacia, yellow locust

Family Leguminosae (Papillionaceae)

Main Attributes Black locust is fast growing. It can be planted and regenerated easily, has no serious diseases, is an important nitrogen-fixing species, and tolerates a wide variety of soils. Because of this adaptability, the species is often used for afforestation of gullies and surface-mined areas in the United States. The wood is perhaps the best firewood in North America.

Description A medium-sized, deciduous tree reaching 18–25 m tall, black locust has an open, irregular crown and a straight bole if forest grown. It has short, upright, brittle branches and a wide-spreading, shallow root system with no taproot. There are many varities of the tree, with variable form and growth. Most are spiny, but spineless individuals are known.

Distribution Native to the Appalachian and Ozark mountains of the southeast and central parts of the United States, this species is now grown in most temperate and Mediterranean zones of the world. Hungary, for example, has almost 300,000 ha of black locust plantations. In central and eastern Europe considerable work on selection and improvement of the species has been carried out for more than a century, using a series of cultivars in pure and mixed-wood plantations.

Use as Firewood As firewood, black locust is popular for its high caloric value and its good combustibility, even when wet. It is slow to ignite, but burns like coal, with a bright blue concentrated flame. The specific gravity of the wood is 0.70–0.80, and it is well suited for charcoal production. In India and South Korea the species has been used to establish fuelwood plantations.

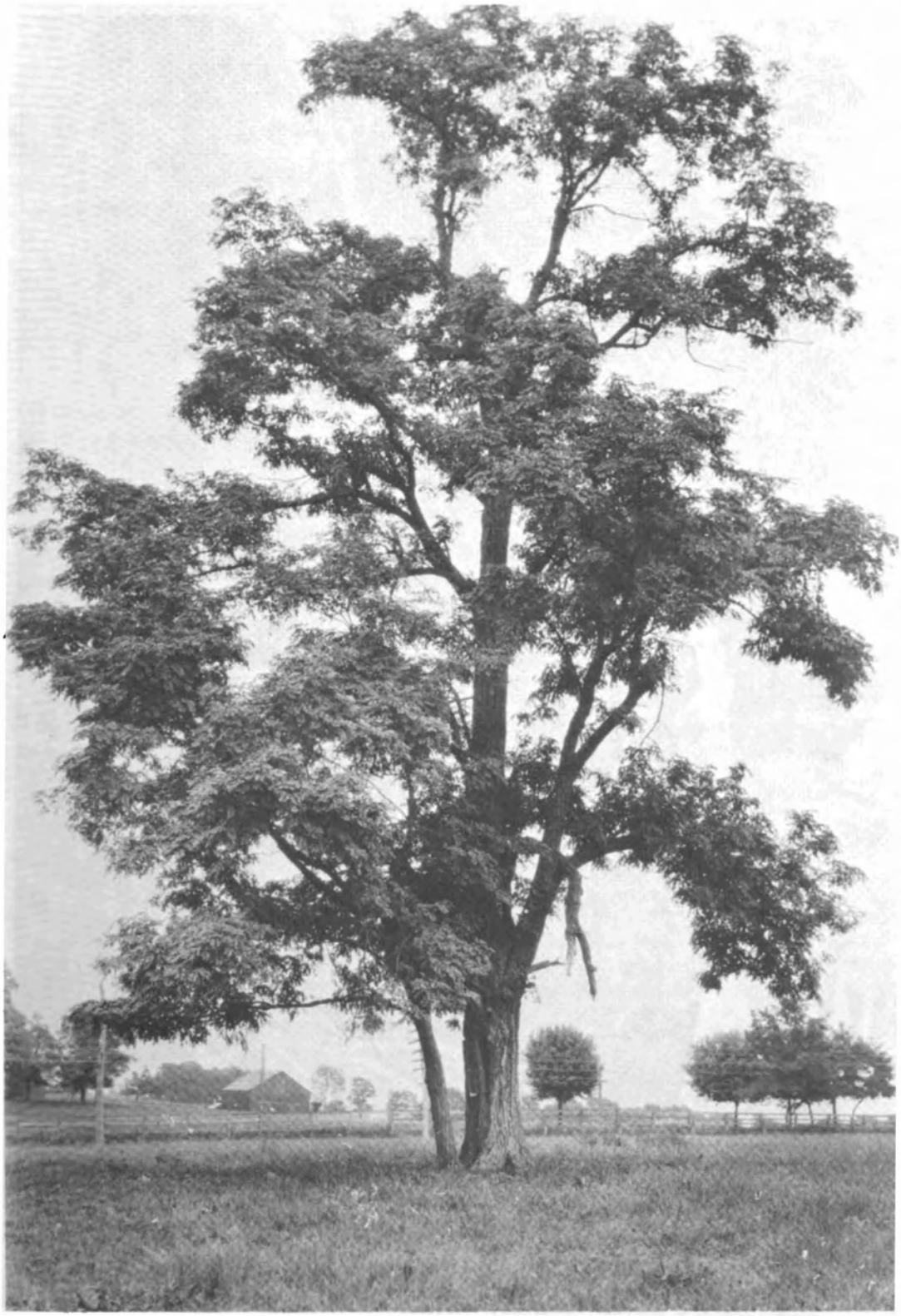
Yield Young black locust trees grow fast on good sites, but the species matures early and growth rate decreases rapidly after 30 years. In Korea, on clay loam, the yield of fuel material per year per hectare from the coppice of black locust fuelwood plantations ranges from 10 to 17 tons 3 years after establishment. In Hungary, where the rotation age is 25–35 years, the average standing volume at age 1–10 is 23 m^3 per ha; at age 11–20, 100 m^3 per ha; at age 21–30, 149 m^3 per ha; and, finally, 184 m^3 per ha at age 31–40. Coppicing brings excellent results and may be done twice without reduction of volume increment.

Other Uses

- Wood. *Robinia pseudoacacia* wood is heavy, hard, and strong. It is highly resistant to shock and is extremely durable. It is used extensively for round, hewn, or split mine timbers and for fence posts, poles, railroad ties, stakes, and electric insulator pegs.
- Erosion control. Black locust is commonly planted for erosion control. Because of the nitrifying bacteria in nodules on its roots, it is especially effective in improving the fertility of eroded soils. It has also grown quite well when planted on spoil banks created by mining.
- Shelterbelts and sand dune stabilization. Because of its wide-spreading root system, which suckers vigorously, it is used all over the temperate regions of the world for fixing coastal and continental sand dunes. It has also often been planted in shelterbelts.
- Fodder and wildlife use. In Hungary the leaves are readily eaten by game and grazing animals, with no harmful effects observed. The seed is eaten by quail.
- Ornamental. The tree has attractive flowers and is widely planted as an ornamental on farmsteads and roadsides. The flowers are used intensively by bees for producing honey, which is regarded as one of the finest in the world.

Environmental Requirements

- Temperature. The tree grows in areas with a mean annual temperature of 8°–18°C and a mean minimum temperature in the coldest month of −8.1°C. It is tolerant of temperatures as low as −18°C to −20°C. It is a light-demanding species.
- Altitude. Black locust is found from sea level up to 2,500 m.
- Rainfall. Precipitation in its native habitat is more than 1,000 mm per year, mainly in the summer. The tree has been successfully planted where the rainfall is lower, down to 300–400 mm, and in areas with a winter maximum of rainfall. The species can withstand dry periods of 2–6 months.
- Soil. The species will grow on a variety of soils, including light sand and strongly acid soils and mine spoils, with limestone soils being most



Black locust, Kentucky, USA. (U.S. Forest Service)

Left: Young black locust stumps sprout prolifically after cutting, thus shortening subsequent rotations and making regeneration easy. (S. B. Carpenter)

Above: *Robinia pseudoacacia* stocks, 3 years old, lopped once a year for fuel supply. (Institute of Forest Genetics, Suwon, Korea)

favorable. Compact, plastic soils are unfavorable, since black locust does not grow well in waterlogged areas. It is able to withstand air pollution and is sometimes planted in industrial areas for this reason.

Establishment Good seed crops are produced nearly every year. Seeds number 35,000–70,000 per kg and can be stored for several years under dry, cold conditions. In the past, black locust was established mainly from planted seedlings, but today direct seeding is a common practice, especially on steep slopes on disturbed sites where seeding is easier, safer, and less costly than hand planting.

- Seed treatment. Pretreatment is needed to break seed coat dormancy, either by mechanical scarification, by immersion in concentrated sulphuric acid for 20–60 minutes, or by pouring boiling water (five times as much water as seeds) over seeds. Germination of pretreated seed averages about 70 percent.
- Ability to compete with weeds. Black locust is intolerant of shade but is fairly tolerant of herbaceous competition in humid environments. In the Appalachian area of the United States the trees often coexist with a luxuriant understory of cool-season grasses and forbs.

Pests and Diseases In the United States the saplings are often heavily damaged by the locust borer *Megacyllene robiniae.* Trees in the open and in pure plantations are especially subject to the attack of a woodboring insect (*Cyllene robiniae* Forst.), which frequently renders them unsightly for shade and unfit for timber, but not for fuelwood. However, few pests of any importance have been reported.

Limitations A vigorous growth of suckers with stout spines is produced from the roots, and this can be particularly objectionable in the garden, on the farm, or in public areas.

Although the foliage is used for livestock in some countries, it has been reported that humans, horses, cattle, sheep, and poultry may be poisoned by eating roots, bark, sprouts, seed pods, and trimmings.

Frost damage can decrease growth, and because black locust branches are fragile and the wood splits easily, the tree suffers from wind damage and ice and snow break.

Sapium sebiferum

Botanic Name *Sapium sebiferum* (L.) Roxb.

Synonyms *Stillingia sebifera* Mich., *Croton sebiferums* L., *Excoecaria sebifera* Muell. Arg., *Stillingia sebifera* Boj.

Common Names Chinese tallow tree, Chinese vegetable tallow tree, soap tree, popcorn tree, pau de sebo (Brazil), tarcharbi or pahari shishum (India), arbol de la cera (Cuba)

Family Euphorbiaceae

Main Attributes The Chinese tallow tree holds promise as a highly useful species for short-rotation, intensive silviculture. It is a fast-growing, insect- and disease-resistant tree, and tolerates a wide range of soil conditions, including poorly drained and saline soils. Prolific sprouting occurs from stumps and injured roots.

Description A small, deciduous tree, it seldom grows taller than 12 m. Superficially, it resembles an aspen with glossy, heart-shaped leaves and a rough, gray bark. Form ranges from low, spreading, and multiforked strains to slender and columnar strains with small pendant branches. Seeds are borne in clusters of green capsules, which dry and split to expose white, pea-sized seeds. Their color results from a covering of hard tallow. The trees are notable because they turn brilliant autumn colors even in warm regions where other trees remain green.

Distribution The Chinese tallow tree is native to semitropical areas of central South China. Usually occurring below about 32°N, it may be found at higher latitudes in coastal areas. It has been widely introduced and has been reported in Japan, Taiwan, Vietnam, Burma, northern India, Java, Pakistan, Hawaii, Brazil, Cuba, St. Vincent, Martinique, southern Europe, and the Sudan.* It is very likely present, but simply not recognized, throughout the semitropical and milder temperate zones of the world. In the United States it has become naturalized along the Gulf and southern Atlantic Coasts from North Carolina to Texas, as well as in California.

Use as Firewood Moisture content of tallow tree wood cut in the Texas Gulf Coast ranged from 41 to 45 percent, wet basis. Specific gravity ranged from 0.37–0.48. Energy values ranged from 4,134 to 4,277 kcal per kg. The wood burns well in wood stoves or fireplaces if it has been allowed to dry adequately. It produces a pleasant odor while burning and has been used for Texas barbecues.

Yield In Texas, Chinese tallow plantations with 0.6 m × 0.6 m spacing produced 38.1 tons per ha of oven-dry wood at the end of four seasons of growth (22 m^3 per ha per year). Well-stocked 15-year-old natural stands placed under coppice management produced in excess of 45 tons per ha during 4 years of regrowth (26 m^3 per ha per year). Roots and stumps cut at any time of the year coppice prolifically.

Other Uses

- Wood. In China, the wood reportedly has been used for making implement handles as well as carved-wood products. Its durability and resistance to decay in exterior use are very low. The wood may be suitable for pulp. Fiber lengths in trees from the vicinity of Houston, Texas, averaged 0.8 mm, while similar measurements of trees from Taiwan averaged 1.3 mm.
- Seed. The white, aril-like outer covering of the seed contains a hard, edible tallow (commercially known as Chinese vegetable tallow), which has found use in soap and candle making and other traditional uses of tallow products. The kernel oil (stillingia oil) has been used as an illuminant and is a powerful drying oil that could substitute for similar oils such as tung and linseed. The clusters of white seeds are attractive; in Texas they are used in decorative plant arrangements.
- Flowers. The showy yellow catkins of the male flower first appear during the third growth season and yield a major honey and pollen crop. The honey is moderately dark and exceptionally flavorful.
- Ornamental. The Chinese tallow has been used extensively as an ornamental tree. Because of its rapid growth, it produces quick shade, and some varieties are very colorful in the fall, even in warm climates.

Environmental Requirements

- Temperature. The tree will tolerate frosts and, in the dormant state, will tolerate brief lows of −10°C. There is considerable variability in cold tolerance among strains. Some strains may be sensitive to high temperatures and some may

*D. Hooper. 1904. Chinese or vegetable tallow. Its preparation, uses, and composition. *Agricultural Ledger* 11(2):11–18.

Sapium sebiferum. A single season of growth on the severed stem of a large tree. The cut forks on this tree were 6-8 inches in diameter at the time of severance. (W. Scheld)

require a period of cool weather and dormancy for significant flowering to occur.

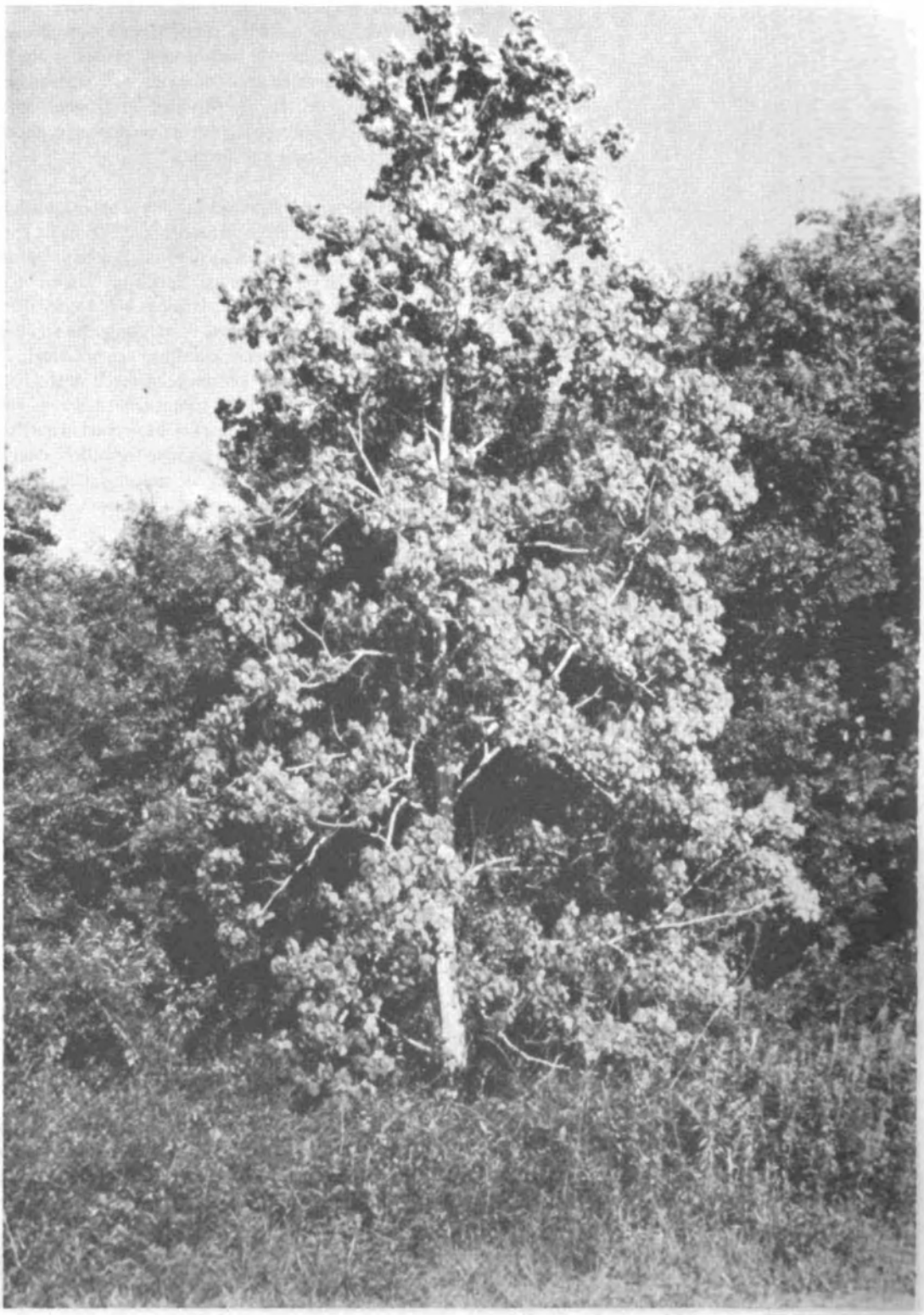
- Altitude. In the United States the tree is naturalized mostly in the coastal lowlands but has been observed as a planted ornamental at elevations of several hundred meters. In China it is reported at elevations of around 1,000 m and in India and Pakistan at about 2,000 m, which is probably its upper limit.
- Rainfall. Although the tree tolerates a wide variation in quantities of annual rain, it is generally considered to be a high-moisture plant; trees have survived for more than 2 years in areas flooded by dam construction. But in one instance, the trees grew well in a year when total annual rainfall was a mere 710 mm, and the species' lower limit is probably somewhat below 500 mm. There is no apparent reason why it cannot be grown in areas under irrigation. Preliminary observations suggest, however, that it is not an efficient user of water.
- Soil. The Chinese tallow tree possesses a remarkable capacity for thriving in widely varying soil types. In the United States it has been found growing on barrier islands, competing effectively in pure sand with oak, pine, and palm; in salt marshes and along salt creek borders; in rocky upland soils; and in dense clay soils subject to extended periods of flooding. Seeds have been observed germinating and the seedlings produced have become established in beds of oyster shell. The tree tolerates and competes well with other vegetation on poorly drained, nitrogen- and phosphorus-poor sites, but its response to phosphorus fertilization is dramatic.

Establishment Plantations may be established from seed, seedlings, or cuttings. The most convenient and economical method for establishing stands is direct planting. Seedlings grown in a nursery are ready for planting 6–8 weeks after germination. Special care in handling the seedling is not necessary. Dense plantings are practical.

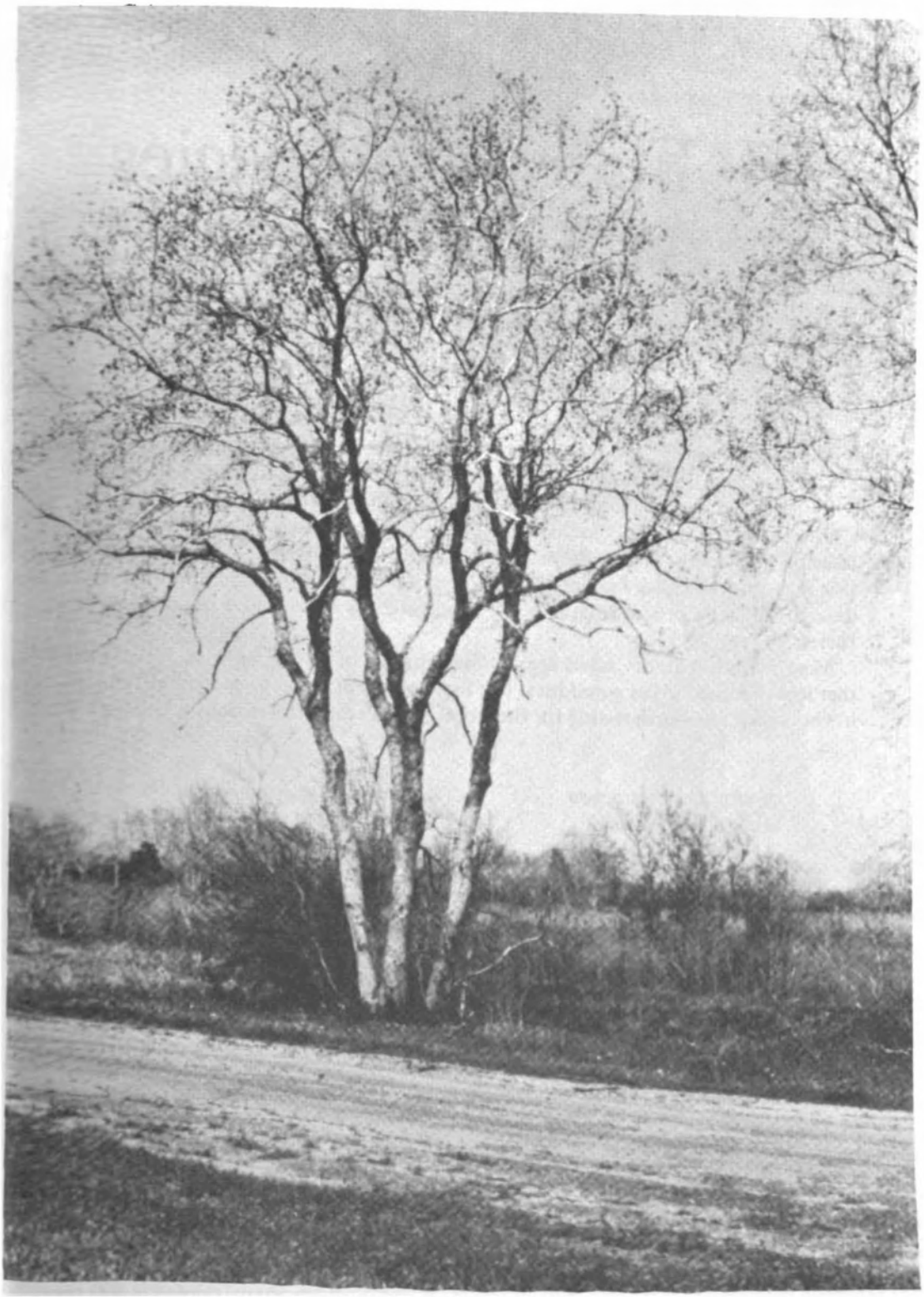
- Seed treatment. Storage of seeds in the cold in sealed glass or metal containers preserves viability for at least 2 years for most varieties. Pretreatment of the seed to remove the tallow coat is not necessary. Planting in autumn appears to promote more complete germination and allows the earliest possible start for growing seedlings. In some races, a significant percentage of seeds do not germinate until the second season after planting, and seeds planted in the late spring and summer often do not germinate until the following spring.
- Ability to compete with weeds. The large seedling is capable of growing ahead of most annual weeds, and in closely spaced plantings crown closure occurs early in the second season of growth, eliminating significant competition from grass and annual weeds. Grass is the major competitor.

Pests and Diseases In the tree's native range, a number of insect pests appear to have evolved with it. Chinese literature refers to the ailanthus silkworm, poisonous moth, water green moth, and aphid. In India a number of insects have been reported to defoliate the tree. It is not known how serious these might be in firewood plantations. In the United States and probably elsewhere outside the tallow tree's native range, there are no significant diseases or insect pests.

Limitations The Chinese tallow tree can be an aggressive weed. The tallow-covered seeds are spread widely by birds, and once established in agricultural lands, lawns, or gardens, seedlings and sprouts are difficult to eliminate because of their capacity for sprouting from stumps and roots. In general, there is a high resistance to herbicides. The reproductive strategy of the Chinese tallow tree is such that breeding and production of seed of known characteristics will be complex. The sap (latex) is a powerful irritant that blisters the skin.



Sapium sebiferum. Growth form ranges from very low to quite tall even in open growing conditions. Above: This tree possesses a strongly dominant single stem with small, usually pendant, branches. Right: An open-grown form with multiple stems may be the result of stump sprouting. (W. Scheld)



III Fuelwood Species for Arid and Semiarid Regions

The dry regions of the earth—those with less than 500 mm of annual precipitation or that have 6 or more totally rainless months—suffer more serious fuelwood problems than either the humid or highland regions of the tropics.

Four hundred and fifty million people live in these areas. Over the centuries, clearing the forests for fuel, farming, and grazing has destroyed most of the vegetation in these fragile dry habitats. Excessive exploitation of the land has often led to desertification, a process that is being accelerated by the demand for scarce wood fuel.

Most nations with dry zones are seriously in need of reforestation to prevent further loss of land and for wood fuel. The first volume of this report described the following species as worth testing for fuelwood crops in these dry regions.

Acacia brachystachya
Acacia cambagei
Acacia cyclops
Acacia nilotica
Acacia saligna
Acacia senegal
Acacia seyal
Acacia tortilis
Adhatoda vasica
Albizia lebbek
Anogeissus latifolia
Azadirachta indica
Cajanus cajan
Cassia siamea
Colophospermum mopane
Emblica officinalis
Eucalyptus camaldulensis
Eucalyptus citriodora
Eucalyptus gomphocephala
Eucalyptus microtheca
Eucalyptus occidentalis
Haloxylon aphyllum
Haloxylon persicum
Parkinsonia aculeata
Pinus halepensis
Pithecellobium dulce
Prosopis alba
Prosopis chilensis
Prosopis cineraria
Prosopis juliflora
Prosopis pallida
Prosopis tamarugo
Tamarix aphylla
Zizyphus mauritiana
Zizyphus spina-christi

These species have shown the capacity to survive where annual rainfall is 500 mm or less or where rainfall is extremely variable. Their adaptive mechanisms include

Planting seedlings of *Casuarina equisetifolia* (see page 38, Volume I) to prevent sand-dune formation south of Da Nang, Vietnam. (WFP photo by F. Mattioli)

deep root systems that penetrate to subsoil moisture or wide-spreading root systems to gather spare moisture, with some species having both root types; adaptation to the high salinity often found in arid areas; small leaf blades or needle-like leaves to reduce transpiration during drought or other physiological mechanisms to conserve moisture by slowing evaporation through the leaves; and unpalatability or thorniness that discourages grazing animals.

This section outlines further examples of successful adaptations by trees and shrubs to arid and semiarid conditions. Other species described elsewhere in this report that should be included are: ***Eucalyptus tereticornis, Gleditsia triacanthos, Melia azedarach,*** and ***Robinia pseudoacacia.***

Ailanthus excelsa

Botanic Name *Ailanthus excelsa* Roxb.

Common Names Ganges, ardu, aura, maharuka, mothoaraduso, peru, mahanium, coromandel ailanto

Family Simaroubaceae

Main Attributes *Ailanthus excelsa* is a fast-growing tree that regenerates well by coppicing. It provides valuable fodder and shade and makes good shelterbelts. Although it is generally unrecognized as a fuel tree, its pruned branches and cut stems are much used as fuelwood in India, its native region.

Description Ardu is a large tree (18–24 m) with rough, grayish brown bark. The deciduous leaves are variable in shape with coarsely and irregularly toothed leaflets.

Distribution This species is native to central, southern, and western India and is often cultivated in various parts of that country.

Use as Firewood The wood is fairly light (specific gravity 0.45) and therefore is not an ideal fuel; however, as already noted, it is used as firewood.

Yield In Assam, India, the species was planted at a spacing of 3 m × 3 m. The growth rate after 9 years averaged 5–6 m in height.

Other Uses

- Fodder. Twice a year this tree produces highly palatable and nutritive fodder. The leaves are commonly sold in the vegetable markets of Rajasthan, India, especially for nourishing stall-fed goats. The leaves are also dried, ground, and added to concentrate mixtures for livestock feed, notably as a protein supplement to poor-quality roughages.
- Wood. The wood of *Ailanthus excelsa* is yellowish white, very light, soft, and perishable. It is used for making boats, fishing floats, knife and tool handles, toys, spear sheaths, drums, cigar boxes, and packing cases.
- Shelterbelt. The tree is planted in rows along farm boundries and irrigation channels.

Environmental Requirements

- Temperature. Ardu grows in an area where temperatures range from 20°–40°C. It can withstand considerable frost.
- Altitude. It is grown at low altitudes.
- Rainfall. It grows best with annual rainfall of more than 600 mm, although it survives on 400 mm a year.
- Soil. The tree grows in a variety of soils, but sandy loams seem most suitable. Soils should be well drained and not clayish or waterlogged.

Establishment The plant is usually propagated by seed; however, it can be raised by shoot as well as by root cuttings. A sapling 30 cm high and 45–60 days old may be transplanted in pits previously prepared and manured. Monthly watering may be needed during the first year or until the trees are established.

- Seed treatment. The papery fruits (actually winged seeds or samaras) contain one to two seeds each. The seeds, however, cannot be separated from the wings undamaged, and it is necessary to sow the entire fruit. Soaking the pods for 3 days before sowing improves the results.
- Ability to compete with weeds. Good, except under drought conditions when ardu's competitiveness is poor.

Pests and Diseases In the rainy season, leaf growth is attacked by a caterpillar that eats the leaves and discharges a sticky material, making a netting and totally spoiling the leaves. Regular pruning provides some control.

Limitations Survivability is poor if the trees are not sufficiently watered during the first and second years of establishment. The leaves have a disagreeable odor when crushed.

Related Species *Ailanthus altissima* Swingle (see *Firewood Crops* Vol. 1, p. 74, *Ailanthus glandulosa* Desf.). A native of northern China, this species has been introduced to Japan, North and Central America, and Mediterranean countries. In Mediterranean regions it is common as an ornamental. It is particularly useful on stony sites. Initially of fast growth up to 25 m high and to a diameter of 60–89 cm, it reproduces by coppice and suckers, and under favorable conditions it may spread and become a weed that invades natural formations (for example, maquis in Corsica and in other parts of southern Italy).

Ailanthus excelsa, India. (N. D. Vietmeyer)

Balanites aegyptiaca

Botanic Name *Balanites aegyptiaca* (L.) Del.

Synonym *Ximenia aegyptiaca* L.

Common Names Desert date, lalob, soapberry tree, thorn tree, Jericho balsam, heglig (Arabic); corona di Jesus, lamunch, shimaron (Curaçao); najlij

Family Balantiaceae (formerly placed in Zygophyllaceae)

Main Attributes This multipurpose, drought-resistant species of the arid zone produces wood that is highly valued for fuel because it produces almost no smoke, making it ideal for use inside dwellings. The trees are slow growing, but they are indifferent to soil conditions and withstand fires.

Description The desert date is a shrub or, more usually, a small tree up to 10 m high with scaly, fissured, gray or brown bark, intricately branched stems, and slender drooping branchlets that bear long green spines. The gray-green leaves with two ovate leaflets are either evergreen or are wholly or partially deciduous during the dry season. The tree has shallow, wide-spreading lateral roots and a narrowly branched taproot that may penetrate several meters to the water table.

Distribution The species is indigenous to African woodlands along the Sahara's southern border from the Atlantic to the Red Sea (Sahel-Sudan region). It is also found on the Arabian peninsula and in Israel and Jordan. Small plantations have been established in Niger and Chad. Individual trees have been planted extensively in African villages far south of its natural range, as well as in India and Puerto Rico. Introduced to the Caribbean island of Curaçao in 1885, it has overrun a large part of the dry east end of the island.

Use as Firewood The pale yellow or yellowish brown wood is hard, heavy, and tough (specific gravity 0.65). It makes excellent firewood and good-quality charcoal. The trees regenerate vigorously after they are cut or lopped. Calorific value is 4,600 kcal per kg.

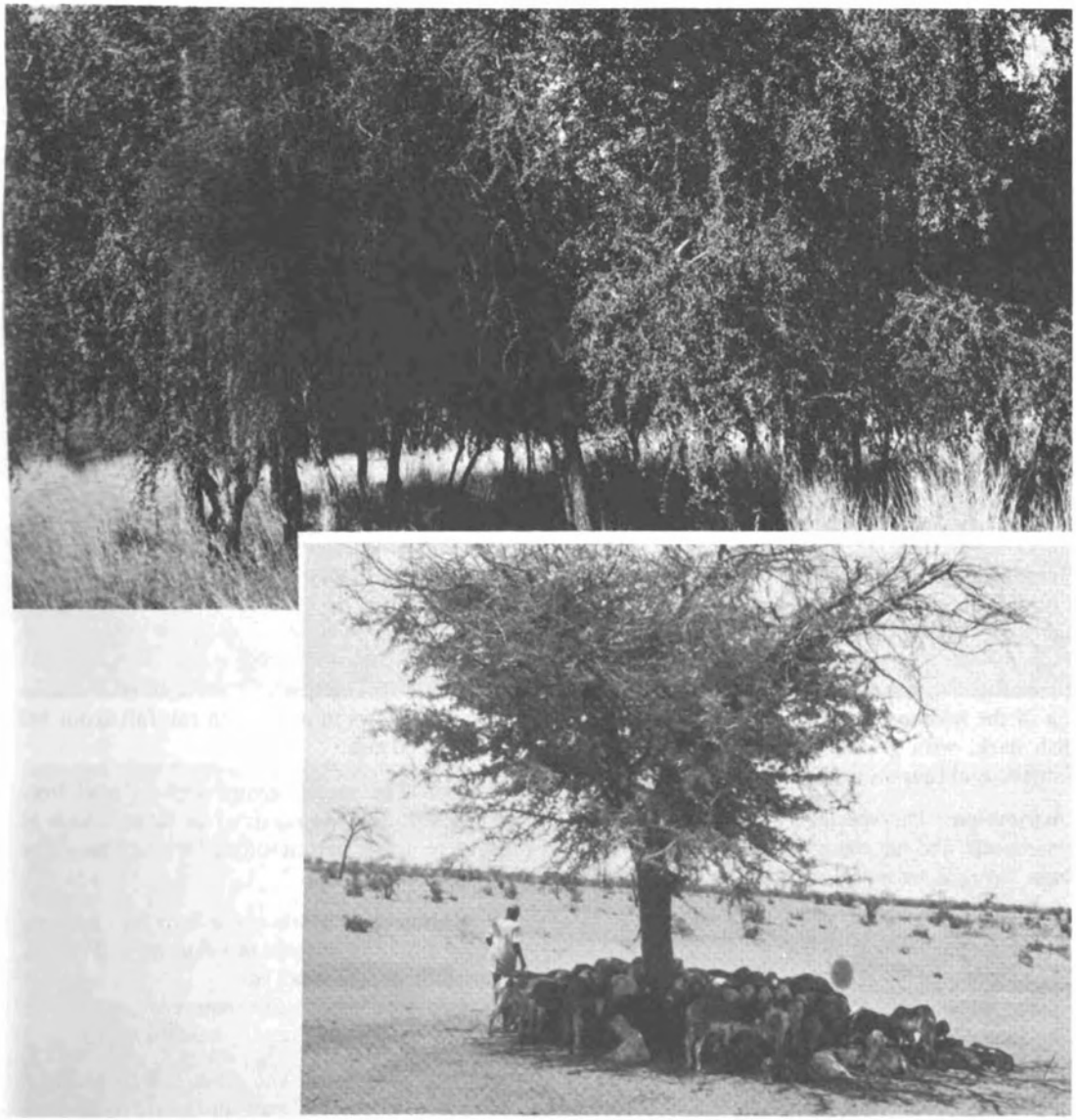
Yield The tree grows slowly. In Puerto Rico, one trial sowing of 43 trees produced specimens only 2–5 m high after 8 years' growth. In Israel 2- to 3-year-old coppice shoots have reached 1–3 m in height.

Other Uses

- Fences. The thorny branches are massed together to form brushwood fencing; root cuttings strike readily to form living fences.
- Wood. The attractive wood is easily worked, fine grained, durable, and resistant to insects. It saws and planes well and is used for bowls, mortars and pestles, tool handles, gunstocks, and cabinetwork.
- Food. The fruit is oblong, resembling a yellowish date with loose, leathery skin. It has gummy, bittersweet pulp that is edible when fully ripe. The pulp contains about 40 percent sugar and is macerated in water to make a refreshing beverage or is sometimes fermented to make an alcoholic drink. The seed kernel has been made into bread and soup and contains 30–58 percent of an edible oil (Zachon oil). The residue, which is 50 percent protein, is used in cooking and soap making.
- Forage. The young leaves, fruits, and even the thorns are eaten by goats, camels, and wildlife.
- Pest control. Extracts of the fruit and bark have been found to kill the freshwater snails that are intermediary hosts for schistosomiasis (bilharzia), and they also kill the free-swimming life forms of this parasite, making it a suitable tree for planting along banks of irrigation canals. A strong emulsion of the fruits is toxic to fish. It is also lethal to the waterflea that harbors dracunculiasis (guinea worm).
- Sapogenin source. All parts of the plant, including the seed kernel, yield the sapogenins diosgenin and yamogenin, both of which are used in the partial synthesis of steroid drugs.
- Soap substitute. Because of the saponin content of the roots, bark, fruits, and wood chips, all of these parts have been used as "soap" for washing clothes.

Environmental Requirements

- Temperature. The desert date easily withstands high temperatures ranging up to 40.5°C.
- Altitude. The altitudinal range of the tree is from 380 m below sea level to 1,500 m above sea level.
- Rainfall. The tree is commonly found where rainfall is between 250 mm and 800 mm per year. In some drier areas it is confined to sites such as riverbanks with available groundwater.
- Soil. Desert date can be found on a great



Balanites aegyptiaca. (Top: H. A. Musnad; bottom: G. E. Wickens)

variety of soils; however, on sandy soils its growth is poor and only scattered trees occur. It appears sensitive to salinity and does not tolerate prolonged waterlogging.

Establishment Seeds casually distributed by humans or animals germinate readily. The trees can also be reproduced by seed and root suckers.

- Seed treatment. None is needed when fruits or seeds are sown in summer or autumn. In winter, seeds are soaked for 24 hours at room temperature.
- Ability to compete with weeds. The tree's slow growth would make it a poor competitor with weeds in fertile soils. It must be protected from fire and cattle for at least 3 years to ensure the survival of plantations.

Pests and Diseases Seeds are often attacked by a borer.

Limitations The desert date is thorny and, as noted, very slow growing. Browsing by animals can inhibit its growth, but it has run wild in abundance in Curaçao despite free-ranging goats. Because the tree is widely distributed in Africa and other continents, it must have several forms, if not subspecies. It is therefore quite possible to find a form with such requisite characteristics as fast growth and small thorns or no thorns.

Combretum micranthum

Botanic Name *Combretum micranthum* G. Don

Synonyms *Combretum altum* Perr., *C. floribundum* Engl. & Diels, *C. parviflorum* Reichb.

Common Names Kinkeliba, randga (Upper Volta); paramerga, lardaga (Ghana); kolobe, koubou, gugumi, gieze, landaga (West African Sahel)

Family Combretaceae

Main Attributes A tough drought- and fire-resistant shrub or tree, *Combretum micranthum* will survive in barren, rocky wastes where little else will grow.

Description *Combretum micranthum* is normally a spreading shrub or spreading small tree 2-5 m high and 5-8 cm in stem diameter, although it can grow to 15 m with a 1.5 m trunk. Typically, it is reduced to a shrubby habit by repeated burning of the savanna. It has a shaggy, peeling reddish bark, with greenish maroon leaves, white flowers, and four-winged, glossy red fruits.

Distribution This species is common in Savanna woodlands and in some places near the coast from Senegal to northern Nigeria. It has been successfully introduced for cultivation in South Vietnam; plantings around Saigon, made in the 1950s, have flourished.

Use as Firewood The branches and stems of *Combretum micranthum* are slim and can be used for firewood, particularly around the towns where it is abundant. In Sokoto, Nigeria, the wood is much used for charcoal.

Yield No data available.

Other Uses

- Craftwork. Young stems are tough and flexible and are used in basketry, while older ones are used as walking sticks and rafters. Unsplit stems are used for the interior center part of a thatch roof.
- Beverage. *Combretum micranthum*'s main use in Senegal and Mali is for the Kinkeliba beverage. Young leaves are collected, dried, and processed into bundles to be sold in cities and along roads. These leaves are boiled, and the liquid is a popular beverage, believed to be effective against various tropical fevers and alimentary disorders.

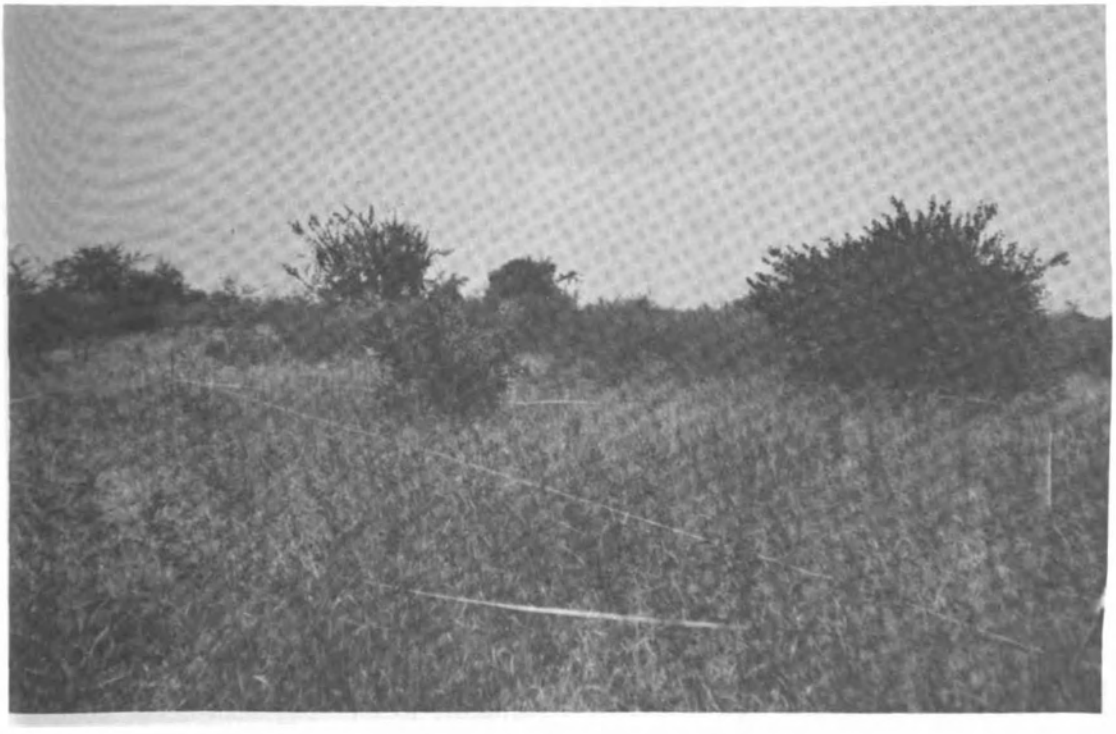
Environmental Requirements

- Temperature. *Combretum micranthum* grows in areas with tropical temperatures such as the Sahel.
- Altitude. The shrubs and trees grow from sea level to 1,000 m.
- Rainfall. The species is drought resistant; in Senegal it grows in areas with rainfall from 300 mm to 1,500 mm.
- Soil. The species grows well on arid ironstone plateaus. It is regarded as an indicator of barren or nearly barren soil and is often found on abandoned farmland.

Establishment The tree spreads by root suckers. The germination of seeds in a nursery is difficult, and establishment is not easy.

- Seed treatment. None required.
- Ability to compete with weeds. High.

Pests and Diseases The roots of *Combretum micranthum* are very susceptible to termite attack.



Combretum micranthum. (R. T. Wilson)

Conocarpus lancifolius

Botanic Name *Conocarpus lancifolius* Engler

Common Names Damas, ghalab

Family Combretaceae

Main Attributes A drought-resistant species, *Conocarpus lancifolius* is one of the more promising trees for trials in arid areas. It is recommended for a variety of soil types, including saline soils, and yields excellent charcoal and valuable wood.

Description Damas is an evergreen tree that grows up to 20 m in height and 60–250 cm or more in diameter. However, it is believed that the larger trees have now been almost entirely felled. Whereas it is usually a multibranched tree in its natural habitat, trees planted in the Sudan formed a single, straight stem.

Distribution Natural stands of damas are found beside intermittent watercourses of northern Somalia and in the southwest part of the Arabian Peninsula. Some of these streams are salty and some sulphurous. The tree is also cultivated in Somalia, as it is in Djibouti, Sudan, Kenya, north and south Yemen, and Pakistan. A small plantation has been established in Sudan's Khashm El Birb Arboretum. About 10,000 trees have been planted successfully in limestone near Mombasa, Kenya.

Use as Firewood The wood is light colored and of medium to heavy density (specific gravity 0.81). It makes good firewood (although some reports suggest that the wood smolders rather than burns) and excellent charcoal.

Yield The annual yield of one irrigated plantation was approximately 21 m^3 per ha. Early growth of more than 2.5 m per year has been achieved in irrigated plantations, though 1.0–1.75 m per year is more typical in early years.

Other Uses

- Wood. Damas wood is strong and is used for poles in house construction and in carpentry. At one time it was exported to Aden, where its chief use was for building dhows, and it is still favored for use as ship knees.
- Fodder. The tree is evergreen and its foliage makes a good fodder.
- Other. It is a good shade and roadside tree. In South Yemen it is used for windbreaks around irrigated agricultural areas and for avenue plantings.

Environmental Requirements

- Temperature. Damas grows best in areas where the mean annual temperature ranges from 20°–30°C, but where the maximum summer temperature has reached 50°C. During summer, the dry, hot air of the tree's natural habitat is laden with sand carried by the southwesterly monsoons. Winter temperatures are moderate and free of frost.
- Altitude. The tree grows from sea level up to about 1,000 m.
- Rainfall. The rainfall in its natural habitat is generally between 50 mm and 400 mm, but the tree grows mainly along seasonal watercourses. It can be grown in plantations in areas with less than about 400 mm but grows well only if irrigated or within reach of groundwater. It withstands drought conditions for several months when irrigation fails.
- Soil. Damas does well on deep soils ranging from pure sand to clays and loams, but has difficulty on shallow soils. It will tolerate moderately saline soils. Experiments carried out in Yemen showed that damas can grow on highly saline-alkaline soils of pH 9.5, provided water is in reach.

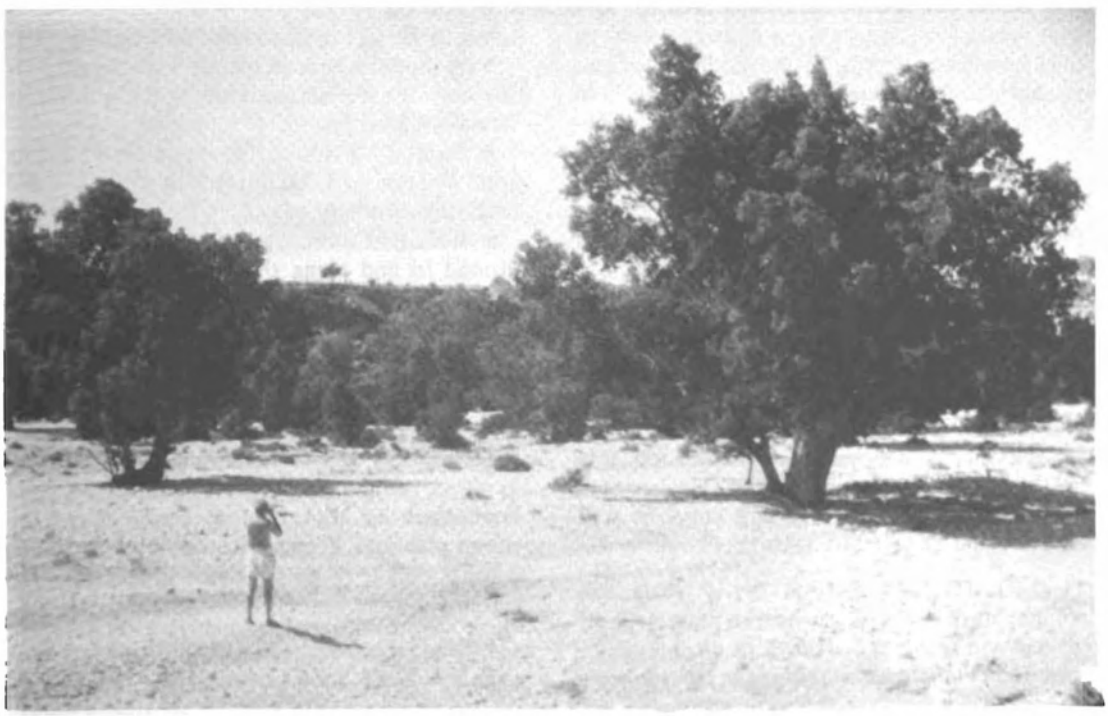
Establishment The tree seeds prolifically at an early age and the seed, which is small and light, has a germination capacity of about 25 percent. When sown, it should preferably be left uncovered or covered only thinly. Seeds should be sown in rows 5 cm apart, broadcast in moist seedbeds, or planted in sandy soil in containers 30 cm × 15 cm with a number of holes drilled in the bottom to facilitate irrigation. Irrigation should be provided daily for the first 6–8 months, after which the plants are ready for planting out. Plants grown in a semishaded area in polyethelene bags can be transplanted when the seedlings gain 4–5 leaves. Damas can also be raised by cuttings.

- Seed treatment. None required.
- Ability to compete with weeds. Weeding and watering are essential after planting to ensure establishment.

Pests and Diseases Newly germinated seedlings are highly susceptible to damping-off. Damas is attractive to browsing animals, and complete protection is necessary if plantations are to survive.

Limitations Without irrigation or ready access to soil moisture, the tree grows more slowly and on some sites may not reach usable size in a reasonable time.

Conocarpus lancifolius. (Left: Mohsen A. R. Bazara'a; below: R. Melville)



Dalbergia sissoo

Botanic Name *Dalbergia sissoo* Roxb.

Common Names Sissoo, sisu, sarsou, shisham, nelkar, karra, tanach, shewa, tali, yette

Family Leguminosae (Papilionoideae)

Main Attributes *Dalbergia sissoo* is a moderately fast growing tree that adapts well to semiarid conditions and produces first-class firewood. Its timber is highly valued for construction and general utility purposes. Under savanna conditions the trunk is usually crooked, but it is much sought for furniture, shipbuilding, and fuel.

Description A large, fast-growing tree with a spreading crown, sissoo grows to a height of 10–15 m in arid regions and up to 30 m high in the irrigated plains of Pakistan, in the northern part of India with its high rainfall, and along riverbanks. The tree has long, superficial roots, which send up suckers when injured, and small yellowish flowers with a pervasive fragrance.

Distribution Sissoo occurs throughout the Indian subcontinent from the Indus to Assam. It descends the river valleys for some distance into the plains and is planted or self-sown in many parts of India and Pakistan. It has been extensively grown in irrigated plantations, along roads and canals, and around farms and orchards as a windbreak. The tree shows promising results in the Khartoum greenbelt (Sudan) under irrigation. It has been less successful in Ghana, northern Nigeria, northern Cameroon, and Togo; however, it is being increasingly planted as a street tree in southern Florida, where it is running wild. There are experimental forestry plantings in Puerto Rico, the West African Sahel, South America, and the Middle East.

Use as Firewood Sissoo wood is classed as an excellent fuel; calorific values of the sapwood and heartwood are 4,900 and 5,200 kcal per kg, respectively. Specific gravity is between 0.64 and 0.7, depending on the locality. The wood is also suitable for making charcoal. As fuelwood, it is grown on a 10- to 15-year rotation. The tree produces profuse root suckers and coppices well enough to be managed on a short rotation.

Yield Yield on a rotation of 10 years will amount to 61–99 tons per ha per year, or 9–15 m^3. Growth is strongly dependent on soil conditions. Under favorable conditions in Ghana, trees grew an exceptional 3.0–3.7 m in the first year and 9–11 m in 5 years. Compared with other species (for example, eucalyptus) the yield is relatively low with the same input of labor and sissoo should be used in sites not favorable for other species.

Other Uses

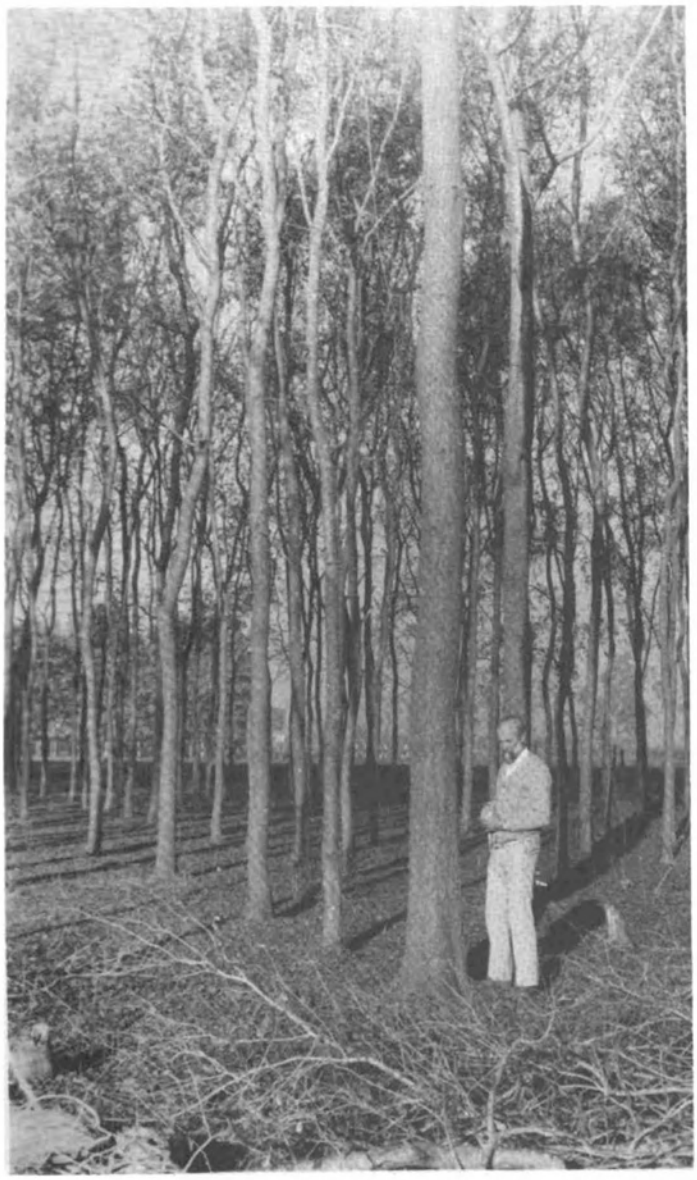
- Wood. The wood is hard, elastic, and close grained, with a little white sapwood and dark-brown heartwood that soon becomes dull. The heartwood is durable and valued for furniture, including bentwood items, and for veneers, carved articles, structural work, handles, cart wheels, railway carriages, boat building, ploughs, toys, frames for tennis rackets, hockey sticks, skis, and minute parts of musical instruments.
- Fodder. Young branches and leaves are used for fodder.
- Erosion control. The strong development of root suckers and runners favor sissoo's use as a living barrier against soil movement, and it is planted for this purpose across the bottom of eroding gulleys.
- Ornamental. In many Mediterranean countries the tree is valued as an ornamental.

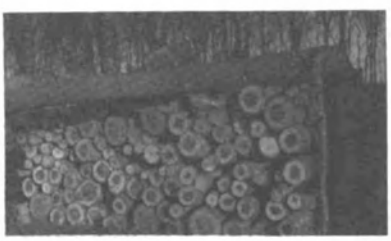
Environmental Requirements

- Temperature. Sissoo grows in an area where the temperatures range from just below freezing to nearly 50°C. It is considered frost hardy.
- Altitude. Although mainly a species of river bottoms, the tree also ascends to 1,500 m in the Himalaya foothills.
- Rainfall. Sissoo thrives in rainfall ranging from 500 mm to 2,000 mm and can tolerate arid and semiarid conditions.
- Soil. It is most typically found on alluvial ground in and along the beds of streams and rivers or on sand or gravel along the banks of rivers or on islands. It also springs up on landslips and other places where mineral soil is exposed. Porous soil with adequate moisture seems best; stiff clay should be avoided.

Establishment Sissoo is normally propagated by direct seeding. However, in arid regions it is established by transplanting seedlings or by stump plantings. It may also be raised by shoot cuttings. Shade or partial shade is necessary for germination and seedling development.

- Seed treatment. It is difficult to extract seed from the sissoo pod, so the pods are usually





Dalbergia sissoo, Sagarnath, Nepal, on a 9.5-year-old plantation. This tree was 20 cm in diameter and 22 m in height. (D. B. Amatya)

broken and pieces containing one or two seeds are sown. The broken pods should be soaked in water for at least 24 hours before sowing. Sissoo seeds germinate best at 30°C.

- Ability to compete with weeds. Regular weeding is necessary in the plantation during the first 2–3 years.

Pests and Diseases Insects have been noted to damage the root system. Irrigated plantations may be severely damaged by root fungus. In India and Pakistan a leaf fungus (*Phyllactinia*) and a leaf wilt (*Fusarium solani sensa*) have damaged plantations. Sissoo is also susceptible to attack by the pinhole borer. The tree is a host of *Loranthus* spp., *Tapinenthus dodoneifolius*, and the defoliator *Plecoptra reflexa*. Young plants are browsed by deer and cattle.

Limitations There is evidence in Nigeria and Zaire that after two or three coppice rotations the stumps lose their vigor. A change of species or replanting with fresh *Dalbergia sissoo* is probably necessary in these areas. Sissoo needs protection against fire and animal browsing.

*Populus euphratica**

Botanic Name *Populus euphratica* Oliv.

Synonyms *Populus diversifolia* Schrenk, *P. ariana* Dode, *P. mauritanica* Dode, *P. bonnetiana* Dode, *P. litwinowiana* Dode, *P. glaucicomans* Dode, *P. illicitana* Dode, *P. denhardtiorum* Dode, *P. euphratica* f. pruinosa (Schrenk) Nevski

Common Names Euphrates poplar, bahan, bhan, hotung, hodung, gharab, palk, saf-saf, Indian poplar

Family Salicaceae

Main Attributes *Populus euphratica* grows fast. Annual diameter increments of 4.0–5.3 cm have been measured. It can tolerate a high degree of salinity and extremely arid and "continental type" climatic conditions, provided the subsoil is moist. It also grows on land that is seasonally flooded and on which no other form of cultivation appears possible.

Description *Populus euphratica* is a small- to medium-sized tree (7.5–15 m in height) capable of attaining a diameter of 30–70 cm under good conditions. It is often seen in Syria with a bent and nearly always forked stem.

Distribution The tree extends from China to Spain and western Morocco and as far south as Kenya. It is found chiefly in Turkestan, Iran, Iraq, and Syria, where natural stands are economically important, but it occurs also in Turkey, Pakistan, Israel, Egypt, Libya, Algeria, and the Chinese provinces of Hopei, Sinkiang, Shansi, and Manchuria. In India the tree is typically gregarious, occurring in pure stands or associated with other species. Remarkably adaptable, it reaches to the upper elevation of tree growth and is found even in the hottest parts in the plains, where in fact it thrives under river inundations.

Use as Firewood Formerly, *Populus euphratica* constituted dense forests (mixed with willow, tamarisk, and mulberry) along watercourses and their tributaries throughout its vast range, but these forests have been almost completely destroyed to supply firewood. A few remnant forests are still exploited for firewood, but now mainly by coppice on short rotations of one or two years. The wood is only moderately dense (specific gravity up to 0.48). The calorific value is reported to be 5,019 kcal for the sapwood and 5,008 kcal for the heartwood.

Yield Unreported.

Other Uses

- Fodder. The leaves afford a good fodder for sheep, goats, and camels.
- Dental use. The twigs are chewed and used for cleaning teeth.
- Wood. The wood is easy to saw and works to a good finish. It is a good turnery wood and can be peeled off on a rotary cutter. It is used for planking, lacquer work, artificial limbs, match boxes, and splints. It is also suitable for plywood, cricket bats, shoe heels, and bobbins, and can be used for pulp.

Environmental Requirements

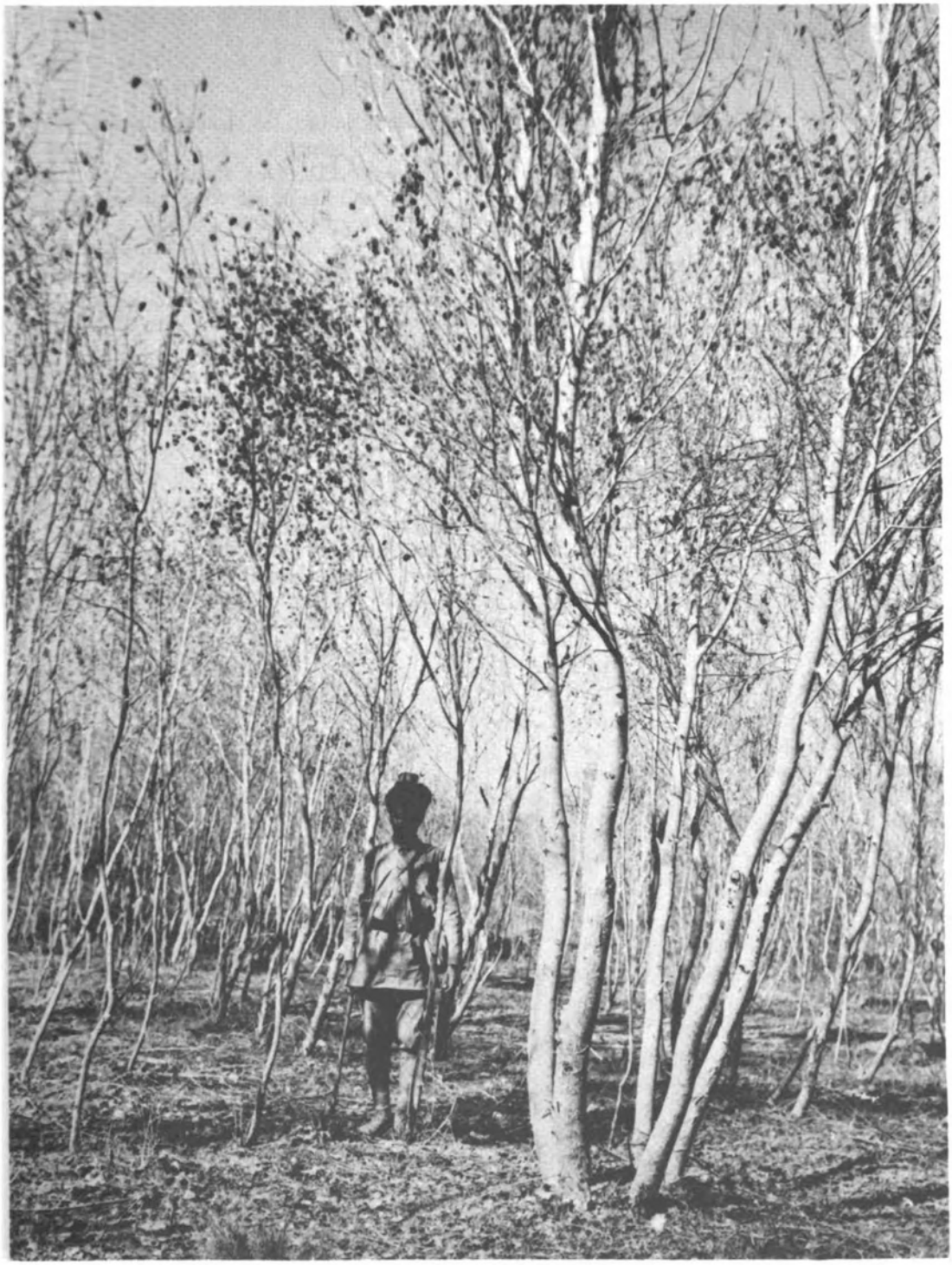
- Temperature. *Populus euphratica* grows in areas with a minimum temperatue of −5°C to a maximum of 49°–52°C. It is frost hardy. During the growing season it requires much light and heat.
- Altitude. It is found from below sea level in the Middle East to an altitude of 4,000 m in Ladakh (India) and western Tibet.
- Rainfall. Rainfall range is 75–200 mm, but it mostly grows as a riverine species whose growth does not depend on rainfall.
- Soil. *Populus euphratica* occurs naturally in soils with a high salt content, as much as three parts per thousand.

Establishment Natural reproduction is through root suckers or seeds. The seedlings spring up on fresh alluvial soil after the floods recede. Three sizes of cuttings are used for rooting in the nursery for subsequent planting in India. Planting is done at a spacing of 2 m × 3 m, although wider spacing is sometimes used to provide space for sowing alfalfa for improving soil and to provide fodder. The tree coppices well. It is well adapted for treatment under coppice or coppice-with-standards, reproduction being obtained from root suckers and coppice shoots.

- Seed treatment. None required.
- Ability to compete with weeds. High.

Pests and Diseases In the Near East the tree is

**Populus euphratica* Oliv. is a complex species with many varieties and ecotypes. Formerly classified as *P. inphratica* (now a separate species): (1) pro syn *P. euphratica* Oliv.; (2) pro syn *P. euphratica* Oliv.; (3) pro syn. *P. euphratica* Oliv.; (4) formerly pro syn *P. pruinosa* Schrenk.



Three-year-old *Populus euphratica* coppice stand in India. (A. L. Griffith)

subject to attack by various beetles of the genus *Capnodis* and by *Cuscuta monogyna*. It is also attacked by a number of other insect defoliators, borers, and gall-forming pests.

Limitations The finest specimens of *Populus euphratica* were felled long ago, and the trees that now remain (for example, along the banks of the Euphrates) are inferior in form.

Sesbania sesban

Botanic Name *Sesbania sesban* (Linn.) Merrill

Synonym *Sesbania aegyptiaca* (Pòir.) Pers

Common Names Sesban, Egyptian rattle pod, suriminta, soriminta

Family Leguminosae (Papillionaceae)

Main Attributes Sesban is a fast-growing, short-lived tree that regenerates rapidly after pruning. It has a tendency to form root nodules by symbiotic association with soil bacteria capable of fixing atmospheric nitrogen.

Description A shrub or small tree, sesban grows 4.5–6 m high. It is copiously branched, with pinnate leaves, pale yellow flowers, and slender, slightly twisted seedpods up to 25 cm long and containing many seeds.

Distribution Sesban is said to be one of the first garden plants grown in Egypt. It is now widespread in tropical Africa and throughout tropical Asia. It is cultivated and naturalized to some extent in Hawaii.

Use as Firewood In Africa and in India, where fuel is scarce, the tree is sometimes planted to provide firewood, which is used especially for boiling the sap of the sugar palm. The wood yields an excellent gunpowder charcoal.

Yield A stem growth of 5 m in 12 months has been reported, and the yield recorded in India was 30 tons per acre (10 percent moisture) in 1 year.

Other Uses

- Food. In Bihar the flowers are eaten as a vegetable. The leaves are eaten in Thailand. The seeds, high in protein (33.7 percent), are eaten as a famine food in India; they are first soaked for 3 days and then cooked for half an hour to remove the toxic constituent caravanine.
- Fodder. The leaves and young branches are cut for fodder for cattle and sheep.
- Wood. The wood weighs 432 kg per m^3. In Senegal the stems are used for arrows and pipes. In Assam the wood is split and plaited into mats. The very soft wood is made into toys in Burma. In India and Pakistan, stems are used as roofing for huts; in fact, the plant is cultivated as a substitute for bamboo.
- Fiber. The bark fiber is used for making ropes, while the pith serves as fishing floats.
- Other. In India, sesban is extensively planted as a windbreak and shade for vegetable gardens; as support for grape, black pepper, cucurbits, and betel vines; and as a shade for coffee, turmeric, sweet oranges, mandarin oranges, and cotton. In Pakistan it is planted as an intercrop for soil improvement because it is unusually rich in nitrogen. In India it is often grown as green manure in both dry and wet rice fields and plowed in before the crop is planted. It is also grown as a support for sugarcane, each plant bracing six canes. Lopped leaves are composted for use as fertilizer.

Environmental Requirements

- Temperature. In Pakistan the tree requires from 10°C to 45°C.
- Altitude. Sesban grows at 300–500 m in Pakistan. In India it is grown throughout the plains and up to an altitude of 1,200 m.
- Rainfall. It requires 350–1,000 mm rainfall.
- Soil. It tolerates a wide range of soil conditions, withstanding acid soil, periodic flooding, and waterlogging. It can endure 0.4–1.0 percent salt concentration in the seedling stage and 0.9–1.4 percent near maturity.

Establishment

- Seed treatment. None required.
- Ability to compete with weeds. Good; two or three weedings will be required during the first 2 months.

Pests and Diseases The seed is destroyed by insects. Several species of fungi attack the plant. The baterium *Xanthomonas sesbaniae* affects the stems and foliage. The tobacco caterpillar eats the leaves; a weevil, *Alcidodes buho*, damages the plant; and the larvae of *Azygophleps scalaris* tunnels through the main stem. Infested plants must be uprooted and burned.

Limitations The area under cultivation requires protection from cattle; it bears very palatable foliage and is subject to browsing.

Sesbania sesban, 1 year old, Central Soil Salinity Research Institute, Karnal, India. (I. P. Abrol)

Tarchonanthus camphoratus

Botanic Name *Tarchonanthus camphoratus* L.

Synonyms *Tarchonanthus litakunensis* DC., *Tarchonanthus minor* Less., *Tarchonanthus camphoratus* var *litakunensis* (DC) Harv.

Common names Camphor bush, camphor wood, kanferhout, vaalbos (South Africa); leleshua (East Africa)

Family Compositae

Main Attributes This is a many-branched shrub or small tree that is common in open sites in many parts of southern and eastern Africa. It is easy to establish, grows fairly fast, and coppices well. The wood burns with a pleasant-smelling smoke and can be used as fuel even when not completely dry.

Description Under favorable conditions large specimens may reach 9 m, forming a medium-sized tree. More usually, in semiarid areas it remains a densely leaved and bushy shrub some 2–3 m in height. The leaves are oblong to elliptic, 1.3–15 cm long, gray-green above and wooly white below. When crushed they give off a pleasant scent of camphor. The tree is dioecious and has small flowers on different plants, the female forming decorative, many-headed sprays. The fruiting heads that follow are also densely coated with glossy, fluffy white hairs.

Distribution The camphor bush grows from the coast to semiarid inland areas and from the southern tip of Africa to Ethiopia and Somalia. In some areas it is common, forming an extensive shrub savannah.

Use as Firewood The usual multistemmed growth makes the camphor bush easy to harvest for fuel. The bole from which the branches grow adds a substantial piece of firewood. The wood is dense and burns slowly; it ignites well even when only partly dried, making it valuable when shortages of fuel require the harvesting of live wood. People like the pleasantly scented smoke. Good-quality charcoal can be made from the wood.

Yield The camphor bush coppices well under heavy utilization, sprouting even when the bole is burnt or cut almost to the ground. Although precise yield data are not available, its adaptation to harsh environments and fairly rapid growth suggest it as a valuable fuelwood species.

Other Uses

- Windbreak. With its tolerance of wind and extremes of temperature from hot days to freezing nights, the plant makes a valuable windbreak in semiarid areas. It can grow at the shoreline fully exposed to salt spray, making it useful in fixing drifting sands.
- Fodder. The dense, leafy canopy provides good fodder for livestock, especially during droughts and in midwinter when there is a shortage of grazing. In some semiarid areas of Africa, it is the principal source of fodder for wild and domesticated animals.
- Wood. The wood is heavy, tough, close grained, and termite proof. It is good for fence posts, boatbuilding, spear shafts, musical instruments, and decorative work.

Environmental Requirements

- Temperature. The camphor bush thrives in temperate to semidesert climates with daily extremes of temperature.
- Altitude. The plant grows from sea level to about 2,000 m.
- Rainfall. The rainfall ranges from 150 mm to more than 800 mm per year. The plant can tolerate long periods of drought.
- Soil. The camphor bush grows well on open, semiarid plains and rocky places. It is not found in arid areas with deep sands.

Establishment The camphor bush grows easily from seed and may be propagated from cuttings. Seedlings transplant well.

- Seed treatment. Probably none is needed since it seeds and germinates profusely.
- Ability to compete with weeds. It is invasive in overutilized vegetation (bush encroachment), but not in vegetation in good condition.

Pests and Diseases The camphor bush is remarkably free of pests and diseases, being apparently repellant to insects.

Limitations The bush encroaches on grazing lands in East Africa, and because of its tenacious root system it is highly resistant to burning or cutting. Repeated chemical control is successful after the first regeneration. Although it is thornless, a splinter from the wood produces a troublesome sore that heals with difficulty.

Related Species The camphor bush is often seen together with other woody members of the Com-

Tarchonanthus camphoratus (camphor bush) growing near the sea, south of Cape Town, South Africa. (A. V. Hall)

positae family, particularly of the genus *Brachylaena*. In KwaZulu in South Africa, it often grows in association with *Brachylaena ilicifolia*, which is as much used locally for firewood as the camphor bush.

APPENDIX 1

Summary of Characteristics by Climatic Zones

The table following reviews the attributes of the various species duscussed in each section of Volumes I and II of *Firewood Crops: Shrub and Tree Species for Energy Production.* It only includes data contained in the two reports: environmental requirements, yields, calorific values, other uses (uses other than for firewood), coppicing abilities, and nitrogen-fixing abilities.

Our table is based on one prepared by Alan Grainger for his review of Volume I of *Firewood Crops* in *International Tree Crops Journal* Volume 2 No. 1, 1982.

Abbreviations used in table:

Temperature	F	Frost tolerant
	LF	Tolerates light frost
	NF	Not frost tolerant
Altitude	Extremes are given in parentheses.	
Rainfall	Extremes are given in parentheses. <100 + indicates that trees tolerate less than 100 mm but also a much higher rainfall.	
Yields	Estimates are in m^3/ha/year except when stated otherwise. Typical rotations are given in parentheses when available.	

Other Uses

B	Bee forage	P	Perfume
DY	Dye	PC	Pest control
F	Food	PW	Pulpwood
Fd	Fodder	R	Resin
Fi	Fiber	SB	Shelterbelts
G	Gum	SC	Soil conservation
GM	Green manure	Sh	Shade
H	Hedges	Si	Silkworm forage
M	Medicine	T	Timber, of whatever quality
O	Oil	Ta	Tannin
Or	Ornamental		

Species	Temperature °C	Altitude m	Rainfall mm	Drought Resistance	Soil Needs	Coppicing Ability	Yields m^3/ha/yr	Calorific Value kcal/kg	Other Uses	Nitrogen Fixing
Acacia decurrens	12–25 F	25–1,000 (2,500)	900–1,600	–	Adaptable	Yes	6–16 25 (Sri Lanka) (15)	3,530–3,940	Ta, T, Sh, SB, H	–
Acacia mearnsii	F	300–1,100	500–1,000	–	Adaptable, not calcareous soils	Poor	10–25 (Indonesia) (7–10)	3,500–4,000	Ta, SC, GM, PW	Yes
Ailanthus altissima	F	to 2,000 +	350–600	Up to 8 months	Very adaptable	Yes	–	–	T, SC, Sh, SB	–
Alnus acuminata	4–27 F	1,200–3,200	1,000– 3,000 +	–	Adaptable, likes deep well-drained loams or loamy sands	Naturally	10–15 (Costa Rica) (20)	–	T, SC	Yes
Alnus nepalensis	–	1,000–3,000 (300)	over 500	–	Adaptable as above, but needs moist soil	Yes	–	–	T	Probably
Alnus rubra	– 20–45	below 750	600–3,000	–	Adaptable, likes moist soils	Yes	17–21 (USA)	4,600	T, PW, SC	Yes
Eucalyptus globulus	Moderate temperature	to 3,000	800–1,500	No	Adaptable, but needs well-drained soils	Yes	10–30 (Spain) (5–15)	4,800	T, SC, PW, O, B	–
Eucalyptus grandis	– 3–40 LF	to 2,700	1,000–2,500	Moderate	Prefers moist, well-drained soils	Yes	17–45 (Uganda) (6)	–	T, PW	–
Eucalyptus robusta	3–32 LF	to 1,600	1,000–2,000	4 months	Bottom slopes, swamps, and saltwater estuaries	Yes	10–35	–	T, SB, Sh, PW, Ta	–
Eucalyptus tereticornis	17–38 F	600 –1,000	800–1,500 (400–3,500)	Yes	Adaptable	Yes	20–25 (15)	–	T, PW, SC, O, B	–
Gleditsia triacanthos	Varies	1,500 +	500– 1,500 +	Yes	Adaptable	Yes	–	–	T, F, Sh, SC, H, SB, Or	–
Grevillea robusta	Mean 20 NF	to 2,300	750–1,500 (400–2,500)	Yes	Adaptable, likes deep, not waterlogged soils	Poorly, but pollards	–	–	T, Sh, B, Or	–
Inga vera	–	Lowland	–	Some	Adaptable	Yes	–	–	T, Sh, B, F	–
Melaleuca quinquenervia	18–34 LF	to 500 (1,400)	1,000–5,000	–	Wet soils	Yes	–	–	T, B, O, Or	–
Melia azedarach	– 15–18	to, 2,000	600–1,000	Yes	Adaptable	Yes	–	5,043–5,176	T, PC, Fd, Sh, Or	–
Robinia pseudoacacia	– 20–18	to 2,500	1,000 (300–400)	2–6 months	Adaptable	Yes	10–17 tons from 3 years (Korea)	High	T, SC, SB, Fd, Or	Yes
Saplum sebiferum	Varies	to 1,000 (2,000)	710 + (500)	–	Adaptable	Yes	26 (4)	4,134–4,277	T, O, B, Or	–

Humid Tropics

Species	Temperature °C	Altitude m	Rainfall mm	Drought Resistance	Soil Needs	Coppicing Ability	Yields m^3/ha/yr	Calorific Value kcal/kg	Other Uses	Nitrogen Fixing
Acacia auriculiformis	26–30 +	to 600	1,500–1,800	Up to 6 months	Adaptable to even the poorest soils	Poor, but regenerates well	17–20 (Indonesia) (10–12)	4,800–4,900	PW, Sh, Or, SC, Ta	Yes
Albizia falcataria	22–29	to 1,000 (1,500)	4,500	0–2 months	Well-drained, deep with high fertility	Yes	39–50 (10)	2,865–3,357	PW, Sh, Ta, T	–
Bursera simaruba	LF	to 1,000 (1,800)	500–1,400	–	Very adaptable, best in rich lowlands, saline tolerant	Yes	–	–	T, H, R, Or	–
Calliandra calothyrsus	–	150–1,500	1,000	Moderate	Adaptable	Yes	35–65 (Indonesia) (1)	4,500–4,750	SC, Fd, B, Or	Yes
Casuarina equisetifolia	10–33 NF	to 1,500	200–5,000	6–8 months	Tolerates calcareous or slightly saline soils, not heavy clays	Not readily	7.5–20 (Malaysia) tons/ha (7–10)	4,950	T, SC, DY, PW, SB, Ta	Yes
Coccoloba uvifera	LF	to 500	500–1,400	–	Pure sand to inland, good drainage, saline tolerant	Yes	–	–	T, H, F, B, Ta, Or, DY	–
Derris indica	0–50	to 1,200	500–2,500	Yes	Adaptable, highly saline tolerant	Yes	–	4,600	T, Fd, O, PC, Fi, SC	–
Eucalyptus brassiana	to 32 NF	to 650	1,000 minimum	3–5 months	Adaptable, typically infertile	Yes	–	–	T	–
Eucalyptus deglupta	24–32	to 1,800	2,500–3,500	–	Adaptable, colonizes volcanic ash and pumice	Usually not	20–40 (Papua New Guinea) (15)	–	PW, T	–
Eucalyptus pellita	6–33 LF	to 750	900–2,300	–	Adaptable	–	–	–	T, B	–
Eucalyptus urophylla	18–28	300–3,000	1,300–2,500	–	Medium to heavy soil derived from noncalcareous rock	Yes	20–30	–	T, PW	–
Gliricidia sepium	22–30	500 (to 1,600)	1,500–2,300 +	–	Adaptable to both moist and dry soils	Yes	–	4,900	T, Sh, H, Fd, B, GM, Or	Yes
Gmelina arborea	to 52 NF	to 1,000	750–4,500	Some provenances	Adaptable to acid, calcareous and lateritic soils but not water-logged or leached soils or dry sand	Yes	20–35 (5–8)	4,800	T, PW, B	–

Guazuma ulmifolia	Tropical	to 1,200	700–1,500	4–7 months	Adaptable	–	–	Moderately hard	T, Fd, B, Sh, F	Yes
Hibiscus tiliaceus	NF	to 500	1,400	–	Adaptable, highly salt tolerant	Yes	–	–	Fi, T, SC, H, Or	–
Leucaena leucocephala	NF	to 500	600–1,700	Yes	Adaptable, not acid soils	Yes	30–40 (Philippines)	4,200–4,600	F, T, SC, Fd, GM	Yes
Maesopsis eminii	16–27	100–700 (to 1,200)	1,200–3,000	–	Moderate fertile, well-drained soils	–	20–30 (Uganda) (30) 8–20 Common in many areas	–	F, T, Sh, PW	–
Mimosa scabrella	–	to 2,400	–	–	Adaptable, not wet soils	Yes	–	–	PW, GM, Or	Yes
Muntingia calabura	Humid tropical	to 1,300	1,000–2,000	–	Tolerates poor soils, saline tolerant	–	–	–	Sh, PW, Fi, F, Or	–
Pinus caribaea	22–28 (5–37)	1,000 (1,500)	1,000–1,800 (3,900) (660)	–	Variable, generally well drained	–	21–40	–	PW, T	–
Psidium guajava	NF	to 800 (1,500)	1,000	4–5 months	Acid soils, poor in heavy clays	Yes	–	4,792	F, Ta, T, DY	–
Rhizophora species *Avicennia* species	NF	Estuarine/ coastal zones	1,000	–	Tidal areas	Yes	–	4,000–4,300	T, SC, PW, Ta	–
Sesbania bispinosa	Versatile	to 1,200	550–1,100	Yes	Adaptable, tolerates salines, alkaline, and wet soils	–	15 tons/yr (Italy) (2 harvests/yr in the tropics)	–	G, PW, Fi, GM, Fd	Yes
Sesbania grandiflora	NF	to 800	1,000	Few months	Adaptable to dry and moist soils	–	20–25 (Indonesia)	–	F, Fd, SC, PW, G, Ta, Or, SB, H, GM	Yes
Syzygium cumini	–	to 600 (1,800)	1,500–10,000	–	Adaptable	Yes	–	4,800	T, F, H, SB, Ta, B, Or	–
Terminelia catappa	Tropical, humid	to 300	1,000	Yes	Adaptable, saline tolerant	–	2–3.6 tons/ha/yr (10)	–	T, F, Ta, SC, Sh, Si, Or	–
Trema species	–	to 2,000	Varies	Varies	Adaptable to poor soils	Yes	–	4,500	SC, Sh, PW, T, Fd	–

Species	Temperature °C	Altitude m	Rainfall mm	Drought Resistance	Soil Needs	Coppicing Ability	Yields m³/ha/yr	Calorific Value kcal/kg	Other Uses	Nitrogen Fixing
Acacia brachystachya	4–58	to 600	200–500	Yes	Adaptable	–	–	–	T, Fd	–
Acacia cambagei	to 34 +	75–500	125–500	5 months	Adaptable	–	–	–	T	–
Acacia cyclops	5–31 LF	300	200–800	Yes	Adaptable, tolerates salinity and dune crests	Rarely	– (7–10)	–	Fd	–
Acacia nilotica	– LF	to 500	Varies	High	Adaptable	Only occasionally	– (20–30)	4,800–4,950	T, Fd, Ta, G, B	–
Acacia saligna	13–30 NF	to 300	350–600 (1,000)	High	Adaptable to calcareous, acid, alkaline, saline soils	Yes	1.5–10 (5–10)	–	SC, SB, Fd, G	–
Acacia senegal	14–43	100–1,700	300–450 (200–800)	High, 8–11 months	Sand and clay soils, but not waterlogged sites	Yes	–	–	T, G, Fd, F, SG, Fi	Yes
Acacia seyal	Hot	Lowland (to 2,100)	350	Yes	Adaptable, including moist sites	–	–	–	T, Fd, G	Probably
Acacia tortilis	to 50 NF	Lowland	100–1,000	High	Prefers alkaline soils	Yes	54 tons/ha (12)	4,400	T, Fd, SC	–
Adhatoda vasica	NF	to 1,300	500–1,650	–	Adaptable	Yes	–	–	M, GM, PC, DY, H	–
Ailanthus excelsa	20–40	Low	600 (400)	–	Adaptable but not clay or waterlogged	Yes	–	–	Fd, T, SB, Sh	–
Albizia lebbek	– LF	0–1,600	500–2,000	Yes	Likes moist conditions, saline tolerant	Yes	5 (India) (10–15)	5,200	T, Sh, B, Fd, SC, GM	Yes
Anogeissus latifolia	–	to 1,300	600	Yes	Dry, sandy, or rocky soils	Yes	–	4,900	T, G, Ta, DY, Fd, Si, PW	–
Azadirachta indica	0–44	50–1,500	450–1,150 (130 min)	High	Adaptable, not waterlogged or saline soils	Yes	13–17 (Ghana) (8)	High	T, O, SB, Sh, SC, Ta, PC	–
Balanites aegyptiaca	to 40.5	380–1,500	250–800	Yes	Adaptable, sensitive to salinity and waterlogging	Yes	–	4,600	H, T, F, Fd, M, PC	–
Cajanus cajan	18–29 NF	to 3,000	600–1,000 (400–2,500)	Yes	Adaptable, not waterlogged soils	Pollards	2 + woody stalks/ha/growing season	–	F, Fd, Si, Sh, SB, SC, H	Yes
Cassia siamea	NF	Lowland	1,000 +	–	Deep, well-drained soils	Yes	to 15 (5–10)	–	T, SB, SC	–
Colophospermum mopane	36 + LF	to 900	200–450 (125–800)	–	Adaptable, tolerates dry alkaline or saline soils	Yes	–	High	T, Fd, SC	No

Combretum micranthum	tropical	to 1,000	300–1,500	Yes	Arid ironstone plateaus	–	–	–	Pl, F	–
Conocarpus lancifolius	20–30 (50)	to 1,000	50–400	Yes	Adaptable, moderate saline soils	–	21 (irrigated)	–	T, Fd, Sh, SB	–
Dalbergia sissoo	to 50 F	to 1,500	500–2,000	Yes	Porous soil with moisture	Yes	9–15 (10)	4,900–5,200	T, Fd, SC, Or	–
Emblica officinalis	to 46 LF	to 1,800	–	–	Adaptable, likes moist soils, tolerates poor alkaline conditions	Yes	–	5,200	T, F, Fd, GM	–
Eucalyptus camaldulensis	varies	1,200 +	400 – 1,250	–	Various with provenance	Yes	20–25 (Argentina) 30 (Israel) (7–10)	4,800	T, SB, Sh, B, PW	–
E. citriodora	to 29–35 LF	to 900 (2,000 poss.)	900 (600 min)	Yes	Adaptable to poor soils	Yes	15 (Tanzania) (8)	–	T, P, B, Or	–
E. gomphocephala	Mild	to 2,000	700–1,000 (300)	Yes	Adaptable, tolerates saline, but not waterlogged soils	Yes	6–7 (difficult sites) 21–44 (irrigated) (7–10)	–	T, SC, Sh, SB	–
E. microtheca	5–38 F	80–340 (to 700)	200–1,000	Yes	Prefers clay and/or alkaline soils	Yes	– (6)	–	T, SB, Sh, SC	–
E. occidentalis	2–38 F	50–300	300–760	Yes	Prefers clays, saline tolerant	–	–	–	T, Sh	–
Haloxylon aphyllum	– 35–50	Lowland	100 +	Yes	Adaptable, sandy soils, saline tolerant	Yes	1.4 tons/ha/yr (5)	–	SC, Fd, SB	–
Haloxylon persicum	Less resistant to cold than above	–	100 +	High	As above, but less saline tolerant	Yes	–	–	SC, Fd	–
Parkinsonia aculeata	to 36 LF	to 1,300	200–1,000	High	Adaptable to poor soils, saline tolerant, not waterlogged soils	Yes	Fast growth	–	SC, Fd, Or, H	–
Pinus halepensis	18 to high F	to 1,000 (2,000)	250–800	Yes	Adaptable, does not tolerate saline or waterlogged soils	–	3–12 5–6 (Italy)	–	T, R, Or, SC, SB	–
P. eldarica	to 45 F	–	200 +	Yes	As above	–	–	–	–	–
Pithecellobium dulce	–	to 1,800	450–600 (to 1,650)	Yes	Very adaptable	Yes	–	5,200–5,600	T, Sh, SB, F, Fd, O, Ta, H, Or, B	–
Populus euphratica	– 5–52 F	to 4,000	75–200	–	Tolerates high salinity and arid conditions provided subsoil is moist	Yes	–	5,008–5,019	Fd, M, T, PW	–
Prosopis alba	15 + LF	Lowlands (to 1,000)	100–500	Yes	Likes sand with clay, saline tolerant	–	7 (Argentina) (10)	–	T, Fd, F, SB	Yes

Arid and Semiarid Regions (*continued*)

Species	Temperature °C	Altitude m	Rainfall mm	Drought Resistance	Soil Needs	Coppicing Ability	Yields m^3/ha/yr	Calorific Value kcal/kg	Other Uses	Nitrogen Fixing
P. chilensis	Hot (27) LF	340–1,230 (to 2,900)	200–400	High	Adapted to light soils	–	–	–	Fd, T, Or	Yes
P. cineraria	−6–50 LF	Lowland	75–850	Yes	Adaptable, tolerates salinity or high alkalinity	Yes	21	5,000	Fd, SC, T	Yes
P. juliflora	Hot	to 1,500	150–750	High	Adaptable	Yes	5–6 tons/ha/yr (10)	High	T, B, F, Fd	Yes
P. pallida	NF	0–300	250–1,250	Yes	Adaptable	Yes	–	High	Fd, F, SC	Yes
P. tamarugo	−12–36	1,000–1,500	0–10	High	Highly saline tolerant	Yes	Slow growth	–	T, Fd	–
Sesbania sesban	10–45	300–500 (1,200)	350–1,000	–	Adaptable	Yes	–	–	F, Fd, T, Fi, Sh, SB, GM	Yes
Tamarix aphylla	−10–50	–	350–500 (100 +)	Yes	Very adaptable, high saline tolerance	Yes	–	–	T, SC, SB	–
Tarchonanthus camphoratus	–	to 2,000	150–800	Yes	Adaptable but not deep sands	Yes	–	–	SB, SC, Fd, T	–
Zizyphus mauritania	Hot F	< 600	350–500 (to 2,000)	Yes	Adaptable	Yes	Fast growth	4,900	T, F, H, Ta, Si, Fd	–
Zizyphus spina-christi	Hot	to 1,500	100 +	High	Adaptable, likes deep alluvial soils	Yes	–	High	T, Fd, SC, H, SB	–

APPENDIX 2

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48. **Workshop on Energy and Agriculture in Developing Countries.** 1981. Discusses the energy used in agricultural production as well as the energy used to transport, process, and store agricultural products and to prepare food. It reviews current issues and advises USAID of promising opportunities to help solve energy-related problems in agriculture in developing areas.

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8. **Ferrocement: Applications in Developing Countries.** 1973. 89 pp. Assesses state of the art and cites applications of particular interest to developing countries such as boat building, construction, and food and water storage facilities.

14. **More Water for Arid Lands: Promising Technologies and Research Opportunities.** 1974. 153 pp. Outlines little-known but promising small-scale technologies to supply and conserve water in arid areas. (French language edition is also available from BOSTID.)

21. **Making Aquatic Weeds Useful: Some Perspectives for Developing Countries.** 1976. 175 pp. Describes ways to exploit aquatic weeds for grazing, and by harvesting and processing for use as compost, animal feed, pulp, paper, and fuel. Also describes utilization for sewage and industrial wastewater treatment. Examines certain plants with potential for aquaculture.

28. **Microbial Processes: Promising Technologies for Developing Countries.** 1979. 198 pp. Discusses the potential importance of microbiology in developing countries in food and feed, plant nutrition, pest control, fuel and energy, waste treatment and utilization, and health.

31. **Food, Fuel, and Fertilizer for Organic Wastes.** 1981. 150 pp. Examines some of the opportunities for the productive utilization of organic wastes and residues commonly found in the poorer rural areas of the world.

34. **Priorities in Biotechnology Research for International Development: Proceedings of a Workshop.** 1982. 261 pp. Examines opportunities for biotechnology research in developing countries. Includes background papers and specific recommendations in vaccines, animal production, monoclonal antibodies, energy, biological nitrogen fixation, and plant cell and tissue culture.

Plants

16. **Underexploited Tropical Plants with Promising Economic Value.** 1975. 187 pp. Describes 36 little-known tropical plants that, with research, could become important cash and food crops in the future. Includes cereals, roots and tubers, vegetables, fruits, oilseeds, forage plants, and others.

22. **Guayule: An Alternative Source of Natural Rubber.** 1977. 80 pp. Describes a little-known bush that grows wild in deserts of North America and produces a rubber virtually identical with that of the rubber tree.

25. **Tropical Legumes: Resources for the Future.** 1979. 331 pp. Describes plants of the family Leguminosae, including root crops, pulses, fruits, forages, timber and wood products, ornamentals, and others.

37. **The Winged Bean: A High Protein Crop for the Tropics.** (Second Edition) 1981. 59 pp. An update of BOSTID's 1975 report of this neglected tropical legume from Southeast Asia and Papua New Guinea that appears to hold promise for combatting malnutrition worldwide.

47. **Amaranth: Modern Prospects for an Ancient Crop.** 1984. Before the time of Cortez grain amaranths were staple foods of the Aztec and Inca. Today this nutritious food has a bright future. The report also discusses vegetable amaranths.

Innovations in Tropical Reforestation

27. **Firewood Crops: Shrub and Tree Species for Energy Production.** 1980. 237 pp. Examines the selection of species suitable for deliberate cultivation as firewood crops in developing countries.

35. **Sowing Forests from the Air.** 1981. 64 pp. Describes experiences with establishing forests by sowing tree seed from aircraft. Suggests testing and development of the techniques for possible use where forest destruction now outpaces reforestation.

40. **Firewood Crops: Shrub and Tree Species for Energy Production.** Volume 2. 1983. 100 pp. A continuation of BOSTID report number 27. Describes 27 additional species of woody plants that seem suitable candidates for fuelwood plantations in developing countries.

41. **Mangium and Other Fast-Growing Acacias for the Humid Tropics.** 1983. 63 pp. Highlights 10 acacias species native to the tropical rain forest of Australasia. That they could become valuable forestry resources elsewhere is suggested by the exceptional performance of *Acacia mangium* in Malaysia.

42. **Calliandra: A Versatile Small Tree for the Humid Tropics.** 1983. 56 pp. This Latin American shrub is being widely planted by villagers and government agencies in Indonesia to provide firewood, prevent erosion, yield honey, and feed livestock.

43. **Casuarinas: Nitrogen-Fixing Trees for Adverse Sites.** 1984. These robust nitrogen-fixing Australasian trees could become valuable resources for planting on harsh, eroding land to provide fuel and other products. Eighteen species for tropical lowlands and highlands, temperate zones, and semiarid regions are highlighted.

52. **Leucaena: Promising Forage and Tree Crop for the Tropics.** (Second edition in preparation) Describes *Leucaena leucocephala*, a little-known Mexican plant with vigorously growing bushy types that produce nutritious forage as well as tree types that produce timber, firewood, and pulp and paper. The plant is also useful for revegetating hillslopes and for other purposes.

Managing Tropical Animal Resources

32. **The Water Buffalo: New Prospects for an Underutilized Animal.** 1981. 118 pp. Water buffalo are performing well in recent trials in new locations in the United States, Australia, and Brazil. Report discusses the animal's promise, particularly emphasizing its potential for use outside Asia.

44. **Butterfly Farming in Papua New Guinea.** 1983. 36 pp. Indigenous butterflies are being reared in Papua New Guinea villages in a formal government program that both provides a cash income in remote rural areas and contributes to the conservation of wildlife and tropical forests.

45. **Crocodiles as a Resource for the Tropics.** 1983. 60 pp. In most parts of the tropics crocodilian populations are being decimated, but programs in Papua New Guinea and a few other countries demonstrate that, with care, the animals can be raised for profit while the wild populations are being protected.

46. **Little-Known Asian Animals with a Promising Economic Future.** 1983. 124 pp. Describes banteng, madura, mithan, yak, kouprey, babirusa, Javan warty pig, and other obscure, but possibly useful, wild and domesticated indigenous Asian animals.

General

29. **Postharvest Food Losses in Developing Countries.** 1978. 202 pp. Summarizes existing work and information about losses of major food crops and fish; discusses economic and social factors involved; identifies major areas of need; and suggests policy and program options for developing countries and technical assistance agencies.

30. **U.S. Science and Technology for Development: Contributions to the UN Conference.** 1978. 226 pp. Prepared for the U.S. Department of State as a background document for the U.S. national paper presented at the 1979 United Nations Conference on Science and Technology for Development.

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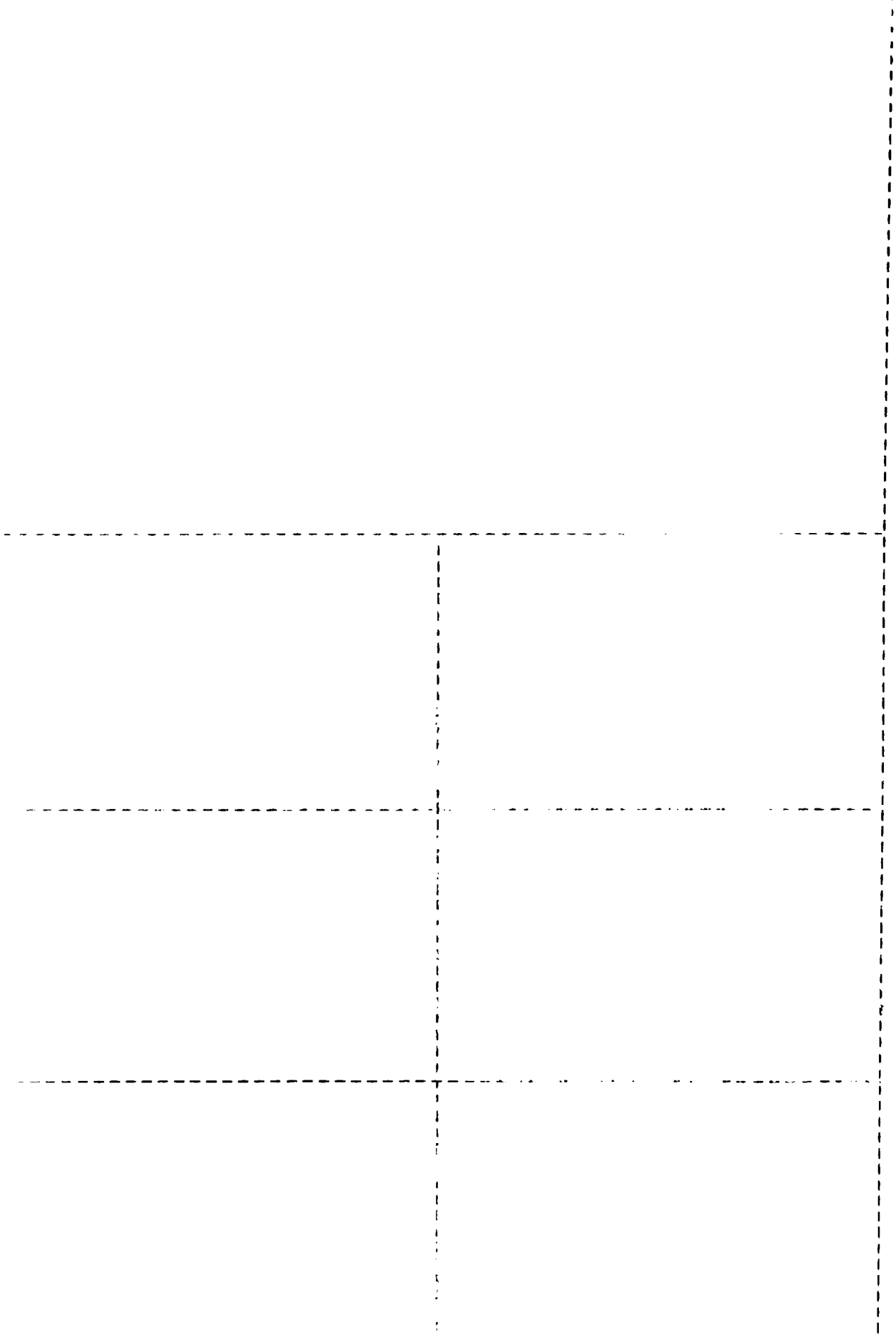

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The Board on Science and Technology for International Development

The Board on Science and Technology for International Development (BOSTID) of the Office of International Affairs addresses a range of issues arising from the ways in which science and technology in developing countries can stimulate and complement the complex processes of social and economic development. It oversees a broad program of bilateral workshops with scientific organizations in developing countries and conducts special studies. BOSTID's Advisory Committee on Technology Innovation publishes topical reviews of unconventional technical processes and biological resources of potential importance to developing countries.