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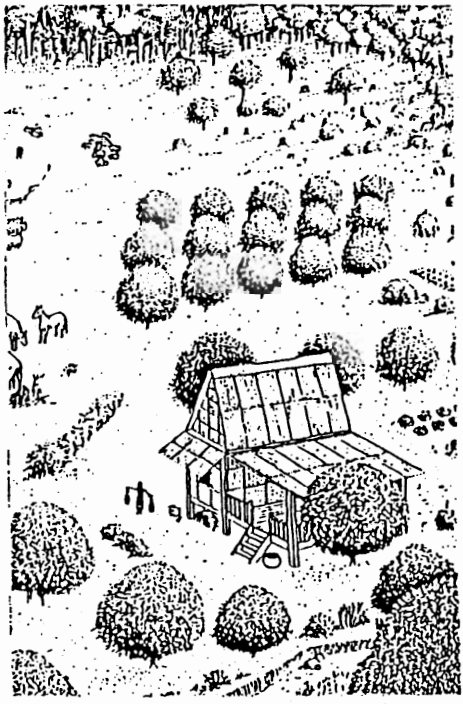
Growing Multipurpose Trees on Small Farms

A manual for field workers



This manual provides readily understandable technical information to extension workers so they can respond to farmers' questions on how to grow and manage multipurpose tree species (MPTS). The manual is, for the most part, a technical reference. It also advocates a

collaborative process that makes adjustments for local social and economic conditions.

The Multipurpose Tree Species Research Network in Asia produced the manual with support from a number of national and international agencies in the region. This Network now includes scientists in 11 countries.

For convenience in the field, the modules are packaged into 9 pocket-sized volumes. The first series is concerned with establishing MPTS plantings. This includes modules on 1) *Selecting Multipurpose Tree Species* 2) *Nurseries and Propagation*, 3) *Multipurpose Trees in Agroforestry*, and 4) *Small Plantations of Multipurpose Trees*.

The second series concentrates on management of MPTS. This covers 5) *Tending Multipurpose Trees*, 6) *Harvesting Crops of MPTS*, 7) *Selling Tree Crops* and 8) *Principles of Effective Extension*.

Module 9 is a set of *Species Fact Sheets* which summarize what we know about selected MPTS. Each entry describes the origin of the species, its ecology, a botanical description, a summary of its advantages and disadvantages, its management, and agroforestry uses. These are indexed in 8 languages and include botanical drawings for identification.

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Module 1

Selecting Multipurpose Trees

Growing Multipurpose Trees on Small Farms

5

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Information for the species fact sheets was compiled primarily from NFTA's *NFT Highlights*, ICRAF's *Multipurpose Tree and Shrub Database*, Wageningen Agricultural University's *Tree Species for Tropical Agroforestry Systems*, The Prosea Foundation, and IIRR's *Resource Book on Sustainable Agriculture for the Uplands*.

Mr. Wyatt Latimer of the US Peace Corps compiled the first version of the fact cards while Henry Wood expanded and revised these based on feedback from Dr. J.K. Chaturvedi and other experienced foresters in the region. Technical review was done by Dr. Rick J. Van Den Beldt and

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Finally, Dr. Tom Niblock provided consistent inspiration and support to bring this idea to fruition.

James H. French
Communications/Publications Officer
F/FRED, Bangkok, Thailand

Preface

This manual aims to provide readily understandable technical information to extension workers so they can respond to farmers' questions on how to grow and manage multipurpose trees for household use or local markets. The manual is, for the most part, a technical reference. However, it also advocates a collaborative process that makes adjustments for local social and economic conditions. Without careful consideration of these and other factors, no tree-planting program, however technically sound, can succeed.

The Multipurpose Tree Species Research Network in Asia produced the manual with support from a number of national and international agencies in the region. This Network consists of a group of scientists and institutions in Asia who have the shared goal of improving the production of trees that meet the needs of small-farm households. The Network now includes scientists in 11 countries. Participants conduct research on MPTS assessment, improvement, management, and related applied social science research topics.

Research is complemented by training, network development, germplasm exchange, and preparation of publications. A secretariat manages

the Network out of Kasetsart University's Faculty of Forestry, Bangkok, Thailand. It has received technical assistance since its inception in 1986 from the Winrock International Institute for Agricultural Development. This was made possible under a cooperative agreement between the United States Agency for International Development (USAID), the Government of Thailand, and Kasetsart University.

Rick J. Van Den Beldt
F/FRED Team Leader
Bangkok, Thailand

How This Manual Is Organized

This manual is designed so that it can be used for both training and extension purposes. Each module includes a statement of its intended purpose and reminds the reader of the most important points covered. The modules also include a list of suggested readings for those who wish to learn more about the topic.

For convenience in the field, the modules are packaged into 9 pocket-sized volumes. The first series is concerned with **establishing MPTS plantings.** This includes modules on 1) *Selecting Multipurpose Tree Species* 2) *Nurseries and Propagation,* 3) *Multipurpose Trees in Agroforestry,* and 4) *Small Plantations of Multipurpose Trees.*

The second series concentrates on **management of MPTS**. This covers 5) *Tending Multipurpose Trees,* 6) *Harvesting Crops of MPTS,* 7) *Selling Tree Crops* and 8) *Principles of Effective Extension.*

Module 9 is a set of *Species Fact Sheets* which summarize **what we know about selected multipurpose tree species** in the Asian region. Each entry describes the origin of the species, its ecology, a botanical description, a summary of its advantages and disadvantages, its management, and agroforestry uses. These "fact sheets" are indexed in 8 languages and include botanical drawings for identification.

Module 1

Selecting Multipurpose Trees

This module provides basic guidelines on how to select species of multipurpose trees that will meet farmers' particular needs. The importance of matching tree species with the characteristics of the site where they will be grown is stressed. The module also outlines the possible advantages of growing trees, whether it be for domestic purposes or for generating income.

What Is a Multipurpose Tree?

Farmers have been growing trees for different purposes for thousands of years. Certainly, all trees provide shade and protection from soil erosion. In this sense, all trees can be said to have at least two purposes. More precisely, though, this manual uses the term multipurpose tree species to mean:

Tree species that are grown to provide more than one significant crop or function or form. These may include soil conservation, shade, fuelwood, timber, fiber, fodder, food or medicine.

Tree species can be multipurpose in two ways:

- **A single tree can yield more than one crop.** For example, farmers in Central

America and the Philippines grow *Gliricidia sepium* as living fences that provide fuel, fodder, and green manure for agricultural crops—all at the same time.

- **Trees of the same species, when managed differently, can yield different crops.** In the Philippines, for example, *Leucaena leucocephala* is managed so that some trees will principally yield wood while others principally produce leaf meal.

Farmers can grow multipurpose trees in various combinations with other crops, as in agroforestry, in block plantings of trees, or in naturally regenerating tree farms.

In certain settings, multipurpose trees are grown and managed for only one purpose. In the Solomon Islands, *Gliricidia sepium* is grown only to provide shade in coffee plantations. The same species is planted in Central America and the Philippines, yet the way it is managed results in a very different shape and use.

Farmers facing changing conditions in their environment or market can also change the way they manage a tree. For example, market changes may persuade farmers, who previously grew trees for fodder and fuel, to cut their trees for sale as roundwood for construction material.

Why Grow Multipurpose Trees?

Reducing Risk of Total Crop Failure

Growing multipurpose trees can reduce the risk of total crop failure. For example, if farmers usually grow *Leucaena leucocephala* for animal fodder and the tree's leaves are destroyed by pests, they will still have wood that can be used for fuel, pulp, or light-weight construction material.

Having a variety of plants on a farm, as in agroforestry systems, can also reduce the risk of total crop failure. Evidence shows that combining several types of plants provides a type of insurance. If the economic benefit of one crop is reduced by pest damage or market failure, the farmer can make up for it by harvesting another crop. Also, growing a variety of species makes the farm less vulnerable to any one pest.

Income Generation and Distribution

Agroforestry practices can increase farmers' annual income. Some increases in revenue come from harvesting different tree crops in different seasons. For example, in many Asian countries farmers use the leaves of *Artocarpus heterophyllus* (jackfruit) as fodder during the driest season. The same trees produce fruits providing income and food to the owner at other times. The result is that income and employment are distributed more evenly throughout the year.

Of course, there are many other reasons for growing trees on farms. Trees provide shade for a cooler soil temperature, reduce loss of soil moisture and also protect the soil from wind and water erosion.

Selecting Appropriate Species

Successfully growing multipurpose trees depends, to a great extent, on selecting the most appropriate species. To do this, farmers must first have a clear idea of why they wish to grow multipurpose trees and which tree crops match the needs of their particular farming system and local agroecological conditions.

People grow trees for different purposes: to obtain timber, fuelwood, fodder, or food; to

conserve the soil; or a combination of these. Trees can also be grown in different land-use systems, such as alley cropping, home gardens, farm woodlots, or industrial plantations. These different purposes and growing systems determine the criteria that farmers must consider when selecting which species to grow.

Fuelwood

Species grown for this purpose should:

- Adapt to a wide range of site conditions.
- Grow quickly and yield a maximum volume of wood in a short time.
- Stabilize the soil and maintain its fertility.
- Require minimum time and effort for management.
- Tolerate diseases and pests.
- Tolerate drought and other climatic stresses.
- Coppice well, that is, readily sprout shoots from stumps.
- Have other uses that contribute to the farm enterprise.
- Produce trees without thorns and whose stems or branches have a diameter small enough to be cut with hand tools and be easily transported.
- Produce wood that splits easily.
- Have a low moisture content or dry relatively quickly.
- Produce minimal and nontoxic smoke (low ash and sulphur content), when burned.
- Not spit or spark while burning, for safety reasons.
- Produce dense wood, to burn longer.

Some species often used for fuelwood are: *Acacia auriculiformis, Casuarina equisetifolia, Gliricidia sepium, Calliandra calothyrsus,* and *Leucaena leucocephala.* (See Species Fact Sheets.)

Roundwood (poles and posts)

Species grown for this purpose should:

- Have a straight stem.
- Have a single main stem rather than multiple stems.
- Produce few or thin branches.
- Be self-pruning and without knots, for strength.
- Have little taper from bottom to top.
- Have bark that strips easily.
- Produce wood that is durable, light, and capable of supporting heavy cross loads.
- Resist termites and other wood borers.
- Be able to absorb chemical preservatives easily.

Some species often used for roundwood are: *Acacia auriculiformis, Acacia mangium, Albizia lebbek, and Casuarina equisetifolia.*

Fodder

Species grown for this purpose should:

- Produce leaves or pods that animals like to eat.
- Withstand lopping, pruning, pollarding, and coppicing.
- Grow quickly, especially in early stages.
- Adapt easily to different sites and environments.

- Withstand intense shade if planted with other species.
- Fix nitrogen to enhance soil fertility.
- Withstand damage by pests, diseases, and browsing animals.
- Have other uses.

Some species often used for fodder are: *Faidherbia albida, Albizia lebbek, Leucaena leucocephala, Azadirachta indica, Artocarpus heterophyllus, Gliricidia sepium, Prosopis cineraria* and *Sesbania grandiflora.*

Live Fences

Species planted for this purpose should:

- Grow under adverse conditions.
- Grow well in close spacing.
- Require minimal maintenance.
- Withstand lopping and trimming.
- Propagate easily from cuttings.
- Grow fast to a medium height, and be long-lived.
- Have prickles or stiff branches and leaves that animals don't like to eat.
- Produce suckers.

Some species often used for live fences are: *Cajanus cajan, Erythrina poeppigiana, Calliandra calothyrsus, Gliricidia sepium, Casuarina equisetifolia,* and *Pithecellobium dulce.*

Windbreaks and Shelterbelts

Species grown for this purpose should:

- Tolerate harsh environments.
- Have a bushy, deep crown that still allows some wind penetration.
- Keep lower limbs for a long time.

- Have strong roots.
- Grow quickly.
- Live long.
- Tolerate pests and diseases.
- Not harbor pests that affect nearby crops.
- Not have roots that compete excessively with nearby crops for water and nutrients.

Some species often used for windbreaks and shelterbelts are: *Casuarina equisetifolia, and Erythrina poeppigiana.*

Soil Protection and Rehabilitation

Species grown for this purpose should:

- Grow fast.
- Grow well under adverse conditions.
- Have a spreading crown.
- Have a vigorous root system to bind the soil and a strong taproot especially in areas prone to landslides.
- Associate well with nitrogen-fixing organisms and mycorrhizal fungi in the soil.
- Reproduce vigorously, for example, from root suckers, or through abundant natural seed fall and seedling development.
- Tolerate fire.

Some species often used for soil protection and rehabilitation are: *Acacia auriculiformis, Casuarina equisetifolia,* and *Prosopis juliflora.*

Shade and Nurse Trees

Species grown for this purpose should:

- Have fast early growth.
- Establish easily, preferably by cuttings.

- Be evergreen.
- Live long.
- Tolerate soil compaction by animals walking and sitting beneath them, as happens on pasture land.
- Coppice well and withstand some lopping.
- Fix nitrogen in the soil to enhance soil fertility.
- Have a dense, spreading crown, if used to shade grazing animals.
- Have a light crown, if used as nurse trees for other crops.
- Not compete with crops for soil nutrients if used as nurse trees.

Some species often used as shade or nurse trees are: *Erythrina poeppigiana, Gliricidia sepium, Leucaena leucocephala,* and *Sesbania grandiflora.*

Decoration and Enjoyment

Species grown for this purpose should:

- Grow fast.
- Perhaps be evergreen.
- Have attractive flowers and possibly fruits that can be eaten by birds and small animals.
- Have a heavy and spreading crown, if shade is desired.
- Establish easily.
- Tolerate adverse site conditions.
- Tolerate some pruning.
- Require little maintenance.
- Protect the soil.

- Not have a large lateral rooting system, where planting is near buildings or paved roads.

Some species often used for decoration and enjoyment are: *Acacia auriculiformis, Casuarina equisetifolia, Pterocarpus indicus, Albizia saman,* and *Tamarindus indica.*

Industrial Uses

Species grown for sawn timber, plywood, veneer, pulpwood, or other industrial uses should:

- Grow fast.
- Have a maximum rate of growth in early stages of development.
- Have a straight stem, uniform size, and small branches.
- Show good natural pruning with rapid healing of wounds if used for producing sawn timber and plywood.
- Have good physical, mechanical, seasoning, preserving, and processing properties if used for producing sawn timber.
- Have wood that is easy to peel, slice, and free of knots if used for producing plywood and veneer.
- Have wood with a high density and, preferably, long fibers if used for producing pulp.

Some species often grown for industrial uses are: *Pinus* spp., *Tectona grandis, Populus* spp., and *Terminalia* spp. (for sawn timber); *Dipterocarpus* spp., and *Tectona grandis* (for plywood and veneer); *Acacia* spp., *Leucaena* spp., *Pinus* spp., and *Eucalyptus* spp. (for pulpwood).

Trees can also be planted to produce other commodities: *Eucalyptus* spp. (essential oils and honey), *Acacia* spp. (tannin for making dyes), *Azadirachta indica* (pesticides), *Morus alba* (silk production), and *Hevea brasiliensis* (latex).

Matching Species to Requirements

Site Characteristics

Multipurpose trees offer many opportunities but they do not guarantee benefits. When selecting a species, it is important to consider soil conditions, climate, and topography. After deciding on the planting objective and learning about the soil, rainfall, and other conditions of the planting site, the farmer can decide whether to grow indigenous or exotic species.

Indigenous Versus Exotic Species

Species found growing in nearby natural stands, or trees growing well in neighboring plantations are good choices. Some of these species may be indigenous, which grow and reproduce naturally in the region. Others may be exotics, that is, have been introduced from another region or even another country. For example, *Eucalyptus* spp. were introduced throughout Asia from Australia.

When introducing an exotic species, it is important to determine whether the soil, rainfall, and other requirements of the species match the conditions of the planting site. If the most suitable species are not known and there are only a few sources of tree seed in the area, indigenous species as well as local exotic species should be considered first. Local exotic species are those found in botanical gardens, on farms, in parks, or along roadsides and that have survived under local agroecological conditions.

Environmental Matching

The most frequently used technique for selecting an exotic species is called environmental matching. The technique calls for examining the species in its home environment or testing its growth in other countries with environmental conditions similar to those found in the home environment. Some species grow well in areas far from their original home if the new place has the same type of environment. When ordering seeds from outside the area to be planted, obtain supplies from more than one source. If one source performs poorly, there is still a chance that seed from another source will succeed.

Preferences of End Users

Species should match the preferences and needs of end users. When farmers grow trees for their own use, they know the types of tree crops that they wish to obtain. When farmers grow trees for sale, it is important that they know the preferences of buyers.

Technical Requirements

Some species require intensive management techniques beyond the means of small-scale farmers. Such species should be avoided, regardless of potentials they may appear to have.

Potential Competition with Other Crops

Introducing an exotic species can result in undesirable side effects. One possible problem is that the species will adapt so well to its new environment that it will become a "weed" and take over crops that are important to farmers' livelihood. For example, *Prosopis juliflora,* native to Central America and the West Indies, was introduced to India as a fodder and fuelwood tree.

Some scientists say that it grows so well in its new environment that it inhibits the germination and growth of other plants that are more valuable to the farmer.

Availability of Planting Material

Seeds or seedlings of the selected species should be readily available. Availability of planting material can be limited because:

- It is difficult to grow seedlings in local nurseries.
- It is difficult to establish the seedlings in local plantations.
- There are quarantine restrictions on seed coming into the country.
- Seeds and seedlings of the species are susceptible to local diseases and pests.

Suggested Readings

Boland, D.J. 1986. Selection of Species and Provenances for Tree Introduction. In: J.W.Turnbull, ed. *Multipurpose Australian Trees and Shrubs: Lesser-known Species for Fuelwood and Agroforestry*. Canberra, Australia: ACIAR.

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Remember

Multipurpose trees are grown to serve more than one significant on-farm function. These may include soil conservation, shade, fuelwood, timber, fiber, fodder, food or medicine.

Selecting the species is the most important decision the planter makes.

Site characteristics include soil, climate, topography. Unless these are known, it is difficult to make a good species selection.

Why multipurpose trees will be grown is important to consider when selecting species. This means knowing who will be using the tree crops and for what use. Markets and transport facilities should be available.

This Module was prepared by Winrock International staff at the Secretariat of the MPTS Research Network in Bangkok, Thailand.

Institutional Background

The **Forestry/Fuelwood Research and Development Project (F/FRED)**, funded by the **U.S. Agency for International Development (USAID)**, is designed to help scientists address the needs of small-scale farmers in the developing world for fuelwood and other tree products. As an outcome of collaborative meetings in the region, a ***Multipurpose Tree Species Research Network*** was established through which scientists exchange research plans, methods, and results. Research and development activities center on the production and use of multipurpose trees that meet the household and market needs of small farmers.

F/FRED is being executed by the **Winrock International Institute for Agricultural Development**. Winrock is a private, nonprofit U.S. organization working in agricultural development around the world. It was established in 1985 through the merging of the Agricultural Development Council (A/D/C), the International Agricultural Development Service (IADS), and the Winrock International Livestock Research and Training Center. Winrock's mission is to improve agriculture for the benefit of people, help increase agricultural productivity, improve nutrition, and advance the well-being of people throughout the world. Winrock's main areas of emphasis are human resources, renewable resources, food policy, farming systems, and agricultural research and extension.

Growing Multipurpose Trees on Small Farms

Module 1:
Selecting Multipurpose Trees

Module 2:
Nurseries and Propagation

Module 3:
Mulitpurpose Trees in Agroforestry

Module 4:
Small Plantations of Multipurpose Trees

Module 5:
Tending Multipurpose Trees

Module 6:
Harvesting Crops of Multipurpose Trees

Module 7:
Selling Tree Crops

Module 8:
Principles of Effective Extension

Module 9:
Species Fact Sheets

Module 2

Nurseries and Propagation

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Module 2
Nurseries and Propagation

This module provides details on major components of nursery establishment. It also contains guidelines on seed collection, different methods of raising seedlings, and other ways to propagate plants. Fruit-tree grafting techniques are explained, as well as the function of nitrogen-fixing organisms and mycorrhizae. Some principles of nursery management are outlined.

Establishing a Nursery

Before going ahead with nursery plans, a thorough economic analysis is suggested since a good nursery can be an expensive undertaking. In many situations, commercial seedlings are the best and cheapest source of quality planting material.

Selecting the Site

The nursery site is important to ensure efficient production of good-quality plants and easy nursery management. The following factors should be considered:

- **Water:** Locate the nursery next to a source of water that will be adequate throughout the year, for example, a river, spring, swamp, pond, dam, or perennial well.

- **Soil:** A good source of sandy loam or loamy soil, preferably forest topsoil, should be as close as possible to the site to reduce transport costs. This is particularly important if a large number of potted seedlings will be produced. If only heavy soils (for example, clays) are available, there should also be an easily accessible supply of sand for making suitable potting mixtures.
- **Topography:** The site should be relatively flat with a 1-2% slope. The gradual slope allows for runoff, preventing waterlogging and erosion. In hilly areas, nurseries must be built on terraces.
- **Microclimate:** The site should not be exposed to drying winds, such as those prevailing on hilltops, or to flooding or severe frost, that can occur in valley bottoms. The site should receive sunlight for the major part of the day.
- **Materials:** Easy access to supplies (manure, chemical fertilizers, compost, polybags, pesticides, etc.) and materials for building fences, shadehouses, sheds, and compost bins, helps reduce operating costs.
- **Location:** To minimize transportation time and cost, the nursery should be located as closely as possible to the planting area.
- **Access:** The site should be close to a good road so that the nursery will be accessible throughout the year.
- **Ownership:** Identify who owns the land on which the nursery is to be established. A written agreement giving the right to use the land and access to the water should be

obtained. Also, the duration of the agreement should be specific to avoid conflicts in following years.

- **Labor**: There should be enough local labor available for nursery construction and, from time to time, for soil transportation, potting, and weeding.
- **Size:** This is determined mainly by the number of plants to be produced, the time they will spend in the nursery, and their density in the beds. Other factors include the need for roads, paths, buildings, fences, and windbreaks. (See next section for details.)

Determining Nursery Size

Calculation of nursery size is based principally on the expected demand for seedlings and the main plant growing area required. It is also important to remember overlapping production cycles, for example, seedlings being grown to replace those that die after the first planting. These replacement seedlings (at least 10-20 % and as high as 45 %, depending on initial germination and survival) will take up space in the first cycle as well as the second cycle. This means that, over a period of two cycles, nearly half of the seedlings will take up twice as much space as the seedlings that are outplanted first.

Example

Let's calculate the size of a nursery required for the following average annual production:

- 12,000 plants in 3 x 7 in. (7.5 cm x 17.8 cm) pots
- 18,000 plants in 4 x 7 in. (10 x 17.8 cm) pots
- 500 single-node bamboo cuttings

- 2,000 stump plants, on a trial basis

The stumps, bamboos, and half of the plants in polypots require from 12 to 24 months in the nursery.

1) **12,000 polypots (3 x 7 in.)**

Space is required for 12,000 x 1.25 = 15,000 polypots (to allow for 25% loss and culling). Approximately 200 polypots cover an area of 1 m^2 when spaced out:

$$15{,}000 \div 200 = 75\ m^2$$

Half of these plants require twice as much space, because they are in the nursery for more than 12 months and need to be spaced further apart to avoid crowding.

$$37.5\ m^2 + (37.5\ m^2 \times 2) = 112.5\ m^2$$

2) **18,000 polypots (4 x 7 in.)**

Space is required for 18,000 x 1.25 = 22,500 polypots (to allow for 25% loss and culling). Approximately 115 polypots cover an area of 1 m^2 when spaced out:

$$22{,}500 \div 115 = 196\ m^2$$

Half of these plants require twice as much space, because they will be in the nursery for more than 12 months:

$$98\ m^2 + (98\ m^2 \times 2) = 294\ m^2$$

3) **500 bamboo cuttings**

Space is required for 500 x 1.40 = 700 polypots (to allow for 40% failure in rooting).

Four cuttings can be planted per square meter:

$$700 \div 4 = 175\ m^2$$

Twice as much space is required because the cuttings spend more than 12 months in the nursery:

$$2 \times 175 = 350 \text{ m}^2$$

4) **2,000 stumps**

Space is required for 2,000 x 1.25 = 2,500 stumps (to allow for 25% loss and culling). Approximately 100 stumps cover an area of 1 m^2:

$$2{,}500 \div 100 = 25 \text{ m}^2$$

Twice as much space is required, because the stumps spend more than 12 months in the nursery:

$$25 \text{ m}^2 \times 2 = 50 \text{ m}^2$$

5) **The total area required for the above 4 nursery beds = 806.5 m^2**

To allow for paths between beds and for terrace risers, this area must be multiplied by a factor of 1.5 for a nursery that is not terraced (slope of up to 2%), and by a factor of 3 for a terraced nursery (slope of 3 - 20%).

A nursery that is not terraced would, therefore, need 1,210 m^2 for the main plant growing area. A terraced nursery would, therefore, need 2,420 m^2.

In addition, space will be needed for seed beds, a potting shed, a compost-making area, an office, and parking area. The total area required is likely to be 1,600 - 1,700 m^2, on a level site, and almost twice as much (3,200 - 3,400 m^2) on a steep site.

Basic Site Requirements

- **Access roads and paths:** An all-weather access road to the nursery should be constructed. It should be wide enough to

enable vehicles to turn around as necessary. Within the nursery, access paths between beds should be about 60 cm wide for convenient transport, weeding, watering, etc.

- **Fencing**: Depending on the site, a 1.5 m-high fence should be built to protect the nursery against browsing and trampling animals. Thorny branches and tree poles can be used as temporary fences. Living fences and hedges consisting of trees and bushes are more permanent and offer good protection against wind and animals. They also can reduce invasion of weed seeds into the nursery. If a living fence is planted, tree species that can be easily propagated by cuttings are recommended. Cuttings from these fences can be an important source of planting material.
- **Shelter for tools, materials, and workers**: A simple hut built out of locally available materials (tree poles, bamboo, palms, mud, etc.) is essential for keeping tools and materials. Depending on the site, a shelter for workers may also be erected.
- **Soil dump**: Space should be available for storing the soil, sand, compost, or humus required for seedling production. For convenience, these should be close to where they are mixed and the pots filled.
- **Seedbeds:** Seedbeds, approximately 1 m wide and 2-5 m long, should be prepared in a well-drained area. There should be a 60 cm-wide path between them. Ideally, the seedbed should include three layers:

- the bottom layer should consist of 5 cm of gravel, small stones, or bricks, for good drainage
- the middle layer should consist of 2-3 cm of humus–rich soil, for holding water
- the top layer should consist of 2 cm of a 1:1 mixture of sieved sand and humus–rich soil.

Note: Where waterlogging is frequent, raised seedbeds should be used.

- **Potbeds**: 1 m x 5-10 m potbeds with a 60 cm-wide path between them should be built. Frames made of local materials such as stones, bamboo, tree poles, sawn timber, bricks, rope, or simply earth, should be placed on all sides to keep the pots upright. Normally, potbeds should be level with the ground, but they should be raised above the ground in areas where waterlogging is frequent (Figure 1).
- **Shading:** To prevent water loss and excessive build-up of heat in seedbeds or containers, shade must be provided. Shade protects germinating seeds and young seedlings. A 50 cm-high shade frame can be erected by using bamboo or wooden sticks. The shades themselves can be made from bamboo slats, crop residues, grasses, leaves, etc., tied together. Some space should be left between the slats to allow light and air to penetrate. The shades should also be removable (Figure 2). Trees should never be planted within a nursery, because full light is required for hardening seedlings before planting.

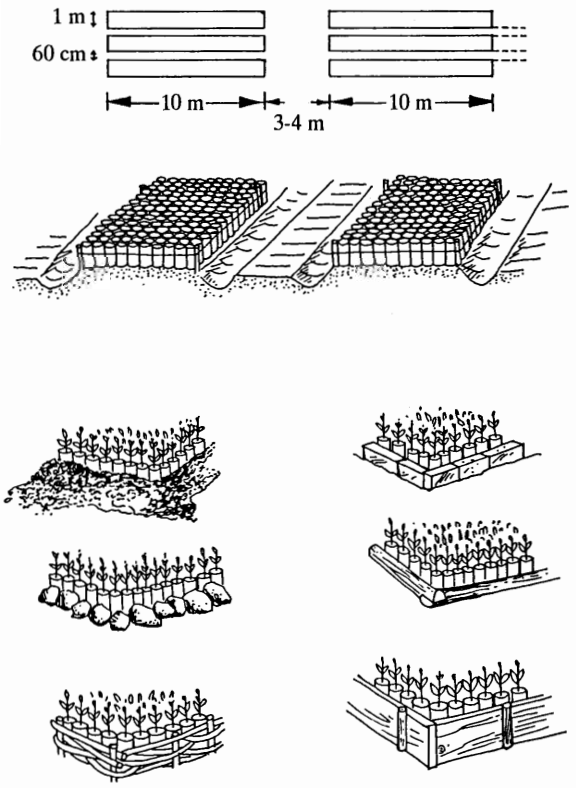
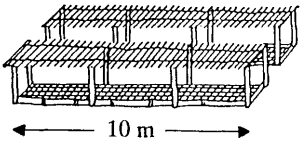
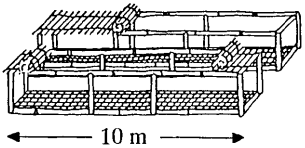


Figure 1.

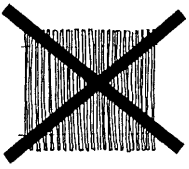
Normally, potbeds are level with the ground. But in waterlogged areas, they should be raised. Frames can be made of local materials such as stones, bamboo, and sawn timber.



Seedbed with tied bamboo/cane shading.



Seedbed with shading rolled up.



Shading should not be too dense.

Figure 2.

Potbeds should be shaded to prevent water loss and excessive heat.

In addition, a nursery can also have a:

- **Windbreak:** In areas where there are high prevailing winds, it is recommended to build a windbreak consisting of at least two rows of shrubs and one row of fast-growing trees. These should be placed on the side of the nursery facing the wind. The trees should be far enough from the beds so that their crowns will not shade the beds (Figure 3).
- **Compost heap/pit**: In high-rainfall areas, compost is prepared in heaps and piles rather than pits because the latter fill up with water. The pile can be 1-1.3 m high, 2 m wide, and 2-4 m long. In drier areas, pits 1-1.5 m deep, 1 m wide, and 2 m long are dug. In both cases, a shading roof is suggested for protection from the weather.
- **Seed-extraction area**: An area of about 10 m^2 for drying and extracting seeds should be set aside. This area should be level and receive direct sunlight.

Nursery Design

Before beginning construction, a sketch plan should be drawn which includes:

- fencing
- access paths
- water tanks, if necessary, and a water distribution system
- seedbeds and potbeds
- soil-storage shelter
- working area
- compost heap or pit.

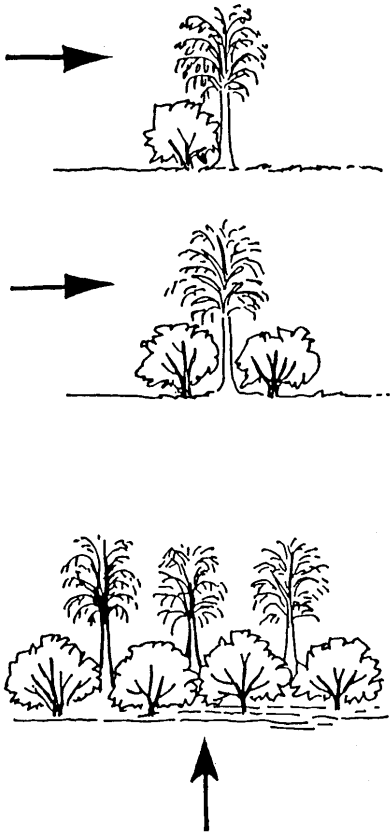


Figure 3.

Windbreaks of one or two rows of shrubs should be placed on the side of the nursery facing the wind.

The shape of the nursery should be square or rectangular. An irregular shape means that boundary lines are longer and this increases the amount of fencing. The ideal shape is square since this reduces the distance between seedbeds/potbeds and the area where seedlings are planted.

When the plan is complete, every element should be checked carefully at the nursery site. Farmers should ensure that the location of each component is the best one possible by keeping in mind what it is supposed to do and how this function is connected to other components.

Nursery Construction

Land should be cleared of all vegetation and rocks. Where earthworks such as terraces are necessary, drains should be built early to prevent rain damage. Drains should be built along the top edge and down the sides of the nursery, as well as alongside the paths to prevent the paths themselves from becoming drains.

Strong fences, large enough to keep all animals away, are a good investment. The gate should be simple and easy to open.

When the area for the seedbeds and potbeds has been leveled, the corners and edges can be marked with wooden sticks and strings. Flat stones, wood planks or other barriers can then be set on edge in trenches along these boundary lines to support the beds. The top of the barrier should be 10-12 cm above soil level. The ground around the stones or other material should be compacted so that they don't erode into the beds.

Tools Required

Nursery operators should refer to the following suggested checklist of tools and equipment. In different countries these tools will vary slightly.

- **Pickaxe:** for breaking up hard and stony ground.
- **Hoe:** for loosening the soil.
- **Shovel**: for moving earth, sieving soil, and mixing soil.
- **Flat-pronged fork**: for loosening soil, lifting bare-rooted seedlings, and turning over compost.
- **Rake:** for breaking up and levelling the soil.
- **Sieve:** for sifting soil for the seedbeds and potting, (approximately 1.5 cm mesh wire fitted to a 1 x 1.5 m wooden frame).
- **Funnel:** for filling pots with soil mixture.
- **Scoop:** for filling and compacting soil in pots.
- **Watering can:** for watering seedlings.
- **Wheelbarrow:** for transporting potting soil, filled pots, tools, seedlings, etc.
- **Pruners, knives, shears, or trowels:** for pruning the roots that grow out of the pots.
- **Machete, or other long knife:** for cutting fence posts, removing woody weeds, trimming living fences, etc.
- **Germination tray:** for germinating small quantities of seed.
- **Pointed sticks:** for weeding seedbeds and potted stock.
- **Tools for pricking:** for lifting germinated seedlings into pots (a small shovel, a flat

piece of wood, or simply a spoon are useful).

Seed Handling

Seed Collection

Seed can be collected locally or obtained from distributors, seed centers, forest services, and research institutes. Successful planting is more likely if the seed is:

- a suitable species
- from an area most closely resembling the planting site
- of good quality
- in sufficient quantity
- available at the right time.

If collection is local, it is important to know where the best trees are located. Seed should come from an area that is as similar as possible (altitude, amount of rainfall, type of soil, etc.) to the area where the seedlings will be grown. Seed should be collected from donor trees with the desired characteristics (see Module 1). For construction wood and timber, for instance, straight trees are desirable. For fuelwood production, fast growth and ready coppicing are more important than a straight, unbranched trunk. For fodder, abundant leaf production and good recovery after pruning or browsing are essential features. For fruit, local taste and market patterns are most important.

Remember:

- Seed should be collected from mother trees that are healthy and vigorous.
- Seed should be collected from several trees.
- Seed should **not** be collected from isolated bushy or very young trees (Figure 4).

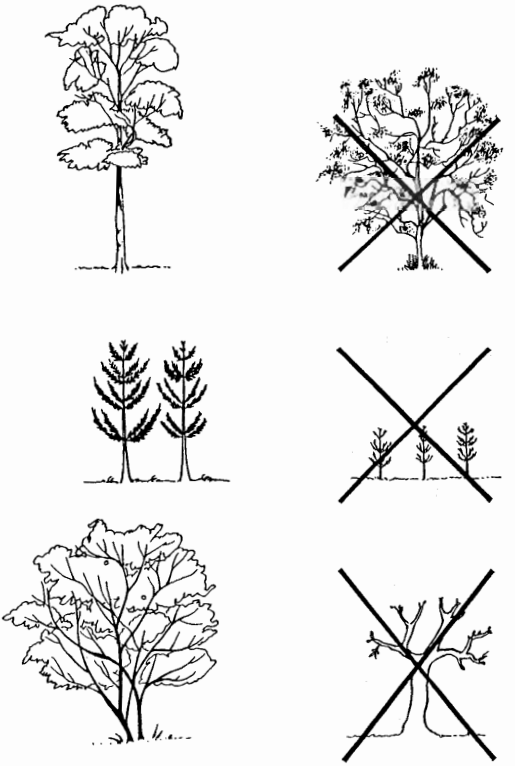


Figure 4.

Seed should be collected from mother trees that are healthy, vigorous, and have characteristics desirable for the intended use.

It is important to know when to collect seed:

- Collect seeds only from ripe fruits. If fruits are collected too early, the seed might be immature and weak (Figure 5). If collection is delayed too long, the seed may be attacked by insects and fungi.
- Pick fleshy fruits just as they turn from green to their ripe color.
- Pick dry fruits just before they open.
- Do not use unhealthy fruits or those that have already fallen to the ground.

Whenever possible:

- Pick only from branches or small twigs that bear fruits.
- Spread large pieces of cloth on the ground to collect fruits if it is difficult to climb the tree.

When transporting fruits:

- Do not use plastic bags as the fruits will get too warm and mould quickly.
- Store fruits in cloth or jute bags.
- Store the bags in a place that is shaded, cool, and dry.

Calculation of the amount of seed required

$$S_W = \frac{1.25N}{pW}$$

where S_W = Seed required in kg or other unit of measure.

N = number of seedlings required for planting

1.25 = factor that adds a 25 % reserve

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Figure 5.

Pick only ripe fruits and be careful not to damage the tree.

p = germination rate (if this is not known, a germination test will be needed.)

W = number of seeds per kg (or other unit of weight)

Since a number of seedlings die after they are outplanted and it is a good idea to select for vigor, it is advisable to increase the estimated number of seedlings by at least 10-20 % (the final amount to sow = 1.10 or 1.20 x S_W) depending on the species and local climatic conditions.

Seed Extraction and Storage

For most species, seeds can be extracted by drying fruits in the sun. Use the following procedure:

- Spread fruits in thin layers on pieces of canvas or trays.
- Stir regularly until cones, pods, or capsules open and release their seeds.
- Remove the pulp of fleshy fruits before drying and separate by winnowing or submerging in water.
- Dry good seeds in the sun. The characteristics of "good" and "bad" seeds depend very much on the species. Generally, discard seeds that are cracked, have been attacked by insects (which is often indicated by small holes in the seed cover), or whose size and color differ markedly from most of the other seeds.
- Store seeds in a cool, dry, and dark place. Seeds of leguminous species can generally be stored for many years, even at normal temperatures.

- Maintain storage temperature as constant as possible, even if cool storage is not available.
- Make certain that the storage area is well ventilated.
- Store moisture-sensitive seeds in airtight bottles or tins.
- Keep other seed in wooden boxes or cotton sacks.
- Do not use plastic containers, unless packing is airtight.

Raising Seedlings in Containers

Seed Pretreatment

Unless they are pretreated, some seeds do not germinate or do so only after a long time. These are usually species with hard seed coats that are impermeable to water and air or prevent the emergence of a radicle, which is the first part to come out of the seed.

Depending on species (see Species Fact Sheets), the following pretreatments are recommended:

Tap Water

Soak seeds in tap water for 12-48 hours before sowing. Only seeds that have absorbed water should be planted. Seeds that have absorbed water look swollen and tend to be larger and softer than seeds that do not absorb water.

Boiling Water

Place seeds in cloth bags or used cotton socks, then dip in boiling water (5-10 parts water to 1 part seed) and, using a stick, stir for 3-15 seconds. More time is needed for seeds with thicker coats (Figure 6).

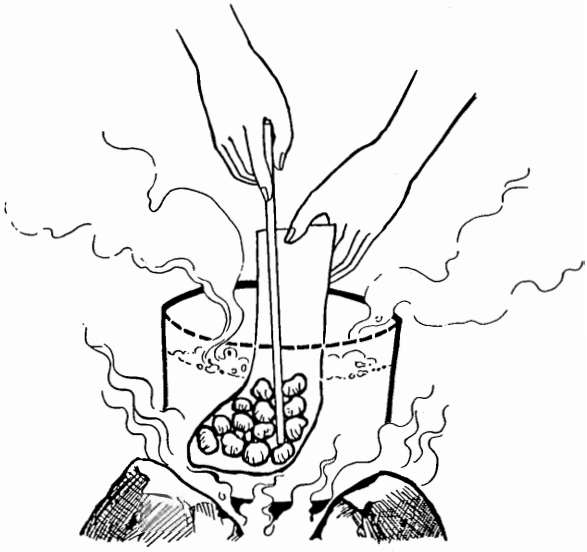

Figure 6.

One way to pretreat seeds is to place them in an old sock or cotton bag and dip them in boiling water for 3-15 seconds. This is recommended for seeds with a hard coat, such as *Acacia auriculiformis, Acacia mangium,* and *Paraserianthes falcataria.*

Hot Water

Pour hot water that has been boiled and then cooled for 10-15 minutes into a container in which seeds have been placed (10 parts water to 1 part seed). Let stand for 3-10 minutes or until water has cooled to room temperature. Let seeds soak overnight.

Mechanical Scarification

Nick off seed coat at the end using a knife, nailclipper, or similar sharp instrument. Sandpaper or a file can also be used to roughen the surface of the seed coat, taking care not to injure any internal parts. This technique is practical when seeds are not too small and there aren't too many of them.

Sowing Seeds

Seeds can be sown directly into pots or seedbeds/seedtrays, depending on species (see Species Fact Sheets). Seeds of species that germinate well, and more or less at the same time, can be sown directly. Direct sowing avoids damage and root distortion caused by transferring plants to larger containers.

Seedbeds/seedtrays should be used when:

- viability is expected to be low (less than 40%)
- germination takes a long time
- several plants germinate from one stone
- seeds are very small, or
- seeds are very scarce or expensive.

For sowing in pots, two or more seeds (depending on germination rate) should be placed into each pot. For sowing in seedbeds, it is recommended that seeds be put in rills running

across the bed, making weeding easier. In both cases, the seeds should be placed at a depth equal to one or two times their diameter. The seedbeds or pots should be watered using cans with fine nozzles.

The time of sowing is determined by calculating the time it takes for germination to take place and the time required for seedlings to reach the size and quality suitable for planting at the beginning of the rainy season. For example, for a species that requires 2 weeks to germinate and 12 weeks to reach outplanting size, seed should be sown 14 weeks before the start of the rainy season.

Pots

The most commonly used containers are plastic bags. These are available in various sizes with or without holes. Bags that measure 10 cm x 15 cm (while flat) are generally suitable. If they do not have holes, 8 holes extending to the base of the bag should be punched (a simple office paper puncher can be used) before filling with potting mixture.

Potting Mixture

The potting mixture depends on the quality of the soil available. A mixture consisting of 50% sandy loam, 40% river sand, and 10% organic material by volume is generally adequate. Compost, manure, peat, and coconut husk are good sources of organic material. A chemical fertilizer such as NPK (12:24:12) can be added to the potting mixture. Thirty to fifty grams (3-4 tablespoons) of chemical fertilizer per 10 liters of potting mixture is adequate. If coconut husk is used, a slow-release fertilizer such as osmocote is preferable.

Making Compost

Compost can be made from almost any organic matter such as weeds, forest litter, crop residues, animal bedding, and dung. Generally, it should consist of at least 20% animal manure. It can be made either in a heap or a pit. In heavy rainfall areas, a heap is better than a pit because pits tend to fill with water. The volume should be 1-4 m^3 with a maximum height of 1.5-2.0 m (Figure 7).

- The bottom layer should consist of brushwood, old branches, or rocks. This ensures good aeration.
- Alternating 20-30 cm layers of organic matter and good loamy soil are then added.
- The heap is covered with a large plastic sheet to keep it moist but not too wet.
- The heap should be turned after 2-4 weeks. A new one can then be made alongside it. The compost will be ready in 2-3 months.
- The heap should be watered from time to time to keep it moist.

Filling Pots

The pots can be filled by hand or with a funnel. When filling the pots, the lower third of the pot should be compacted firmly to prevent the mixture from falling out. The upper two-thirds of the mixture should be only compacted a little so that roots can develop easily.

Transplanting to Pots

When seedlings have developed a first pair of true leaves, they should be pricked from seedbeds/seedtrays and planted in pots. Before pricking, seedbeds and pots should be well watered. Seedlings should be lifted with a small

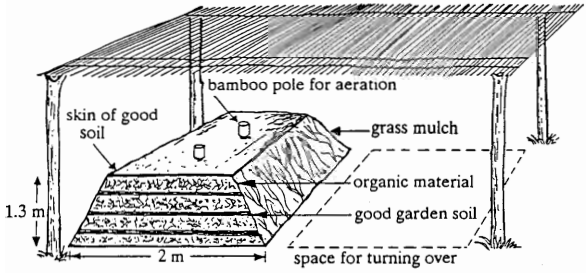

Figure 7.

Compost can be made from almost any organic matter such as weeds, forest litter, crop residues, animal bedding, and dung.

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trowel or a flat piece of wood. Only healthy, well-developed seedlings should be selected. If roots are too long, they should be pruned (Figure 8).

To prevent seedlings from drying out, work should be done under shade in the late afternoon or on a cloudy day. Seedlings should be kept under a moist cover. Dibble holes should be wide and deep enough so that the roots will not bend. Holes can be closed by gently pressing the soil around the plant with the fingers. Plants should be watered and placed in a shaded area. Pots should be placed in the potbeds in an upright position (Figure 9).

Care and Tending

Shading

The seedlings should be in about 50% shade. They should be gradually exposed to higher and, finally, full sunlight 23 weeks prior to planting.

Watering

If the upper part of the containers are dry, they should be well watered in the morning. A fine spray should always be used for watering, particularly when the seedlings are small. To induce hardening off, watering should be gradually reduced 1 week or so before outplanting. Hardening off prepares the plants for the shock of transplanting and more difficult conditions in the field.

Weeding

It is important that seedlings not have to compete with weeds during any stage of development. Careful manual weeding is recommended rather than using herbicides.

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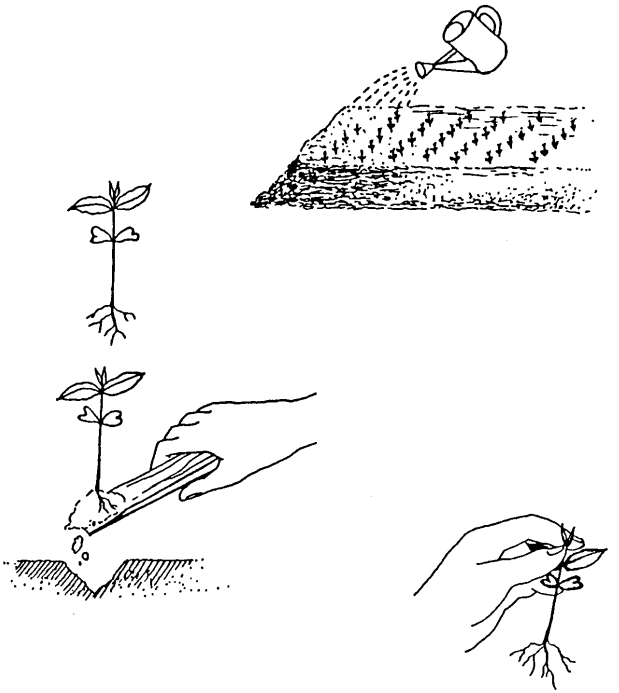

Figure 8.

When seedlings are ready to be planted into pots, water the seedbed and lift the plants with a small shovel or a flat piece of wood. Don't handle the roots.

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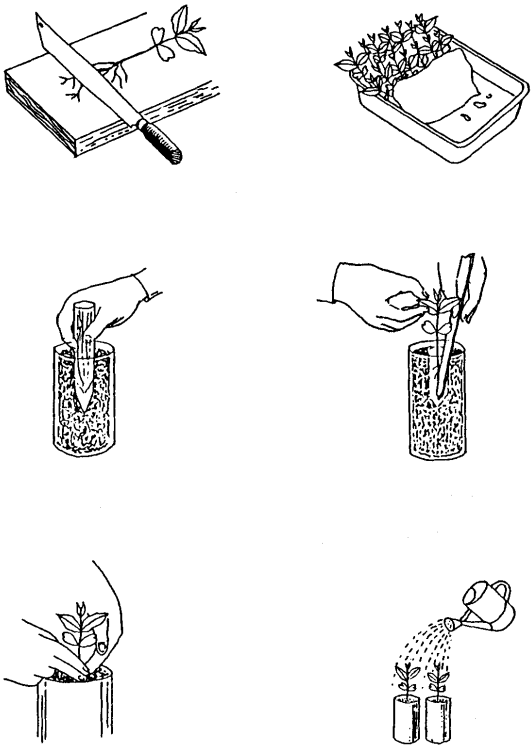

Figure 9.

Potting involves root-pruning, keeping the seedlings under moist cover, making a dibble hole that is the right size for placing the seedling upright in the dibble hole, and firming the potting medium around it before it is watered.

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Grading Beds

To prevent larger seedlings from shading smaller ones, the bed should be graded. Larger seedlings should be placed at one end and the smaller seedlings at the other end. Depending on how long the seedlings remain in the nursery, grading might have to be repeated.

Pests and Fungi Control

In nurseries, damping off and root rot are common diseases caused by fungi. With damping off, seedlings often look pale and weak, finally collapsing at the root collar. This can be prevented by:

- changing the soil in the seedbeds every 2-3 years
- removing plants immediately if they are infected by fungi or attacked by pests
- avoiding excessive watering
- allowing for good drainage
- ensuring good air circulation
- weeding
- thinning the seedlings in the beds
- reducing nitrogen content (less manure and no chemical fertilizers)
- using coconut husk as a potting medium.

In case of fungal attacks, fungicides such as Blitox or Dithane can also be used. The solution can be prepared by dissolving 25 g of the fungicide in 5 liters of water. It is then applied to affected plants with a watering can or sprayer twice a week.

Serious losses from insect damage are less common than losses from fungi; nonetheless, they can sometimes be severe, particularly in nurseries.

Good cultural practices can prevent damage by insects. Many of these pests are soilborne. They can be controlled using insecticides containing methyl parathion such as Metacid and Paramar. A 0.05% solution can be prepared by mixing 1 ml of the insecticide with 2 liters of water. It is then applied with a watering can equipped with a fine nozzle.

Root Pruning

If potted seedlings are placed on plastic sheets, root pruning should not be necessary. However, if seedlings stand on bare soil, it is necessary to prune the roots regularly by cutting those that come out of drainage holes. Root pruning can take place when seedlings are graded (Figure 10).

Preparation for Outplanting

Hardening

To survive after outplanting, seedlings must be able to adapt to harsher field conditions. To help them do this, they must be "hardened" before they are outplanted. The following techniques are useful:

- remove from shaded area 2-3 weeks prior to outplanting
- prune roots
- reduce the amount of watering 1 week before outplanting
- stop applying fertilizer toward the end of the stay in the nursery.

Culling

Plants should be sorted according to their suitability for outplanting. Only good seedlings

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Figure 10.

Roots of seedlings should be pruned regularly if containers stand on bare earth.

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should be outplanted (Figure 11). Good seedlings have:

- a shoot one to two times the length of the root (i.e. the pot)
- a study, woody stem with a strong root collar
- a symmetrical, dense crown
- a dense root system
- a healthy green color, unaffected by insects or fungal diseases.

Packing and Transportation

The seedlings should be well watered before transportation. They should be packed in wooden or plastic boxes. To make certain that the seedlings are not damaged during transportation, they should not be packed loosely. Wind damage during transportation can be avoided by erecting appropriate screens on the truck. Once at the planting site, seedlings should be placed in a protected, shaded area until planting. They should be watered thoroughly each day.

Other Methods of Plant Propagation

Bare-Rooted Seedlings

Bare-rooted seedlings are seedlings raised without the use of any type of container. It is less expensive to raise bare-rooted seedlings. This is possible with *Cassia, Gmelina,* and *Azadirachta* spp. The following are important to remember in producing bare-rooted seedlings:

- **Soil:** The seedlings grow directly in nursery soil. This means that soil quality is

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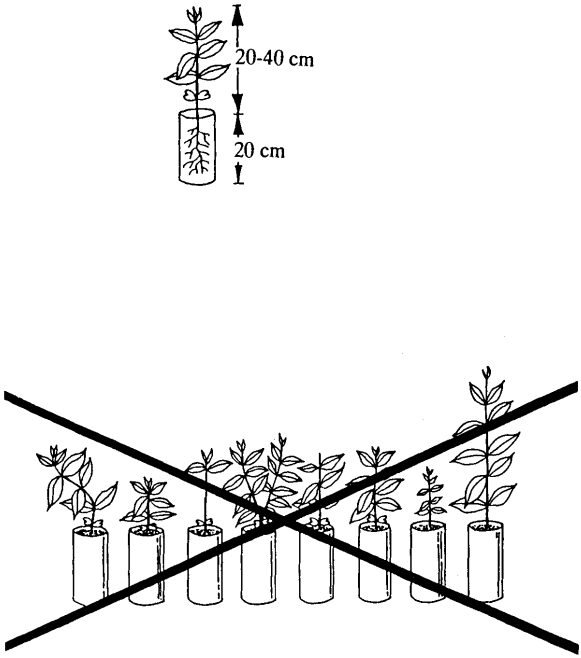

Figure 11.

Plants should be sorted according to their suitability for outplanting. A good seedling (top drawing) has a shoot twice as long as its taproot. The ones in the bottom drawing are not good for outplanting.

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very important. The soil has to be cultivated as if it were a vegetable garden to a depth of 30-40 cm. During cultivation, topsoil should not be mixed with lower soil.

- **Density and area:** Plants in the transplant beds are 5-10 cm apart, and the rows are 20-25 cm apart. This means 50-100 plants per m^2 of bed area. Bare-rooted seedlings, therefore, require a larger nursery area.
- **Transplanting:** Plants to be transplanted into beds should be larger than those pricked into pots. They should be 6-8 cm high with a tap root 4-6 cm long. They should be transplanted in holes prepared with a dibble stick or in a ditch prepared with a wedge spade.
- **Root pruning:** This is done by pulling a wire horizontally 20 cm beneath the bed to cut tap roots. Lateral roots are cut by inserting a sharp spade or machete between plants in a row. Root pruning may be needed every 6 weeks in the transplant beds until seedlings are ready for outplanting.
- **Lifting**: A spade or a flat-pronged fork is inserted vertically about 10 cm from the plant. It should be pushed deep enough to lift the entire root system of the plant.
- **Packing:** After grading and root pruning, seedlings should be packed such that the roots are well protected against drying (Figure 12). Sacks, banana leaves, plastic bags with ventilation holes, or cans can be used. Wet grass, leaves, sawdust, or moss

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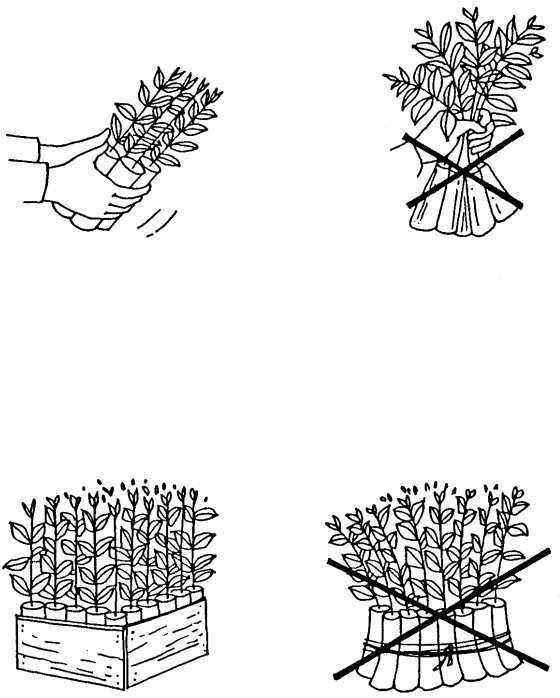

Figure 12.

To avoid damage during transportation, seedlings should not be packed too loosely, or carried by their stems.

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(when and where available) can be used for covering the roots.

Other operations for raising bare-rooted seedlings are similar to those used for raising seedlings in containers.

Stumps

Stumps are seedlings that have had most of their shoots and side roots removed so that only a 20-25 cm length is left. For some broadleaved species such as *Tectona grandis, Gmelina arborea, Cassia siamea, Azadirachta indica, Dalbergia sissoo,* and *Pterocarpus* spp., the use of stumps is effective (Figure 13).

Stumps have the following advantages:

- They are light, easy, and cheap to transport.
- They allow simple and cheap planting techniques.
- They can be cut and delivered when needed.
- They can be stored for up to 1 week without reducing their chance of survival.
- They have, for some species, higher survival rates than bare-rooted seedlings.

The following steps should be followed for producing stumps (Figure 14):

1. Grow bare-rooted seedlings until shoots are 60-90 cm high.
2. Next, lift seedlings and cut shoots 2-5 cm above root collar.
3. Then trim tap root and side roots.
4. Finally, dip into a mud puddle, bundle, and wrap in material such as banana leaves.

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Aspect	Species		
	Tectona grandis	*Gmelina arborea*	*Dalbergia sissoo*
Root collar diameter	1 - 2.5 cm	1 - 2.5 cm	0.7 - 2.0 cm
Shoot length	3 - 4 cm	5 cm	3 - 5 cm
Tap root length	15 - 20 cm	15 - 25 cm	20 - 25 cm
Lateral roots	removed completely	shortened to 2 - 5 cm	removed completely

Figure 13.

Most suitable stump dimensions for producing seedlings.

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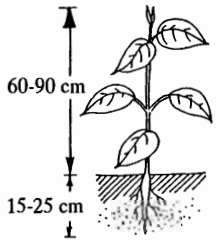
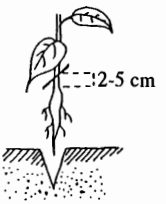
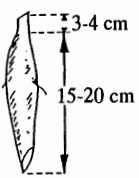


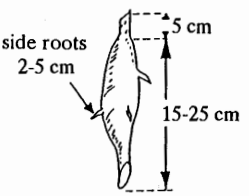


Trim tap root and side roots

Mud puddling



Teak



Gmelina

Figure 14.

For some broadleaved species, the use of stumps is an effective propagation technique.

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Vegetative Propagation

Vegetative propagation is desirable to ensure uniform genetic quality. This also makes for a shorter juvenile phase. Disadvantages are that shallow rooting of plants grown from cuttings or air layering makes them susceptible to wind damage. Also, they create a narrower genetic base and, if used widely, can make plantings more vulnerable to pest and disease attacks.

Hardwood Cuttings

Producing rooted hardwood cuttings is one of the easiest and cheapest ways of propagating plants vegetatively. Young vegetative material for producing hardwood cuttings can be obtained by establishing a scion orchard in an area set aside especially for that purpose. In general, the size of the scion orchard and the size of the planting area are in the ratio of 1:100. For example, a scion orchard of 1 ha is required to plant 100 ha.

The following steps should be followed for producing rooted hardwood cuttings:

1. Prepare cuttings in the morning.
2. Cut shoots into lengths of 12-25 cm using pruning shears. There should be one or two pairs of leaves on each section that is cut.
3. Place harvested shoots in a bucket of water, making certain that their bases are completely covered.
4. Reduce leaf area by cutting the leaves in half.
5. Dip bases of shoots in rooting hormone such as indole butyric acid (IBA) at 500 ppm. This step might not be necessary, depending on the species. It could be of use with species such as *Eucalyptus*

camaldulensis, Acacia mangium, and *Acacia auriculiformis.*

6. Root cuttings in polypots or in previously prepared beds. The potting mixture should be sandy loam or a loamy soil (i.e. a soil that contains at least 50% sand).
7. Water pots or beds immediately and place in shaded area. Pots or beds should always be kept moist until well after root formation.

Grafting

Grafting is the most commonly used method of vegetative propagation especially for fruit trees. In ordinary grafting, a short branch with a few buds (known as a scion) is united with rootstock of another plant so that they grow together as one individual. What is important is that the cambial layers of both scion and rootstock come into contact and continue to grow, forming a bond. Grafting is very useful when the rootstock is immune to a disease that attacks the roots of the scion plant. Generally, stock and scion must belong to the same species to be compatible in grafting.

Farmers might consider obtaining already grafted stock from an experienced fruit tree nursery in their area.

Making a Whip Graft

The whip graft is normally used for young fruit trees when the diameter of both scion and rootstock is not more than 2 cm (Figure 15).

1. Cut the stems of both scion and rootstock at slanting angles.

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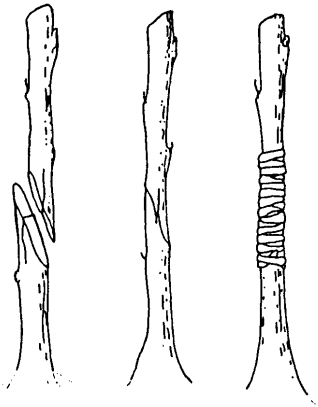
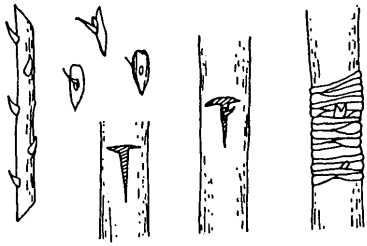


Whip Graft



Bud Graft

Figure 15.

Whip and bud grafts for fruit trees.

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2. At one third of the distance from the pointed end of the cut on each piece, cut a "tongue" lengthwise into the stem.
3. Lock the scion and rootstock together, ensuring that the two layers of cambium are in contact with each other.
4. Tightly wind binding material (commercially available grafting tape is ideal) around the graft.
5. Brush liquid (but not boiling) grafting wax or beeswax over the entire grafted surface to keep air from entering the cuts and drying the cambium. (To make grafting wax, heat and mix 0.4 kg of resin, 2 kg of parafin, and about 30 ml of linseed oil.)

Making a Bud Graft

Bud grafting, or budding, is a special type of grafting in which the scion (or budwood) consists of only one bud. Budding should be done when terminal growth begins, that is, buds start to flush and the cambium is active, or at the beginning of the dry season, when there is still some terminal growth (Figure 15).

1. Make a horizontal cut in the stock and a vertical cut below it to form a "T".
2. Cut a bud from a section of the scion stem in the shape of a small shield.
3. Remove the woody tissue, and insert the bud inside the "T".
4. Wrap the cut area with binding material and apply wax, as described in the section on making a whip graft.

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Nitrogen-Fixing Organisms and Mycorrhizal Fungi

Nitrogen Fixation

Tropical soils, especially those in grasslands, tend to have poor fertility. This makes for poor seedling growth and high mortality in the field. Nitrogen-fixing organisms such as *Rhizobia* and other microbes can enhance growth in seedlings of leguminous species as well as their chances of surviving once outplanted.

The reason is that nitrogen-fixing (mostly leguminous) plants grow vigorously only if they have root nodules that convert atmospheric nitrogen into ammonia that the plant can use for its growth.

The microbes needed to form root nodules are usually found in soils in which leguminous plants grow naturally. This is important to remember because if an exotic leguminous tree species is introduced into a region, it may not find the soil organisms that are needed to allow it to grow vigorously.

There are generally two ways of ensuring strong nitrogen fixation in tree roots:

- Cultured bacteria for the particular genus or species can be obtained commercially or from research institutes. The nursery soil itself can be inoculated directly simply by mixing the soil with a suitable proportion of the bacteria culture.
- Soil from under trees of the leguminous species that are growing well, where microbes are likely to be abundant, is taken and mixed with the nursery soil that will be used to grow the seedlings.

Mycorrhizae

The same principles of soil inoculation also apply to mycorrhizae. These are fungal-type soil microorganisms that live in a symbiotic relationship with the roots of nearly all coniferous and broad-leafed trees. The roots supply energy in the form of excess carbohydrates and other metabolites to the fungus. In turn, the fungus supplies soil nutrients to the tree, especially phosphorus.

As with nitrogen-fixation, the most frequently used method for ensuring mycorrhizal activity in tree roots consists of using local soil rich in mycorrhizae. The use of forest soil normally ensures this. This is why nursery growers are usually encouraged to use forest soil taken from vigorous stands of the same species that they are planting in the nursery.

Nursery Management

Operational Plan

An operational plan is essential because all aspects of running a nursery are closely interrelated. The operational plan must specify the resources that are needed. These are:

- **Infrastructure:** sheds, shelters, roads, fencing, water supply, etc.
- **Tools and equipment:** (refer to the checklist)
- **Supplies:** soil, compost, fertilizer, plastic bags, etc.
- **Labor:** permanent and temporary
- **Seed supplies:** Seed acquisition must be carefully planned. The quantity of seed required must be calculated, sources

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identified, arrangements made for collection, and costs estimated.

- **Supplies of other materials:** The quantities of polypots, sand, soil, and organic matter that are required must be estimated. Arrangement should be made to acquire these materials. Make certain that they are available at the time of year they are needed.

Production Schedule

Since the deadline is the planting season, planning for nursery activities has to start from this date and work backwards, as follows:

- Date of planting: _____
- minus number of days needed for growing from pricking size to planting size: _____
- minus number of days from germination to pricking: _____
- minus number of days from sowing to germination: _____
- equals sowing date: _____

A calendar showing the duration of these stages for each important species is helpful and can be obtained from a trained forester. This calendar can also be developed from records kept on the development of each species in the nursery.

Labor

Good and reliable workers are essential for a successful nursery operation. Workers can be permanent or temporary, depending on the level of skill required for a particular job. Sowing, pricking, and culling require some experience and skill, but preparing potting mixtures and filling pots can be done by workers with less experience.

Ideally, permanent workers should carry out more demanding tasks as well as such routine chores as watering, weeding, and root pruning. Temporary workers can be used during peak periods to carry out intermittent tasks.

Productivity can be maintained or improved if working conditions are pleasant. Safe drinking water, a washroom, shade, and shelter are important.

Record Keeping

It is very useful if the nursery grower has up-to-date information on the performance of the nursery, particularly concerning the rate of seedling growth and production costs. This information can be used to improve planning and future operations. Records should be kept of the following:

- worker attendance and pay
- inventories of supplies such as plastic bags, pots, fertilizer, seedtrays, chemicals, etc.
- seed purchases
- inventories of the number of different species in the nursery and their stage of growth
- inventories of seedlings distributed for outplanting

Suggested Readings

Development and Resources Corporation. 1969. *Orchard Management: Horticultural Practices for Peace Corps Volunteers*. Washington, DC: Peace Corps.

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Tuladhar, L.B.S., K.B. Shrestha, R.B. Bista., P.K. Tyystjarvi, and A.M.J. Robbins. No Date. *Manual on Nursery and Plantation Practices for Community Forestry Development*. Kathmandu, Nepal: Community Forestry and Afforestation Division, Ministry of Forest and Environment.

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Remember

Selecting the site is the most important factor to ensure efficient production of good-quality plants and easy nursery management.

Basic requirements of a nursery are access to all weather roads and paths, fencing, a shelter for workers and materials, a soil dump, potbeds, and shading.

Seed should be collected from mother trees that are strong and healthy, from the most suitable tree species, and from an area that is as similar as possible to the area where the seedlings will be grown. Seed should not be collected from isolated or very young trees.

Sowing can be direct or in seedbeds/seedtrays, depending on the species. Direct sowing is not as expensive as transplanting. This also avoids damaging the roots when the plants are pricked.

Outplanting requires that seedlings be hardened and culled. Care should be taken to avoid damage while transporting seedlings to the planting site. They should be planted soon after transport.

Nursery management calls for a complete operational plan, particularly for supplies and the production schedule. Up-to-date record keeping improves nursery operations.

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Institutional Background

The **Forestry/Fuelwood Research and Development Project (F/FRED)**, funded by the **U.S. Agency for International Development (USAID)**, is designed to help scientists address the needs of small-scale farmers in the developing world for fuelwood and other tree products. As an outcome of collaborative meetings in the region, a ***Multipurpose Tree Species Research Network*** was established through which scientists exchange research plans, methods, and results. Research and development activities center on the production and use of multipurpose trees that meet the household and market needs of small farmers.

F/FRED is being executed by the **Winrock International Institute for Agricultural Development**. Winrock is a private, nonprofit U.S. organization working in agricultural development around the world. It was established in 1985 through the merging of the Agricultural Development Council (A/D/C), the International Agricultural Development Service (IADS), and the Winrock International Livestock Research and Training Center. Winrock's mission is to improve agriculture for the benefit of people, help increase agricultural productivity, improve nutrition, and advance the well-being of people throughout the world. Winrock's main areas of emphasis are human resources, renewable resources, food policy, farming systems, and agricultural research and extension.

Growing Multipurpose Trees on Small Farms

Module 1:
Selecting Multipurpose Trees

Module 2:
Nurseries and Propagation

Module 3:
Mulitpurpose Trees in Agroforestry

Module 4:
Small Plantations of Multipurpose Trees

Module 5:
Tending Multipurpose Trees

Module 6:
Harvesting Crops of Multipurpose Trees

Module 7:
Selling Tree Crops

Module 8:
Principles of Effective Extension

Module 9:
Species Fact Sheets

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Module 3

Multipurpose Trees in Agroforestry

Growing Multipurpose Trees on Small Farms

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Multipurpose Trees in Agroforestry

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Growing Multipurpose Trees on Small Farms

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Module 3
Multipurpose Trees in Agroforestry

This module describes the roles that multipurpose trees can play in agroforestry. More specifically, the module shows how the introduction of multipurpose trees can generate additional income for small-scale farmers, be a productive alternative to shifting cultivation and help protect the environment. The Species Fact Sheets in Module 9 can be used as a handy reference when using this module.

What Is Agroforestry?

Agroforestry involves raising trees in combination with other agricultural enterprises including livestock. Different species of trees can be planted with many types of crops in a variety of patterns. For example, fast-growing trees can be planted when the land is fallow or they can be grown at the same time as agricultural crops (Figure 16).

In addition to providing fodder, fuel, wood, and other products, trees in agroforestry systems promote soil and water conservation, enhance soil fertility, and act as windbreaks for nearby crops.

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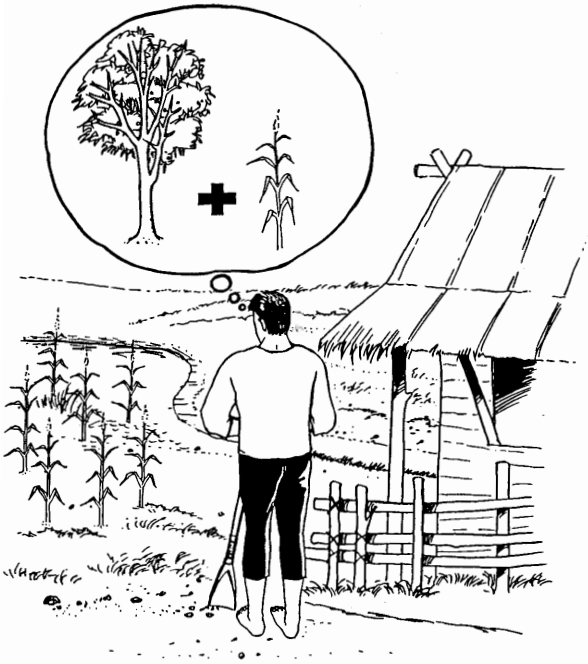

Figure 16

Agroforestry involves selecting the right species and the right growing location for the desired tree crops.

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What Are the Best Multipurpose Trees for Agroforestry?

It is important to select the most suitable trees since it is not easy to replace them once they have been planted. The following factors should be kept in mind when selecting tree species.

Environmental Adaptation

A multipurpose tree must be able to adapt to the area's climate, soil, topography, and plant and animal life. This is especially important for exotic species, that is, species introduced from outside the project area or from outside the country. (See Module 1.)

If a multipurpose tree species is being introduced from outside the project area, it should first be grown on a small scale to determine if it is appropriate.

Needs of Farmers

The species should meet the needs of farm families. For this reason, it is important to involve farmers, both men and women, in selecting species. They should identify desired tree products and planting locations based on local markets as well as conservation needs.

The cost of acquiring seedlings or cuttings should also be kept in mind. Planting stock of most fruit trees, for example, are expensive.

Ease of Maintenance

Some species are more difficult to look after than others. Farmers should consider beforehand how much time they have available to care for the trees. If they require additional skills and

knowledge to grow a particular species, training or demonstration programs should be organized.

Availability of Genetic Materials

Seeds or seedlings of the species being considered must be easy to obtain. If vegetative propagation is required, farmers should receive training in how to do this. Seeds of *Gliricidia sepium* and *Sesbania* spp., for example, might not be readily available. Farmers may need help in how to propagate the trees using root cuttings. They may not even have enough time to harvest the cuttings.

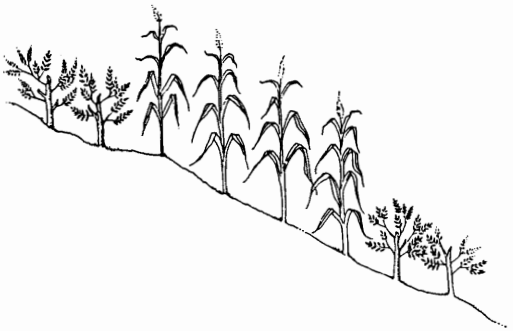
Role of Trees in Agroforestry

Alley Cropping

When planted as hedgerows between rows of agricultural crops, some tree species reduce soil erosion. When planted on slopes, alley crops slow down runoff rainwater and trap sediment, which can form natural terraces after several years.

Alley cropping means growing hedgerows of closely spaced trees (20 cm or less) between rows of food crops. If the land slopes, farmers should plant the hedgerows along the contour, that is, the trees in each hedgerow should be planted at the same level on the slope (Figure 17).

Farmers should prune hedgerows regularly to prevent them from competing with nearby crops for sunlight and water. When pruned regularly, hedgerows can provide a reliable source of animal fodder and fuel. Farmers can cut the trees when they become competitive and carry the branches to pens where animals are sheltered. Longer cutting cycles of 4-6 months provide relatively more wood than shorter cycles. Short cycles produce relatively more foliage. Most species should not be



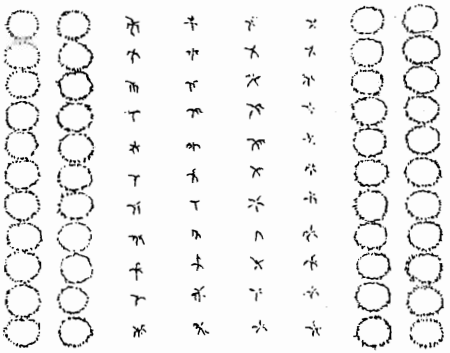


Figure 17.

In alley cropping, trees grow between rows of agricultural crops. When managed properly, they can reduce soil erosion and improve productivity of the farming system.

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pruned more often than every 30 days. (See Species Fact Sheets.)

If planted in double lines (1 m or less between lines) rather than single lines, hedgerows can produce almost twice as much foliage and wood, without greatly increasing the competition with nearby crops for water, nutrients, and sunlight. Where farmers can plant the hedgerows in a north-south rather than east-west direction, this will reduce competition for sunlight. Whether farmers plant single or double rows depends on how much land is available and the slope.

"Green manure" refers to foliage and twigs that are spread among food crops as mulch and organic fertilizer to improve their growth. To obtain green manure, farmers can prune the tops of the hedgerows every 6 or 8 weeks.

Table 1 describes some multipurpose trees that make suitable hedgerows.

Desirable Characteristics of Species

Easily established: require minimum labor for planting and maintenance.

Fast growing: benefits become available to the farm family as soon as possible.

Good sprouting: hedgerows continue to grow regularly after pruning.

Nitrogen fixing: leguminous (nitrogen-fixing) species can contribute to crop nutrition.

Heavy and palatable foliage: provide more green manure and acceptable fodder.

Deep root system: nutrients and water are drawn from lower soil layers.

Not "weedy": should not spread so fast that it threatens other crops.

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Table 1. Some examples of MPTS used as hedgerows

Species	Climate	Other Uses
Calliandra calothyrsus	humid tropics	fodder, fuelwood
Gliricidia sepium	humid tropics	crop shade, food, fuelwood, fodder
Gmelina arborea	subhumid tropics, humid tropics, humid subtropics	firewood, shade, food, fuel
Leucaena diversifolia	humid tropics	fuelwood, crop shade, fodder
Leucaena leucocephala	humid subtropics, humid tropics	fuelwood, crop shade, fodder
Sesbania grandiflora	humid tropics	fodder, fuelwood, food
Sesbania sesban	semiarid tropics subhumid tropics, humid tropics	fodder, fuelwood, pulpwood

Easy to propagate: generally, growing hedgerows from seed requires less labor than vegetative propagation.

Adaptable to close spacing: hedgerows require dense planting.

Homegardens and Other Multistory Systems

Homegardens, mixed plantings of annual and tree crops around dwellings, are a common type of multistory agroforestry system. Multistory means that there are at least two "layers" of plants growing to different heights in the system. In

homegardens, the lowest level often consists of vegetables or root crops; the second level includes fast-growing trees or crops such as banana, spices, and cacao; a third, higher level may consist of large trees that provide fruit, timber, and shade. Homegardens also provide a pleasant shaded living area (Figure 18).

Many farmers already grow multipurpose trees in their homegardens for flowers, fruits, and seeds. If farmers want to grow a tree for its food rather than its wood or leaves, they should plant seedlings at least 5 m from each other.

Also, trees grown mainly for food should not be pruned regularly for fodder or fuel. Pruning can interfere with flowering and fruiting. Instead, farm families can collect fallen branches for fuelwood.

Women make many of the decisions on how to tend the homegarden. They often choose the species to be grown. Attempts to improve the use of trees in homegardens should involve discussions with women and men farmers to better understand how they use trees and what products should be optimized.

Other multistory systems include those where trees in farmlands are left to grow amid the food crops (Figure 19). In coffee or cacao plantations, growers plant fast-growing species to provide shade.

Desirable Characteristics of Species

Cast the desired amount of shade: understory crops need the right amount of light for optimum growth. Typically, the crown should be high, small, open, and foliage sparse.

Figure 18.

A homegarden is an example of a multistory system in which trees provide fruit, fuelwood, timber, and fodder.

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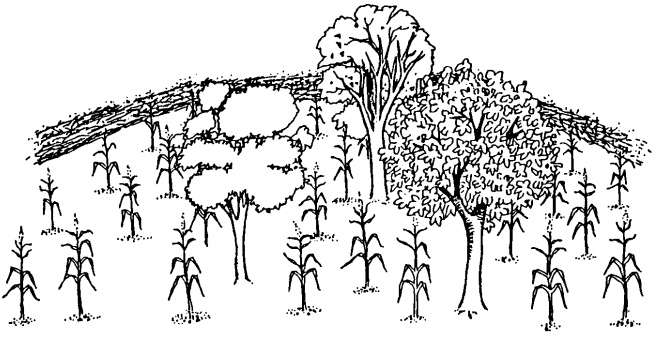

Figure 19.

Trees grown amid field crops can enhance productivity and farmers' income.

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Deep rooted: they can draw nutrients and water from deeper soil layers and will not compete with shallow-rooted crops.

Roots should not spread laterally too far from the trunk: minimize competition with nearby crops.

Nitrogen fixing: to grow well under adverse conditions and help improve soil fertility.

Living Fences

In many places, farmers plant multipurpose trees in rows along farm boundaries as "living fences." In addition to providing fodder and fuelwood, living fences provide privacy and protection from browsing animals (Figure 20).

Desirable Characteristics of Species

Tolerate minor "injuries": living fences are susceptible to frequent injuries from pruning or animals and should tolerate them well.

Fast growing: provide benefits to farm families as soon as possible.

Compatible with annual and perennial crops: should not have adverse effects on other tree species or crops they are associated with.

Provide fodder: serve as a source of animal feed.

Fire resistant: act as a firebreak.

Thorns: stiff branches, thorns, spines, nettles, or irritating latex help keep animals out if that is a problem.

Vegetative propagation: ensures fast establishment while reducing the chance of spreading to pasture and cultivated areas.

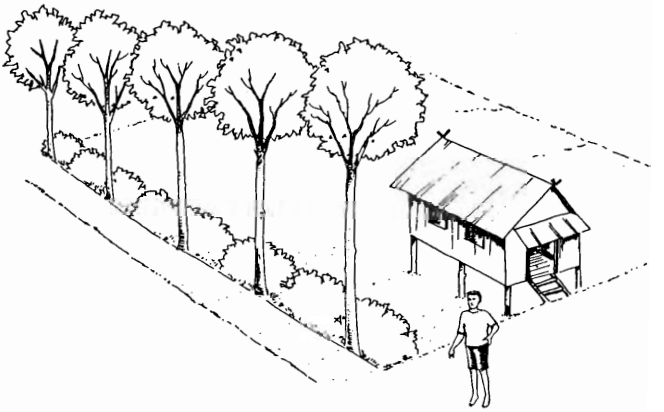

Figure 20.

Multipurpose trees planted along farm boundaries as "living fences" can provide fodder, fuelwood, privacy, and protect crops from browsing animals.

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Windbreaks

Windbreaks are strips of trees, shrubs, and vines planted closely together along the edges of croplands perpendicular to winds, prevailing. Especially in dry areas, windbreaks can provide protection to crops and soils from the detrimental effects of wind (Table 2).

Table 2. Some examples of MPTS as windbreaks and living fences

Species	Climate	Other Uses
Acacia nilotica	arid, semiarid tropics	beverage, fuelwood
Azadirachta indica	semiarid tropics	timber, lumber, manure, essential oils, fuelwood
Casuarina equisetifolia	humid tropics	fuelwood, timber
Eucalyptus camaldulensis	humid tropics, subhumid tropics, semiarid tropics	timber, fuelwood
Gliricidia sepium	humid tropics	food, fuelwood, poles, fodder
Grevillea robusta	subhumid tropics, humid tropics	timber, fuelwood, building materials
Leucaena leucocephala	humid subtropics, humid tropics	fuelwood, poles, timber, fodder
Sesbania grandiflora	humid tropics	fodder, fuelwood, food

Windbreaks provide protection to crops over a distance equivalent to 15-20 times the height of the trees in the windbreak. For large areas, windbreaks should be planted at this distance from each other. For example, windbreaks comprising trees that grow to a height of 8 m should be planted not more than 120-160 m apart (Figure 21).

Farmers should replace dead trees from time to time. As the trees in the windbreaks grow larger and compete with each other, farmers should remove some of them.

Desirable Characteristics of Species

Wind resistant: withstand strong winds.

Deep, spreading root system: adds stability to the windbreak by making the trees less susceptible to wind damage.

Small, open crown: reduces the risk of wind damage.

Easy to propagate: minimizes labor inputs.

Improved Fallow Systems

In many regions, population increase has resulted in faster rotation cycles of crop cultivation and shorter fallow periods. In some instances, fallow time is simply too short to allow the soil to recover. Blocks of fast-growing trees, particularly species that fix nitrogen in the soil, can help the soil recover as well as provide fuel, poles, and fodder. Farmers can plant stump cuttings in the fields at the same time as the harvest of the last annual crops before the fallow period. The cuttings do not shade other crops until after 4-6 months.

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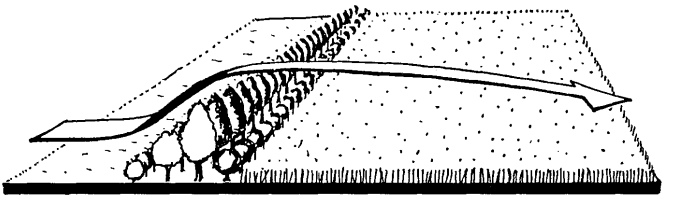

Figure 21.

A windbreak protects crops over a distance roughly equal to 15-20 times its height.

Desirable Characteristics of Species

High nitrogen content in tissue: hastens soil rejuvenation, since nitrogen is the most important deficiency of tropical soils.

Fast biomass production: litter from the tree, especially foliage, can add important nutrients to the soil.

Trees and Raising Livestock

Farm systems that combine tree plantations with livestock that graze beneath them are found generally in drier areas, where natural grasslands and farm sizes are larger. In such systems, farmers graze sheep or cattle on forage grasses or in stands of trees.

In wetter areas, which tend to have smaller land holdings, alley cropping and other "cut and carry" methods for procuring fodder are more important (Table 3).

Advantages to integrating tree growing with livestock production include:

- increasing the production of meat protein without sacrificing large tracts of agricultural land
- reducing surface soil erosion by preventing open grazing and reducing dependence on grasses
- using animal manure to fertilize the soil and intercrops, reducing reliance on inorganic fertilizer.
- providing additional income through sale of livestock.

Desirable Characteristics of Species

High protein and nutrient content: improve livestock nutrition.

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Table 3. Some examples of MPTS as sources of fodder

Species	Climate	Other Uses
Acacia tortilis	semiarid tropics	fuelwood
Albizia lebbek	humid tropics, semiarid tropics	fuelwood, timber
Calliandra calothyrsus	humid tropics	lumber, fuelwood
Dalbergia sissoo	semiarid tropics	timber, fuelwood
Gliricidia sepium	humid tropics	food, fuelwood, poles
Leucaena leucocephala	humid subtropics, humid tropics	fuelwood, poles, crop shade, timber
Prosopis cineraria	semiarid tropics, arid tropics	windbreak
Sesbania grandiflora	humid tropics	fuelwood, food
Ziziphus mauritiana	semiarid tropics, subhumid tropics	food, shade

Palatable: livestock are selective about what fodder they will eat.

Free of toxic substances: some fodder species contain toxic substances that can be consumed only in small amounts. *Leucaena* spp., for example, contain mimosine which, in large dosages, is harmful to animals. It must, therefore, be used in combination with other fodder sources.

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Sprout well: recover rapidly after pruning.

Stabilizing Stream Banks and Gullies

Trees can help reduce soil erosion along streams and gullies. They should be planted at the medium- to high-level water mark. Their roots serve to hold the soil in place and reduce the impact of storm water (Figure 22).

Suitable Species

Some tree species suitable for stabilizing stream banks and gullies are *Paraserianthes falcataria, Gmelina arborea, Leucaena leucocephala, Sesbania grandiflora,* and *Moringa oleifera.*

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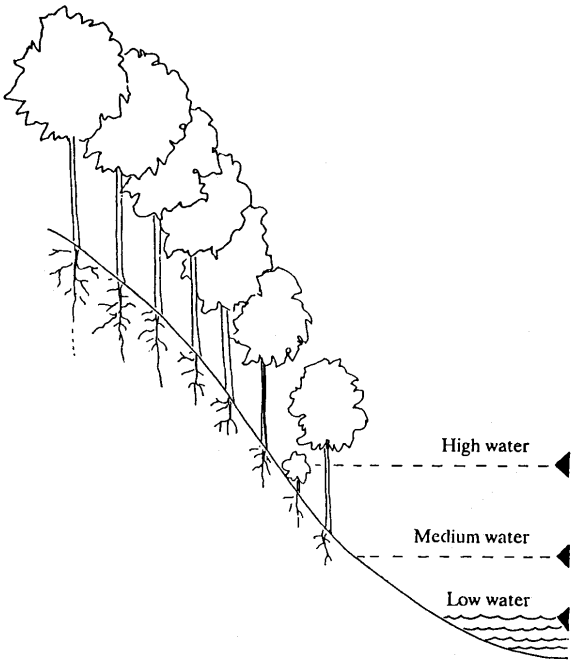

Figure 22.

Trees planted at the medium- to high-level water mark can help reduce soil erosion along streams and gullies.

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Remember

Agroforestry is an approach to land use that combines raising trees together with agricultural crops and/or animals. Multipurpose trees in agroforestry can yield wood for construction, fuelwood, fodder, and fruits.

In alley cropping, rows of trees are planted closely together between rows of agricultural crops. These hedgerows can reduce soil erosion, and, when pruned regularly, provide valuable fuel and fodder.

Homegardens and other multistory tree systems can provide a large range of tree and other crops such as vegetables, banana, and fodder. The upper story provides shade, protection from strong winds, and litter to enhance soil fertility.

Living fences of multipurpose trees can serve as boundaries, provide valuable products, offer privacy, and protection from browsing animals.

Windbreaks of multipurpose trees protect crops from destructive winds and reduce the effects of wind erosion.

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Institutional Background

The **Forestry/Fuelwood Research and Development Project (F/FRED)**, funded by the **U.S. Agency for International Development (USAID)**, is designed to help scientists address the needs of small-scale farmers in the developing world for fuelwood and other tree products. As an outcome of collaborative meetings in the region, a ***Multipurpose Tree Species Research Network*** was established through which scientists exchange research plans, methods, and results. Research and development activities center on the production and use of multipurpose trees that meet the household and market needs of small farmers.

F/FRED is being executed by the **Winrock International Institute for Agricultural Development**. Winrock is a private, nonprofit U.S. organization working in agricultural development around the world. It was established in 1985 through the merging of the Agricultural Development Council (A/D/C), the International Agricultural Development Service (IADS), and the Winrock International Livestock Research and Training Center. Winrock's mission is to improve agriculture for the benefit of people, help increase agricultural productivity, improve nutrition, and advance the well-being of people throughout the world. Winrock's main areas of emphasis are human resources, renewable resources, food policy, farming systems, and agricultural research and extension.

Growing Multipurpose Trees on Small Farms

Module 1:
Selecting Multipurpose Trees

Module 2:
Nurseries and Propagation

Module 3:
Mulitpurpose Trees in Agroforestry

Module 4:
Small Plantations of Multipurpose Trees

Module 5:
Tending Multipurpose Trees

Module 6:
Harvesting Crops of Multipurpose Trees

Module 7:
Selling Tree Crops

Module 8:
Principles of Effective Extension

Module 9:
Species Fact Sheets

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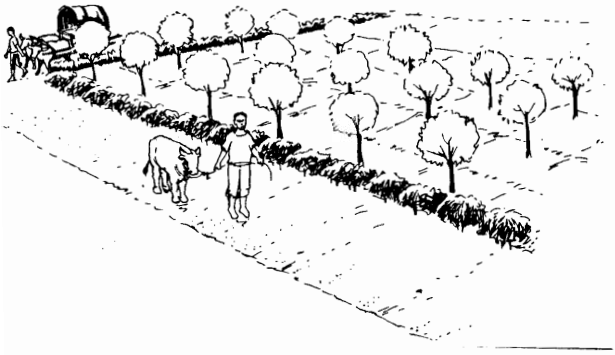
Module 4

Small Plantations of Multipurpose Trees



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Module 4

Small Plantations of Multipurpose Trees

This module shows how a farm family or a group of farm families can establish a small plantation of multipurpose trees that can be cared for using simple hand tools.

A small plantation of multipurpose trees can:

- *Provide valuable crops such as timber, fuelwood, food, and fodder for home use or for sale.*
- *Help protect the farm environment by enhancing soil fertility and reducing soil erosion.*
- *Provide shade for people and farm animals as well as general environmental improvement.*

Planning the Plantation

Costs

Setting up a plantation, even a small one, is expensive. Some costs, such as purchasing land, are not necessary for farmers who have established tenure or user rights. Other expenses

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are difficult to avoid. Key costs are likely to include:

- purchasing planting material
- purchasing or renting land
- hiring supplemental labor
- building roads
- erecting fences
- planting
- maintenance
- transportation

How To Reduce Costs

With good planning, costs can be reduced. Ask yourself:

- Will the site be cleared with local labor and hand tools or contracted to persons with heavy machinery? Which is cheaper more cost-effective (Figure 23)?
- How much fencing will be required? What types of materials will be used for the fences and what will they cost?
- If the tree crops are to be taken to market, how will they be transported ?

Financial planning should also consider the trees' rotation period. (See the Species Fact Sheets for typical rotations of different crops.)

Land Ownership and Plantation Size

- Determine legal ownership of the plantation site. Also, investigate if there are any pending land title disputes before commencing planting activities.
- Prepare a written agreement to ensure legal right to use of the land and water resources.

Figure 23.

When setting up a plantation, consider the availability of seedlings and labor.

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- Generally, the bigger the plantation, the lower the costs of production. Exchanging land or cooperative ventures may be considered to make the plantation more economic.

Labor

Most of the work on tree plantations is carried out by farmers and their families during the off-season for agricultural crops. If the plantation is too large to be established or managed by the household alone, hiring local or migratory workers might be necessary. This is often the case during the land clearing and planting seasons. If extra labor is hired, it might be necessary to provide workers with accommodation. If hiring extra labor is too expensive, traditional means of exchanging labor among other small farm households in the village and neighboring areas is a possibility.

Plantation Establishment Schedule

The schedule for establishing a multipurpose tree plantation depends on agroecological conditions. The timetable should cover the following:

- optimal dates for felling the trees, if the area is being reforested
- dates for site preparation
- time of seed collecting and sowing (in the case of direct seeding)
- date of nursery establishment
- time of outplanting (in case of seedlings)
- dates for fertilizing, weeding and replacement of failed seedlings.

The timetable should be followed, making certain each task will be completed on time. This is important to ensure the success of the operation.

Site Selection

Accessibility of Site

To reduce the high cost of road construction, it is best to select a site where there will be as little need as possible for building roads (Figure 24). Transportation is also expensive. The plantation site should be:

- close to main roads and access roads
- close to sources of supplies and inputs
- close to village(s)
- close to markets where tree crops will be taken.

Terrain

Terrain refers to slope steepness, ground configuration, rockiness, elevation and exposure to sunlight. Slope is the most important element to consider. A site where slopes are steep will tend to have shallow soil and be highly susceptible to erosion. In areas where annual rainfall is higher than 2,000 mm and slopes are steep, terracing and other measures may be necessary. This depends on the value and management requirements of the species being planted and the cost of labor in the area.

Soil

The main soil properties that need to be considered for site selection are:

Depth: This is the most important soil property. Deep colluvial and alluvial soils are ideal for planting. Colluvial soil is a type of transported soil that is often found on the lower slopes of gentle hills. Alluvial soil consists of matter deposited by

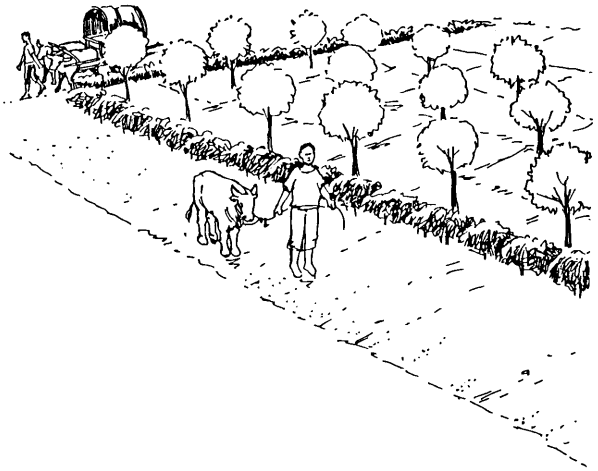

Figure 24.

If possible, select a site close to existing roads to reduce transport costs.

water; it tends to be composed largely of clay and silt. Soils found in midslope (residual soils) are also suitable for planting. In areas where there is a hard pan or dense layer of gravel close to the surface, it is difficult for roots of many species to grow downward, making planting impractical (Figure 25).

Structure, texture, and permeability: The most suitable soils for tree plantations are soils with an intermediate loam texture that is crumbly. Sandy soils, very clayey soils, and soils with poor aeration or a high water table are less suitable for plantations. Soils with poor structure or permeability can sometimes be improved, for example, by installing drains to lower the water table.

Fertility: Loamy sands and loams are not usually very fertile. Fertilizers might have to be applied. Areas previously used for cultivating agricultural crops might not have enough nutrients. Areas with excessive litter might also have temporarily inadequate supplies of nutrients. In high rainfall areas, soils are also likely to be low in nutrients, particularly if they are sandy. In sandy soils, it is important to apply organic matter to increase fertility and improve the soil structure.

Acidity: Neutral soils are generally good for plantations. Moderately acidic and alkaline soils are also suitable for tree planting as long as species are selected that can adapt to these conditions.

Climate

Two aspects of climate must be considered in site selection:

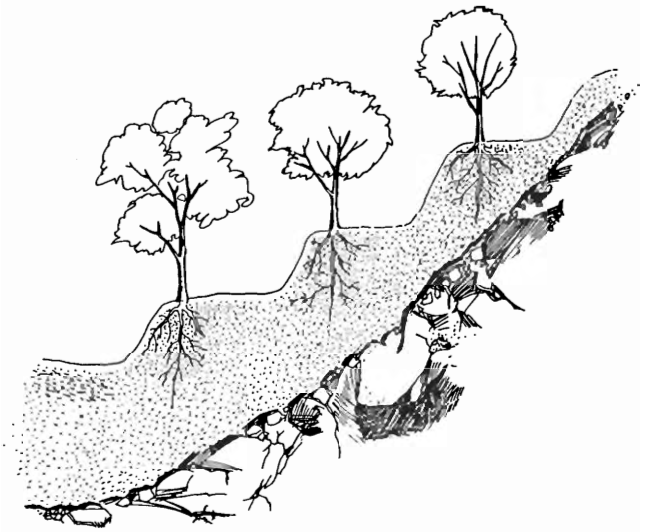

Figure 25.

Sites on steep slopes tend to have shallower soil than at the slope bottom and are more susceptible to soil erosion.

- amount and distribution of rainfall
- minimum and maximum temperatures.

These two aspects of climate determine whether an area is suitable for plantation establishment. They also determine the suitability of particular species. (See the Species Fact Sheets for climatic ranges of different species.)

Detailed information on temperature ranges and rainfall patterns are often available through government agencies or the local extension agent/forester. The local climate is also closely related to the shape of the land, exposure to prevailing winds, topographic position, and exposure to sunlight. For example, in the northern hemisphere, a slope that faces south is generally warmer and drier than a slope that faces north. For certain species this can mean that a slope that faces south will not have enough moisture and may not be suitable.

Site Preparation

To prepare planting sites farmers must remove unwanted vegetation and prepare the soil (Figure 26). How much site preparation is required depends on:

- the species that will be planted
- site conditions, particularly rainfall pattern, soil texture and fertility
- cost and time needed to prepare the site
- value of the tree crops to be planted.

Mechanical site preparation is less suitable for small plantations. It is also more expensive than manual site preparation. For these reasons, this module only discusses manual site preparation.

Figure 26.

To prepare the site, remove unwanted vegetation and work the soil. Site preparation methods depend on availability of labor and budget.

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Manual Preparation

The hand tools that are most often used in site preparation are an axe, cross saw, spade, hoe, and mattock. Sometimes, chainsaws and other hand-held power tools can be used. Manual preparation can also include using draught animals in conjunction with locally made tools.

In open grasslands it might not be necessary to remove vegetation unless it is covered by dense weeds such as *Imperata cylindrica.* Clearing all grass might be undesirable if planting is going to be on steep slopes susceptible to erosion.

Clearing in Strips

In grasslands where the grass is more than 1 m high, the vegetation can be cleared in strips, using the hand tools already mentioned. The taller the grass, the wider the strip that is cleared. This method of clearing is useful when introducing valuable multipurpose trees to degraded scrub forests or where natural forest regeneration has failed.

Clearing in Patches

This method can be used in grasslands or forest areas. It involves burning patches of vegetation where the trees are to be planted. In humid areas, the vegetation resprouts readily after being burned and the process has to be repeated. In drier areas, the vegetation does not grow high enough to interfere with tree growth and the operation does not need to be repeated. Some vegetation also helps to prevent soil erosion.

Felling Without Extracting Stumps

This method is normally used for converting a logged over tropical forest to forest plantation.

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The method calls for clearing the underbrush of the understory — generally plants with a diameter of up to 10 cm — and slashing vines. For felling larger trees, an axe or chainsaw can be used. Application of a stump killer is advised depending on the species. A liberal application of diesel oil to the stump is cheap and effective for many species.

Felling and Extracting Stumps

This method is useful in savannas and grasslands as well as in tropical and subtropical areas with only a scattering of trees and shrubs. The method requires excavating around and under the tree with a spade and mattock, severing the roots with an axe and extracting the stump.

Preparing the Soil

Manual soil preparation is required in dry zones where large planting holes are needed to aerate the soil for efficient establishment of seedling roots. Contour banks can be dug along the slope at regular intervals or crescent-shaped ridges can be made around each seedling. This can help minimize erosion and retain water on the slope.

Burning

For burning to be successful and safe, vegetation should be dry and the weather calm. The fire must be kept under control at all times. In hilly areas, the fire should be lit at the top of the slope and allow it to make its way down. Normally, a firebreak — a cleared area to stop the fire's progress — is prepared around the area to be burnt. Make sure that workers are available to quickly put out any fire that gets out of control (Figure 27).

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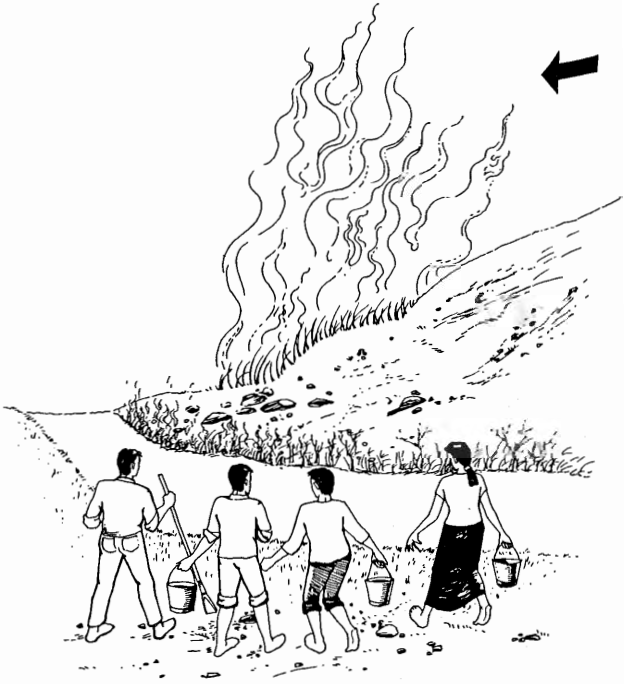

Figure 27.

Before burning, prepare a firebreak — a cleared area to stop the fire from getting out of control. Set the fire to burn down the slope, not upward.

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Herbicides

Herbicides can be used to kill weeds along planting lines, to kill stumps to avoid coppicing or to get rid of remaining overstory trees in logged-over areas (Figure 28).

Under the right conditions, use of herbicides can be cheap and effective. For getting rid of grass, systemic herbicides such as 2,4,-D which kill the roots are normally more effective than burning or manual means. Most herbicides are, however, expensive and must be handled with care. Table 4 contains a listing of some common herbicides.

Safety Considerations

Herbicides are poisonous and great care should be taken when using them. This is especially the case with 2,4,5,-T and Paraquat. Herbicides need careful storing, mixing, and application. They must be used at the recommended concentration and applied with appropriate equipment. Always keep bottles out of reach of children.

Planting

Planting Stock

With the exception of wildlings, the different types, sizes, and qualities of planting stock are discussed in detail in Module 2 (Nurseries). Wildlings are seedlings of forest or plantation species that regenerate naturally (for example, *Gmelina* spp.). In most cases, wildlings are transplanted to enhance soil fertility or fill gaps caused by the death of seedlings of other species.

Cuttings are usually grown in beds. However, cuttings of some species such as poplar (*Populus* spp.) or *Gliricidia sepium* can be planted and root

Table 4. Herbicides and types of vegetation they control

Herbicide	Use to Control
2,4,5,-T	Woody broad-leafed species
2,4,-D	Broadleaved herbaceous weeds
Ammonium sulfamate (AMS amate)	Woody species resistant to 2,4,5,-T; should be applied to cut stumps or stems
Dalapon (Dowpon)	Monocotyledons, especially fibrous plants or plants with shoots that grow above the ground on the stem
Diesel oil	Inexpensive and safe stump killer for many species
Glyphosate (Roundup)	Broad spectrum systemic herbicide
Paraquat (Gramoxone)	Annual grasses, fibrous plants or plants with shoots that grow above the ground on the stem
Picloram (tordan)	Woody plants, particularly for preventing coppicing
Sodium chlorate	Perennial vegetation along roads, railtracks, firebreaks, depots, etc.
Triazine (including simazine and atrazine)	Woody herbaceous species, in conjunction with good soil preparation

Figure 28.

Under the right conditions, use of herbicides can be cheap and effective. Follow directions and safety measures carefully.

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directly in the field—particularly where water is not scarce. *Gmelina* spp. can be propagated from coppiced shoot tips under mist spraying, and outplanted as potted plantlets. Normally, however, cuttings are planted in the field as rooted, dormant plants.

Planting Method

Bare-rooted seedlings and stumps can be manually planted in holes or shallow trenches dug with a spade or mattock (with help of a crowbar in rocky areas). Plants in containers are planted in a small pit (Figure 29). Observe the following general rules for each method:

- Remove containers at time of planting.
- Insert roots into soil up to the root collar. In arid areas, plant as deep as possible so that only a small part of the shoot is above ground. This will help ensure that roots reach moist soil and reduces water loss by evaporation.
- Carefully avoid breaking, bending, crushing, or damaging roots.
- Compact soil around the roots.
- Make a small furrow around the base of the mound to maximize water retention on dry sites.
- Do not force stumps or cuttings into the ground. Place them in specially prepared holes and compact the soil around them as with ordinary plants.

Planting Position and Pattern

Planting should generally be in straight lines to facilitate maintenance (Figure 30). In hilly areas,

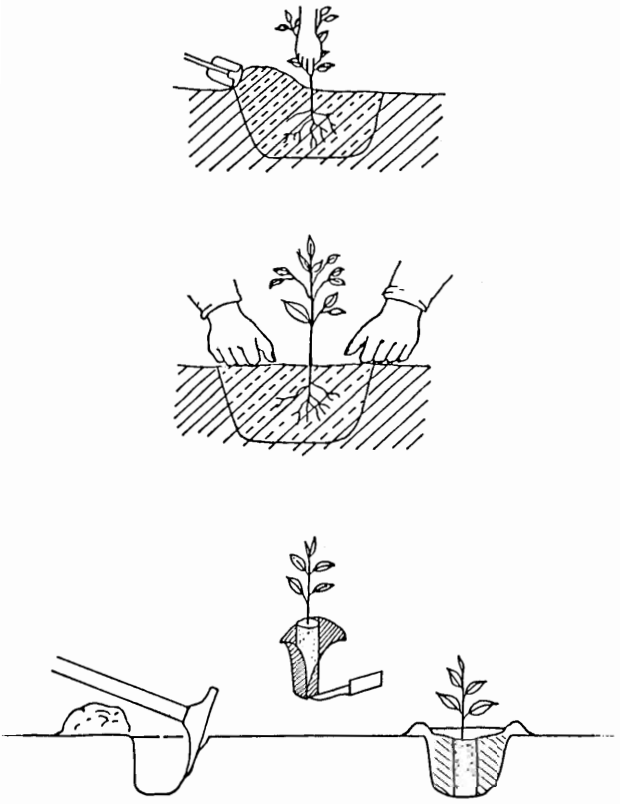

Figure 29.

Roots should be inserted deep into the soil. Containerized plants are planted in a small pit. Containers that do not let water and roots through should be removed.

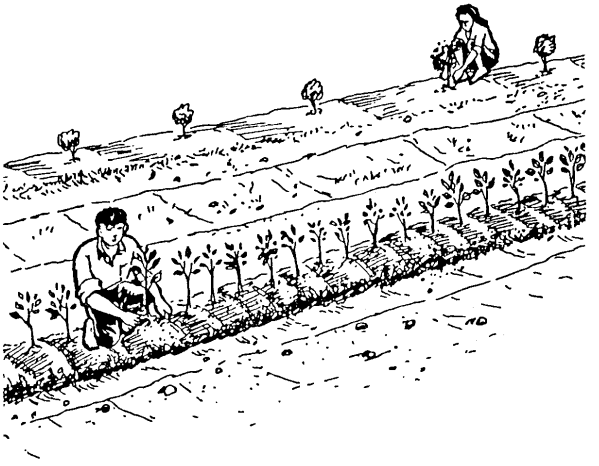

Figure 30

Planting is normally in straight lines. Spacing depends on the species and the intended end-use.

plant trees along the contours for better soil conservation. It is important that rows be aligned and that proper spacing be allowed between trees.

Mark planting positions for each type of terrain where the trees are to be planted. Spacing should be regular with visible rows and evenly spaced trees.

The three principal planting patterns are:

- Square planting, in which the space between the trees in the rows is the same as the space between the rows.
- Rectangular planting, which tends to be used in areas where some vegetative cover is retained for protecting the soil.
- Contour planting, which is modified from rectangular planting to fit the contour.

Spacing

Economic and market considerations are important in determining initial plant spacing. Consider planting costs, expected income, and the possibility of early thinning. Close spacing is more expensive because more plants are needed. Wide spacing tends to underuse the available land. It is best to find a compromise. (See Species Fact Sheets.)

Spacing depends on the types of tree products that will be harvested. For example:

- **Fuelwood:** 1-2 m. The goal is maximizing yield in short rotation harvesting. This spacing is best suited to small- and medium-size timber.
- **Pulpwood:** 2-3 m. The goal is maximizing yield in 5-15 year rotation harvesting. This spacing also allows for pruning branches with a diameter of 1-4 cm for fuelwood.

- **Sawn timber and veneer:** 2.5-5 m. The goal is to produce high value logs that are at least 30 cm in diameter. The rotation period is long and thinning regular. Returns from the wood compensate for low-density planting.

Consider the following biophysical factors when determining spacing:

- **Growth rate of species:** For faster-growing species, competition starts early so wider spacing is more favorable.
- **Branching habit of species:** Trees that branch at wide angles from the trunk (for example, *Terminalia catappa*) require more space between trees for normal growth.
- **Need for rapid crown closure to suppress competing vegetation:** In high rainfall areas where weeds grow quickly, initial spacing should be closer than in areas where weeds are slower to compete with seedlings.
- **Available soil nutrients and moisture:** Where soils contain large amounts of available nutrients and moisture, initial spacing should be wider to prevent competition from starting too early.
- **Influence of drainage:** Sites that become water-logged inhibit normal tree growth. In that case, trees can be planted more closely spaced.

Timing

Accurate rainfall records can help to determine the appropriate time of planting. Generally, in moist tropical areas, planting can take place during much of the year. However, planting should

coincide with the start of regular rains in areas where there are distinct wet and dry seasons.

In arid areas, planting should start after the first heavy downpour. Use soil preparation techniques that trap rainfall and moisture to maximize the use of limited water. For example, dig holes and construct troughs below them so that moisture will collect around the seedlings.

In drier grassland areas, the period for planting can be as short as one month. Planning is important, especially predicting the best possible planting date. Using containerized seedlings can extend the planting time a little before and after the rainy season. Plant the stock in soil that has been watered to a depth of 20-30 cm to enhance the survival rate of seedings.

In most situations, excessive exposure to sunlight is the main cause of seedling death. This can be minimized by:

- planting on cloudy rather than sunny or windy days
- watering the seedlings well just before leaving the nursery
- hardening off seedlings before being transplanted.

Replacing Dead Seedlings

Rarely will planting be so successful that there is no need for at least some replacement of seedlings in the field. Reserve about 20% of the most healthy and vigorous seedlings as replacement stock. This way, the new seedlings will have a good chance of catching up with the first seedlings that were planted.

Replacement planting might be necessary two and sometimes three times. The first replacement

of dead seedlings normally takes place at the end of the first rainy season after outplanting.

The second replacement normally takes place at the beginning of the second rainy season after the first seedlings were outplanted.

Decide if and when further replacements are necessary. Generally, in large-scale plantations, seedlings are replaced only if their survival rate is less than 70 percent.

Direct Seeding

Direct seeding in the field is less expensive than planting nursery stock. Consider direct seeding of a species when:

- seed of that species has a consistent rate of germination
- seedlings grow fast enough that they will not be threatened by competing vegetation
- seed is abundant and cheap

Direct seeding is possible with such species as *Cassia* spp., *Dalbergia sissoo, Gmelina* spp., *Prosopis* spp., some leguminous trees such as *Leucaena* spp., and most *Acacia* spp. (See Species Fact Sheets for details on other species.)

Hand Broadcasting

This method can be used for many species. However, it requires much more seed per unit area planted than other direct seeding methods. For this reason, it is used when the seed supply is abundant and cheap and only a relatively small percentage (30% or less) of germinating seeds are expected to survive. Another difficulty with hand broadcasting is that, if germination and survival conditions are good, seedling density will be too high and thinning will be necessary.

It is best to cover the seed with a protective layer of soil at a depth equal to two or three times the diameter of the seed. This can be done by having a draft animal drag a round log over the planted area. Covering the seed with a protective layer of soil increases the survival rate.

Sowing in Lines

This method is convenient on clean, cultivated sites or those that have been cultivated in lines or strips. The seed is sown by hand or with a dibble.

Use of a dibble stick for making holes 2-5 cm deep and planting 2-3 seeds per hole is appropriate depending on species. Sowing in lines is suited to large seeds. The spacing between and within lines is determined by species, growth rate, and tending methods.

Spot Sowing

This method is recommended for species such as *Gmelina* spp. Seeds are sown in relatively small, cultivated patches spaced at regular intervals that correspond to desired spacing. Two or three seeds are sown in each spot.

Mound sowing

This method is recommended on moist sites with poorly drained soil. Excavate the soil from pits and deposit it in a series of small, flat-topped mounds. Seed is sown at the top of the mound.

Planting on Difficult Sites

Some sites that present special difficulties for plantation establishment are: sites subject to low rainfall or constant high winds; sites without enough topsoil or soil with high mineral toxicity; sites badly damaged by overgrazing or burning. From a purely economic perspective, the planter is unlikely to make money on very difficult sites.

Land rehabilitation efforts will, however, reap long-term ecological benefits as long as agencies subsidize this effort.

Three possible ways to overcome difficult site conditions are:

- using a species or provenance known to grow under the site's conditions
- modifying the site to improve surface stability, moisture level, soil nutrition, or other problems
- erecting fencing or taking other measures to protect trees from possible damage by grazing animals.

On adverse sites, selecting the right species is especially important. Consider using local rather than exotic species. (See Module 1 and the Species Fact Sheets.)

The following are some major site difficulties and their remedies:

Shifting Sand Dunes

Place barriers on slopes or in a chessboard pattern. It is also possible to use a naturally occurring asphalt (bitumen emulsion) to fix shifting sand dunes.

Saline or Alkaline Environments

Dig deep pits or trenches and refill them with good soil to give seedlings a better chance to get established.

Ravine Lands

Dig contour trenches to catch maximum runoff. This type of site is found mainly in low-rainfall areas.

Skeletal Soils

Dig staggered contour trenches (on gentle to medium slopes), pits with a crescent shaped ridge running along the down slope side (on steep slopes) or narrow terraces cut along the contour with an inward slope (on the steepest slopes). This method is also suitable for rocky sites and denuded slopes where labor is available.

Laterite Soils

These soils have poor fertility and are often acid. Application of lime and fertilizer should be considered. Dig deep planting holes to ensure good root growth.

Hardpans

Hardpans are often found in improperly plowed or irrigated land. Some deep rooting species like *Prosopsis* spp. or *Cajanus cajan* can penetrate hardpan but it might be better to find another site.

Coastal Deserts

Dig trenches or deep pits (in areas with salt spray).

Cold Deserts

Dig a trench or pit on sloping areas.

Waterlogged Areas

Dig a trench to provide drainage and make mounds in low-lying, waterlogged depressions containing high levels of salt.

Marshes

Prepare simple mounds in the center of pits to allow leaching of salt, then work the soil. This method is also suitable for salt marshes and raised mud flats.

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Exposed Landslides

Try direct seeding with good colonizing species and, once established, broadcasting with tree species known to tolerate adverse environments. (See Species Fact Sheets.)

Nutrient-Deficient Sites

Mulch with organic compost if available. Commercial fertilizers should be considered.

Open Mining Areas and Industrial Wastelands

Spread topsoil that is retained on the sites; mulch with organic compost; terrace, if the sites are hilly.

Suggested Readings

Burley, J. and J.L. Stewart, eds. 1985. *Increasing Productivity of Multipurpose Species.* Vienna, Austria: IUFRO.

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Remember

Cash Income is the main benefit of establishing a small plantation of multipurpose trees. Others are protecting the environment and providing a source of fuelwood and fodder.

Planning is crucial for success. Proper planning can keep costs down. A schedule for establishing the plantation should be carefully worked out.

Site selection includes a number of key factors such as accessibility to roads, the type of terrain, soil fertility, and climate.

Site preparation requires removing unwanted vegetation and debris and working the soil. Use care in selecting the most cost effective site preparation methods.

Planting calls for selecting appropriate planting stock, determining planting methods, arranging spacing that will encourage growth and facilitate management, and choosing the best time of year to plant.

Spacing is determined by economic factors and components of the crop that will be optimized (fodder, fruit, timber, fuelwood). The closer the spacing, the greater the number of seedlings required. The wider the spacing, the greater the risk of underusing the land.

Direct seeding is less expensive than planting nursery stock and may be appropriate when the germination rate is consistent and growth is fast.

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Institutional Background

The **Forestry/Fuelwood Research and Development Project (F/FRED)**, funded by the **U.S. Agency for International Development (USAID)**, is designed to help scientists address the needs of small-scale farmers in the developing world for fuelwood and other tree products. As an outcome of collaborative meetings in the region, a ***Multipurpose Tree Species Research Network*** was established through which scientists exchange research plans, methods, and results. Research and development activities center on the production and use of multipurpose trees that meet the household and market needs of small farmers.

F/FRED is being executed by the **Winrock International Institute for Agricultural Development**. Winrock is a private, nonprofit U.S. organization working in agricultural development around the world. It was established in 1985 through the merging of the Agricultural Development Council (A/D/C), the International Agricultural Development Service (IADS), and the Winrock International Livestock Research and Training Center. Winrock's mission is to improve agriculture for the benefit of people, help increase agricultural productivity, improve nutrition, and advance the well-being of people throughout the world. Winrock's main areas of emphasis are human resources, renewable resources, food policy, farming systems, and agricultural research and extension.

Growing Multipurpose Trees on Small Farms

Module 1:
Selecting Multipurpose Trees

Module 2:
Nurseries and Propagation

Module 3:
Mulitpurpose Trees in Agroforestry

Module 4:
Small Plantations of Multipurpose Trees

Module 5:
Tending Multipurpose Trees

Module 6:
Harvesting Crops of Multipurpose Trees

Module 7:
Selling Tree Crops

Module 8:
Principles of Effective Extension

Module 9:
Species Fact Sheets

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Module 5

Tending Multipurpose Trees

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Module 5
Tending Multipurpose Trees

This module describes how farmers can manage multipurpose trees to derive as many benefits as possible. The module helps farmers select the best tending regime based on the crops that multipurpose trees yield.

Selecting Tending Regimes for Different Tree Crops

The best way to select a tending regime for multipurpose trees is to determine exactly which crops farmers wish to obtain. It is important to ask farmers what they want before advising them on tending techniques.

The discussion below describes a number of different end-uses that influence the choice of a tending regime.

Fuelwood/Charcoal

Fuelwood trees are usually fast-growing with dense wood for greater fuel value. Since these are also characteristics of pulpwood trees, farmers can obtain fuelwood and charcoal from the same plantations. If grown mainly for fuelwood, the trees can be bushy and have many stems. A

spacing of 1-2 m is generally suitable for fuel and small- to medium-size timber.

Fodder

Fodder trees should produce abundant leaves. They can be managed either by coppicing or pollarding, depending on the species and where they are planted. If fodder trees are planted as hedgerows, they should be coppiced at the same time that the nearby field crops are planted. Short coppicing cycles produce more leaves; longer periods produce more woody matter.

Pulpwood

Trees grown for pulp are particularly fast-growing and have high specific gravity. Generally, a spacing of 2-3 m is considered suitable for logs with a diameter of 1-4 cm.

Timber/Poles

These trees should be straight, with few branches for the first two meters above the ground. Lower branches should be pruned to improve timber quality. Spacing should be 2-3 m.

Fruit

In general, these trees should be widely spaced (2-5 m) and have many lower branches for easy harvesting. Pruned branches can provide fuelwood. Species that bear fruits along the main stems, such as jackfruit, permit narrower spacing and pruning of lower branches so that the stem can provide timber later.

Weeding

Weeds are a major problem in tree farming because they:

- compete with trees for soil nutrients, water, space, and light

- reduce tree vigor
- provide a home for insects and diseases
- increase the cost of tree farming.

Weeding is essential for ensuring maximum growth and survival of seedlings. Weeds that touch or are higher than the seedlings should be removed. If labor is available, all competing vegetation within 50 cm of the seedling can be removed. Sod grass and plants that produce shoots above the ground should be cleared within 1 m of each seedling.

Weeds should be removed from homegardens as well as tree plantations and hedgerows. These weeds can then be fed to farm animals or used as mulch (Figure 31).

Frequency of Weeding

Weeds should be removed before they flower and shed their seed. The first 6 to 8 months after the seedlings have been planted are important. During the first year of planting, weeding should be done every 6 months. This weeding regime should continue until their canopies start to close together. Once that happens, their shade will inhibit the growth of most weeds.

Weeding by Hand or Using Simple Tools

Where labor is inexpensive and easily available, weeds can be removed by hand. Weeds can also be cut or slashed with a knife, sickle, or long machete. Many farmers prefer to dig weeds out of the soil using a hoe.

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Figure 31.

Removing weeds around seedlings improves tree survival and growth. Cut weeds can be used as fodder or mulch.

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Mulching

Mulching is becoming more widely used to control weeds. The main idea of mulching is to prevent sunlight from reaching the weeds so that they will not grow. Many types of material can be used as mulch, including green manure, straw, sawdust, woodchip or bark. Plastic sheeting or stones can also be used as light and moisture barriers.

Organic mulch should not touch the stem of the tree, particularly if rodents or insects are a problem. If the trees are subject to attack by termites, it is best to use a nonorganic mulch such as plastic or a layer of stones.

High-Density Planting

One way to inhibit the growth of weeds is to plant trees close together. This is especially practical when cultivating fast-growing trees whose crowns close quickly, for example, *Leucaena leucocephala*. An initial spacing of 1 x 1 m or 0.5 x 1 m is recommended.

Covercropping with Leguminous Plants

Covercropping means planting a crop that covers the weeds with shade. Planting with leguminous species is particularly desirable because they help recycle plant nutrients. Leguminous cover crops fix nitrogen from the air into root nodules.

The following leguminous plant species are often used this way:

- *Calopogonium* spp.
- *Centrosema pubescens* (centrosema)
- *Phaseolus vulgaris* spp. (field beans)
- *Pueraria phaseoloides* (tropical kudzu)
- *Stylosanthus* spp.
- *Vigna unguiculata* (cowpea)

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Using Natural Enemies

This approach is possible where there is one particularly troublesome annual weed. Insects are usually used. Information on this approach should be obtained from government or university-based specialists.

Mechanical Weeding

In larger-scale plantations, weeding can be done mechanically using disc harrows pulled by a tractor or rototillers.

Herbicides

If weeds become a serious problem, it may be necessary to use herbicides. Herbicides, though expensive, can save time and labor. They can also be used as a last resort to prevent crop failure.

Some frequently used herbicides are:

- Glyphosate (Roundup): broad-spectrum, systemic herbicide
- PCP, Bipyridil: act through contact with leaves of the weed.
- 2,4,-D, 2,4,5,-T, Ammate, Picloram: act through absorption by roots, leaves, or stems of broad-leafed woody species.
- Dalapon, Paraquat: effective against grasses.

When To Apply Herbicides

The best time to apply a herbicide is before or during weed flowering. It is also recommended that herbicides be used before the trees are planted and after site preparation.

How to Apply Herbicides

For herbaceous or young woody weeds, spray the foliage so that the herbicide covers all parts of the weed.

Precautions

The following simple precautions are necessary when using herbicides:

- Use only those recommended for the specific types of weeds to be eliminated.
- Follow directions carefully, using only the recommended concentration.
- Wear protective clothing and launder immediately after use.
- Bathe immediately after applying any herbicide.
- Clean all equipment thoroughly after use.

Thinning

Thinning consists of felling individual trees. This method is often used in an immature stand to improve the growth of remaining trees.

Thinning is necessary only when the trees are grown to produce sawn timber, veneer, or large poles. It is not required if the trees are being grown to produce the highest possible volume of small-diameter branches such as for pulpwood.

Thinning of such higher-value and variable-value trees as teak or mahogany consists of selecting the best trees. Thinning of lower-value and uniform-value trees such as pines or eucalypts involves selecting and removing the poorest trees. The remaining trees will grow faster because competition for light, moisture, and soil nutrients will be less.

Row/Strip Thinning

When labor is scarce or when using mechanized logging operations, the first thinning generally

1SS

consists of felling every third row, leaving the other two rows completely untouched.

Selection Thinning

This consists of removing diseased or pest-infested individual trees, as well as dead or dying trees. It also involves removing genetically inferior trees and plants so they will not compete with superior trees.

Mechanical Thinning

This can be done with a bulldozer or a tractor pulling a disc harrow in alternate strips. This method is applied in uniform block plantations of trees.

Stick Thinning

This method is sometimes used in natural stands. It consists of walking through the stand carrying a stick of desired length. Wherever the stick touches two trees simultaneously, the inferior tree is removed. The spacing that results averages about 1.5 times the length of the stick. To thin a stand to approximately 3 m spacing, use a stick 2 m long.

Coppicing and Pollarding

Coppicing and pollarding are both treatments that involve cutting the bole at different heights to induce regrowth (Figure 32). The advantage of both methods is that trees do not have to be replanted after each rotation.

Coppicing means cutting near ground-level, leaving a short stump. Pollarding means cutting all branches and the stem at a height beyond the

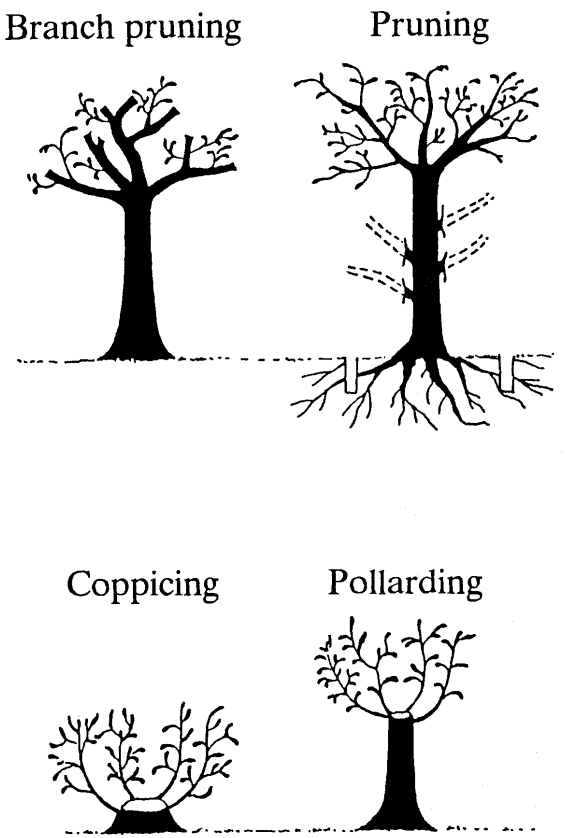

Figure 32.

Coppicing and pollarding induce regrowth and mean that trees do not have to be replanted after each rotation.

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reach of browsing animals. Both operations are suitable for producing fuelwood, slender twigs for basketry, leaves for fodder, and small stakes. Pollarding can be used when growing shade trees for crops such as coffee, tea, and cacao. Pollarding each year can provide these crops with more light during the wet season and shade during the drier, hotter season. For many species, pollarding yields more foliage and branchwood on short cutting cycles than does coppicing. Leave one or two small branches for better regrowth of roots and branches.

When trees are grown in hedgerows, coppicing is generally better because coppiced stumps do not compete with annual crops as much as pollarded trees.

Timing

Most multipurpose trees can be coppiced or pollarded at regular intervals once they are 2-4 years old. Some fast-growing species like *Leucaena leucocephala* can be coppiced or pollarded when they are 1 year old and 3-4 m tall. Species such as *Morus alba* (mulberry), which are managed for silkworm fodder, are usually pollarded when they are 4-5 years old. Following the initial operation, they can be pollarded every second year, after the winter crop of leaves has been gathered. Species such as *Salix daphnoides*, which are used to provide fodder and in basket weaving, can be pollarded every 3-5 years.

The best time for coppicing is usually at the start of the growing season, so that the tree will have enough moisture to resprout. Coppicing ability usually declines with increasing age and stump diameter. Coppicing and pollarding yield best results when the trees are still young and

vigorous. Generally, vigor declines after three coppicing rotations.

Fuelwood Crops

If the trees are being grown to produce woody matter and size does not matter, as is the case with fuelwood, farmers should retain as many shoots as possible. The rotation period can be as short as 1 year. This practice is suitable for *Calliandra calothyrsus, Leucaena leucocephala, Sesbania bispinosa,* and *S. grandiflora.*

Timber Crops

If the trees are being grown to produce wood of a specific size in as short a time as possible, only one or two shoots should be left on the coppiced stump. This can be done in one or two stages, the first thinning usually occurring 9 months to 1 year after coppicing. In some countries, *Eucalyptus grandis,* which is very fast-growing, is thinned to 3-4 shoots per stump at 9 months, and 1-2 shoots at 18 months. For species that grow slower, the interval between thinnings may have to be longer.

Fodder and "Green Manure" Crops

The coppicing period can also be short when trees are being grown for leaf production. Annual coppicing of *Gliricidia sepium* or *Leucaena leucocephala,* at 30 cm can give high yields of quality leaves. A short-rotation period is also suitable for *Morus alba.* Care should be taken not to overcut..

Coppicing and Pollarding Methods

Coppicing and pollarding can be done manually or mechanically. Branches or shoots that remain should not be longer than 5-10 cm. Branches with leaves should not be left on the tree. It is also best

not to cut branches larger than 10 cm in diameter. The operation can be repeated annually without harming the trees.

Generally, coppicing should be 10-15 cm above the ground. If cut lower, the bark around the stump might be loosened. Many species respond best if coppiced at 40-50 cm above the ground.

The cut must be clean and slightly angled. This way the cut stump will be able to drain freely and will be less likely to decay.

Pruning

Pruning consists of removing dead or nonproductive branches from the lower trunk. It accelerates volume growth and encourages the laying on of knot-free timber (Figure 33).

Pruning serves many other purposes:

- Increases the value of the trees.
- Reduces fire hazard.
- Stimulates new growth.
- Keeps branches at a height suitable for manual management and harvesting.
- Ensures a desirable tree form.

Timing

The best time for light pruning is just before the rainy season starts.

The best time for heavy pruning is 2-3 months before the rainy season starts.

Trees should also be pruned at the first sign that branches are diseased or attacked by insects. With most multipurpose trees, the pruning rotation is 2-4 years.

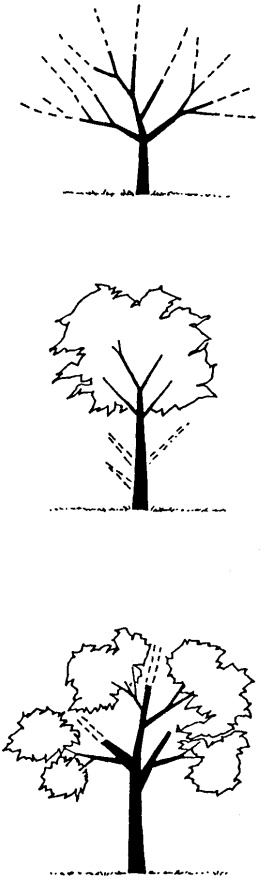

Figure 33.

Pruning consists of removing dead or nonproductive branches. It accelerates volume growth and encourages the laying on of knot-free timber.

Types of Pruning

It is important to know how, how much, when, and how often to prune.

Fodder: pruning for fodder production should aim at increasing the horizontal spread of the trees. This serves to increase the ground cover so that vertical shoots can be harvested repeatedly. Species such as *Leucaena leucocephala* can be pruned severely.

Poles: only the lower branches should be removed, leaving the main stem intact. This lessens stem taper and decreases the number of knots in the bole wood. At the same time, the increment in bole volume is not decreased appreciably, which is highly desirable when trees are being grown to produce higher-value timber.

Hedgerows: regular pruning means that leafy shoots can be harvested easily or are available to browsing animals. It also prevents stems from becoming too large.

Fuelwood: the main stem should be lopped off to encourage branching.

Pruning Methods

- Do not strip bark. This is especially important with large branches because the exposed stem is susceptible to attack by pathogens and insects.
- Use only sharpened tools so that the cut will be clean.
- For heavy branches, first make an undercut through the bark and at least one quarter of the wood to avoid splitting the branch collar (Figure 34). If an enlarged collar has developed around the base of the branch,

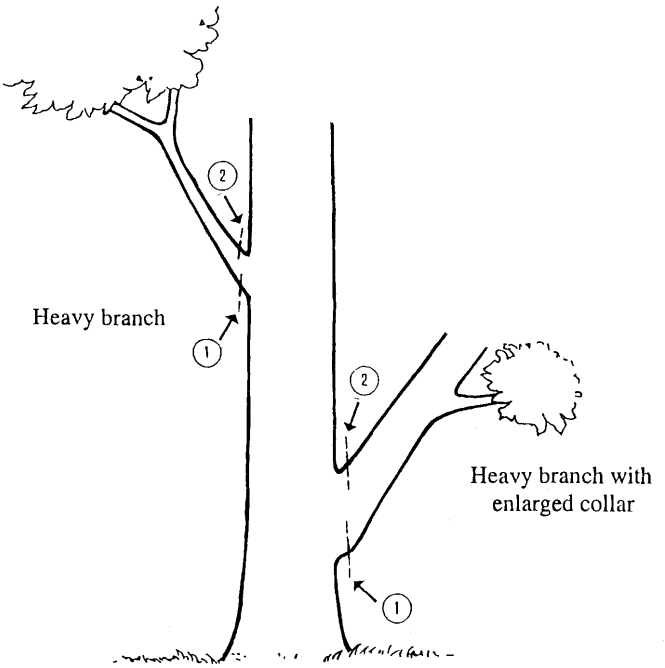

Figure 34.

When pruning heavy branches, first make an undercut. If an enlarged collar has developed around the base of the branch, make the second cut at the outer edge of the collar, not flush with the main stem.

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make the second cut at the outer edge of the collar, not flush with the main stem.

Pruning dead branches does not affect the rate of growth; it encourages the production of clear wood. Pruning dead branches also reduces the risk of disease and pest infestations.

Lopping

Lopping consists of removing branches. For tree farmers and agroforesters, lopping means cutting second- or lower-order branches or first-order branches far from the trunk of the tree. First-order branches are those that grow from the main stem. Second- or lower-order branches are those that originate from first-order branches. For bushes, lopping could also be referred to as "heavy shearing."

Timing

A tree's growth cycle determines when lopping should be done. Deciduous trees, that is, those that drop their leaves annually, are not lopped while they are leafless.

Frequency

Frequency of lopping for ensuring survival and rapid recovery depends on the species, the environmental conditions in which they are growing, and how much foliage is left. In certain dry areas, lopping *Prosopis cineraria* for fodder more often than once every 3 years can result in death of the tree. In many tree species, however, annual lopping results in the greatest yield, especially with large, mature trees. In general, the interval between loppings should be 1 year.

How Much Lopping?

It is difficult to determine optimum lopping intensity for sustained yields of fodder and fuelwood. Where fodder is scarce, there is a danger that lopping will be so heavy that the trees will die. It is also difficult to say what time of year is best for lopping. For most multipurpose trees, 50-75% of the canopy should remain.

Tools for Lopping

- Pruning saw
- Hand saw
- Chain saw
- Ax
- Lopping shears
- Bolo-type knife (Figure 35)

Pests

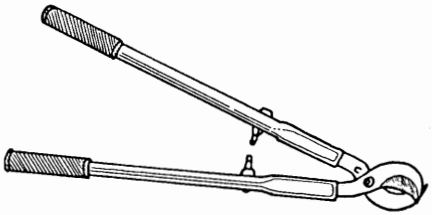
Major pest infestations generally occur during the wet, humid period. Insects can be categorized by the type of damage they cause.

Root-feeding insects: Subterranean termites can cause severe damage. They attack tap roots (main roots) and the root collar of seedlings. Other root-feeding insects are white grubs (larvae of Melolonthidae, Buprestidae, and Rutelidae).

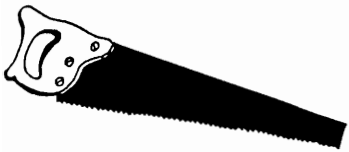
Leaf-feeding insects: Cutworms, grullids, tortricids, and *Myllocerus* beetles are serious pests in nurseries and plantations.

Sap-sucking insects: Aphids, psyllids, cottony cushion scale (*Icerya* spp.) and *Trioza* spp.

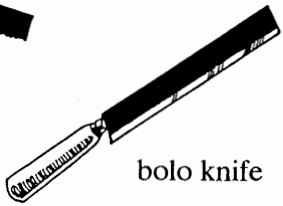
Stem-boring insects: Beetles, moths, and some bark-eating caterpillars.



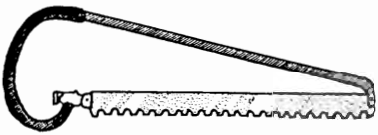
lopping shears



hand saw



bolo knife



bow saw

Figure 35.

Some common tools that can be used for pruning and lopping.

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Pest Control

There are several methods for controlling pests; some use chemicals and others do not.

Removal of Diseased Plants or Plant Parts

This can prevent the spread of a localized plant pest. Plants or plant parts obviously under attack by insects should be removed from the area and burned.

Planting Methods

Mixing plant species can be effective in preventing widespread damage by a single pest. Also, maintaining good plant nutrition will help control pest damage by keeping plants strong.

Biological Control

Some insect infestations can be managed by introducing the insect's natural enemy. One example is the introduction of ladybird beetles from Central America to Southeast Asian countries for controlling leucaena psyllids (jumping plant lice). Another example is the use of the parasite *Cedria paradoxa* to control a mulberry defoliator (*Glyphodes pyloalis* Walker). To obtain such predators, contact the nearest research station or university agriculture department.

In areas with recurrent pest infestations, farmers should obtain improved pest-resistant varieties of trees for planting.

Other Nonchemical Methods

The use of soap, kerosene and water as a spray can control sucking insects. Some crawling insects, including cutworms, can be controlled by spreading and wetting wood ash around the base of seedlings.

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Bacillus thuringiensis (Dipel, Thuricide, Biotrol) is made from a natural bacteria that kills many types of caterpillars. It is non-toxic to people and animals. Apply to young insects for best results.

Chemical Control

Insecticides such as Malathion, Dieldrin, and Dimacron can be effective. Fungicides such as copper oxychloride, Dithane M-45, Agallol, and Cerason can be used to protect tender seedlings.

Farmers must take the following precautions when using insecticides:

- Use only insecticides recommended for the specific types of insects to be eliminated.
- Follow directions carefully, using only the recommended concentration.
- Wear protective clothing and launder immediately after use.
- Bathe immediately after applying any insecticide.
- Clean all equipment thoroughly after use.

Diseases

The most serious diseases in multipurpose trees are canker, root rot, pink disease, and gummosis. Canker results in bark and wood decay. Root rot (*Cylindrocladium* spp.) causes severe defoliation, branch die-back, and even death in 1-2-year-old plants or coppicing shoots. Pink disease, which is caused by *Corticium salmonicolor*, is one of the most serious diseases in 2-3-year-old eucalyptus trees on plantations. Gummosis is characterized by a large number of cracks and oozing reddish resinous gum.

Symptoms of root-rot fungi include yellowing leaves, defoliation, and increased vulnerability to

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wind damage. To control root rot, remove affected stumps. Careful pruning, lopping, and pollarding can help avoid other diseases that enter the plant through open wounds.

Crop rotation and intercropping can help reduce disease problems, but extension agents must help farmers to ensure that the intercrop and tree species do not share common diseases.

Preventing Browsing and Trampling

Keeping Guard

Depending on the availability of labor, farmers who manage small plantations can hire guards to keep animals and other unwanted visitors from disturbing the seedlings and trees. For boundary or small-farm plantings, this may involve setting up agreements by which farmers prevent their animals from entering other farmers' land. Making such arrangements is a crucial part of the planning stage when communities decide to establish small-scale tree plantations.

Fencing

Fences can effectively keep out unwanted visitors. They can be made of split bamboo, thorn branches, barbed wire, hogwire, wire mesh, or palm leaves. The fence should be tight and strong. The gate should open and close easily.

Tree species that are relatively resistant to termite damage, such as *Borassus aethiopum* and *Melia azedarach*, can be used for making fence posts. If other species are used, the posts should be treated with an insecticide or wood preservative.

Living fences can be made by planting thickets or hedges. (See Module 1 for a list of suitable species.)

Fertilizing

Where trees are planted on poor-quality land, nutrients must be added to the soil to help them grow.

Simple analysis of the soil can indicate if a soil is completely unsuitable for a particular tree species. For example, a piece of land might be too acidic or too alkaline to support certain species. The relative acidity or alkalinity of a soil is determined by its pH. A pH of 7.0 indicates a "neutral" soil, that is, it is neither acidic nor alkaline. A soil with a pH greater than 7.00 is alkaline; less than 7.0 indicates an acidic soil. The pH of a soil can be changed by adding fertilizers. To lower the pH, that is, to make the soil less alkaline, a farmer can add ammonium sulfate (for nitrogen). To make the soil more alkaline, add lime, calcium nitrate, or sodium nitrate.

Farmers can often identify which nutrients are missing from the soil by examining the leaves of the trees that are growing poorly. When studying tree leaves in this way, the farmer must first be certain that the poor growth is not due to disease or other soil problems such as extreme pH values or a shallow hard-pan soil layer.

Symptoms of Mineral Deficiencies

In Older Leaves

Nitrogen: yellowish-green leaves; Sometimes, spotting occurs first and is followed by yellowing. In fruit trees this can result in a poor crop of abnormally small fruits that fall early.

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Phosphorus: dark spots appear on green leaves; leaves of seedlings have bluish-purple blotches.

Calcium: reddish spots appear on a pale green background.

Magnesium: yellowing between the main lateral veins.

In Younger Leaves

Sulfur: uniform yellowing; mottling.

Iron: streaking or spotting on leaf blades.

Manganese: yellowing, streaking or spotting between veins.

Boron: yellowing that begins at leaf margins.

Molybdenum: yellowish spots and purplish color along leaf margins.

Copper: abnormal shape, though size is normal.

Zinc: abnormally small, narrow shape.

Potassium: margins and veins dying off, no discoloration. In some fruit trees, blossoms or young fruit will all drop off.

Sources of Nutrients

Nitrogen: anhydrous ammonia, urea, ammonium nitrate, ammonium sulfate, diammonium phosphate, ammonium phosphate sulfate, sodium nitrate. Organic matter such as animal manure, meat meal, cottonseed meal, and fish meal are also good sources.

Phosphorus: phosphate ore, diammonium phosphate, monoammonium phosphate, ammonium phosphate sulfate, slag.

Potassium: muriate of potash, sulfate of potash, sulfate of potash-magnesia.

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Secondary nutrients and micronutrients: Agricultural limestone contains varying amounts of secondary nutrients and micronutrients. Micronutrients are often added separately after a known deficiency occurs.

Complete fertilizers: A complete fertilizer contains nitrogen, phosphorus, and potassium. A 10-10-10 fertilizer contains 10% total nitrogen, 10% available super- phosphorous, and 10% water-soluble potassium.

Timing

Fertilizer should be applied at the time of planting or not later than 3 months after planting.

Dosage

On forest lands, the optimum nitrogen and phosphorous fertilizer level is 60-100 kg per ha. For an individual tree, 10-15 g of a nitrogen-phosphorous-potassium (N-P-K) fertilizer is adequate on most sites.

To figure out how much 10-10-10 is needed to supply 60 kg of nutrient per ha, for example, divide 60 by 10% (0.10). The result is 600 kg. Therefore, if a farm family applies 600 kg of 10-10-10 to its 1-ha tree farm, 60 kg of nitrogen, 60 kg of phosphorus, and 60 kg of potassium will be supplied to the soil.

Watering

Tree plantations in dry areas usually depend completely on rain and groundwater because irrigation is too expensive. In these areas, young trees must be watered during the first dry season after planting.

Soak the soil in the root zone. The frequency of watering depends, in part, on the age of the

seedlings. Generally, older seedlings are watered more intensively than younger ones, but less often.

The type of soil in which the trees are growing also determines how much water to apply. Sandy soils drain more quickly than do clay soils and so need more water. To check if enough water is being applied, dig with your finger to a depth of 10-15 cm near the base of the seedling. If the soil is dry, more water is needed. Do not flood the trees.

Suggested Readings

Briscoe, C. Buford. 1990. *Field Trials Manual for Multipurpose Tree Species 2nd ed.* Arlington, Virginia: Winrock International.

Hutacharern, Chaweewan, K. G. MacDicken, M.H. Ivory and K.S.S. Nair, eds. 1990. *Pests and Diseases of Forest Plantations in the Asia-Pacific Region.* Proc. of an IUFRO workshop. Bangkok: FAO.

Development and Resources Corporation. 1969. *Orchard Management: Horticultural Practices for Peace Corps Volunteers.* Washington, DC: Peace Corps.

Tuladhar, L.B.S., K.B. Shrestha, R.B. Bista., P.K. Tyystjarvi, and A.M.J. Robbins. No Date. *Manual on Nursery and Plantation Practices for Community Forestry Development.* Kathmandu, Nepal: Community Forestry and Afforestation Division, Ministry of Forest and Environment.

Remember

The tending regime depends on the tree crops that will be harvested. Consult the farmer and consider the costs involved.

Weeds compete for soil nutrients, reduce tree vigor, encourage pests, and increase the cost of tree farming.

Herbicide use may be cost-effective if there are many weeds. Only use recommended herbicides. Protective clothing must be worn.

Fertilizers may be necessary in some sites. Note that adding fertilizer adds to production costs and sometimes pest and disease damage may be confused with nutritional deficiencies.

Disease and pest damage can be minimized by removing affected trees, mixed planting, and appropriate pruning/cutting methods.

Thinning means felling individual trees to reduce competition with superior trees. It is necessary only when the trees are being grown for producing sawn timber, veneer, or large poles.

Coppicing and pollarding involve cutting trees at different heights to induce regrowth. Using these methods, trees do not have to be replanted after each rotation.

Pruning makes for better volume growth and knot-free timber. The best time for pruning is before the start of the rainy season.

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Institutional Background

The **Forestry/Fuelwood Research and Development Project (F/FRED)**, funded by the **U.S. Agency for International Development (USAID)**, is designed to help scientists address the needs of small-scale farmers in the developing world for fuelwood and other tree products. As an outcome of collaborative meetings in the region, a ***Multipurpose Tree Species Research Network*** was established through which scientists exchange research plans, methods, and results. Research and development activities center on the production and use of multipurpose trees that meet the household and market needs of small farmers.

F/FRED is being executed by the **Winrock International Institute for Agricultural Development**. Winrock is a private, nonprofit U.S. organization working in agricultural development around the world. It was established in 1985 through the merging of the Agricultural Development Council (A/D/C), the International Agricultural Development Service (IADS), and the Winrock International Livestock Research and Training Center. Winrock's mission is to improve agriculture for the benefit of people, help increase agricultural productivity, improve nutrition, and advance the well-being of people throughout the world. Winrock's main areas of emphasis are human resources, renewable resources, food policy, farming systems, and agricultural research and extension.

Module 1:
Selecting Multipurpose Trees

Module 2:
Nurseries and Propagation

Module 3:
Mulitpurpose Trees in Agroforestry

Module 4:
Small Plantations of Multipurpose Trees

Module 5:
Tending Multipurpose Trees

Module 6:
Harvesting Crops of Multipurpose Trees

Module 7:
Selling Tree Crops

Module 8:
Principles of Effective Extension

Module 9:
Species Fact Sheets

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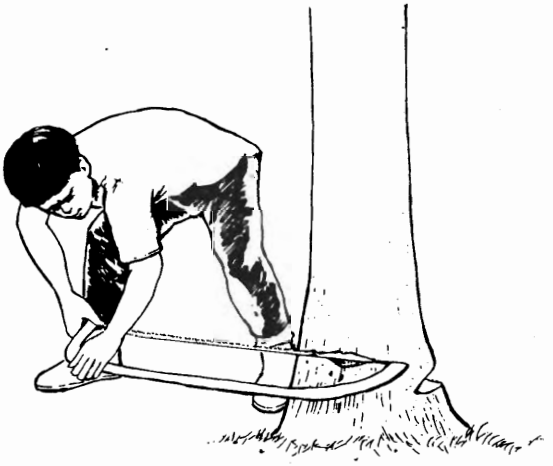
Module 6

Harvesting Crops of Multipurpose Trees



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Module 6

Harvesting Crops of Multipurpose Trees

Harvesting of any tree crop requires planning and care. This module gives particular attention to harvesting timber. This harvesting operation may be less familiar to small-scale farmers because it is more intensive than for fodder or other tree products. The general principles apply to any tree crop.

Harvest Planning

Plan Early

Generally, farmers grow multipurpose trees for domestic use and sale. If enough attention and care are taken in species and site selection, farmers will have secure supplies of wood and other tree crops.

Ideally, farmers should start planning the harvest even before they plant their trees. The plan should specify the species to be grown, particular crops desired, and the end uses of these crops. Extension workers can help individual farm households prepare harvest plans. For community forests or public lands, the community can draft

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plans to identify the best management options for the community at large (Figure 36).

Aim at Sustainable Use

The goal of a harvesting plan should be sustainable use. This means that the farmer should consider yields over the long term as well as the short term. In preparing a plan, the following should be considered:

- soil fertility
- rotation scheme
- slope
- climate
- accessibility of sites to workers and equipment
- labor needs
- harvesting techniques
- availability of harvesting equipment
- transportation of harvested tree crops.

Types of Tree Crops

The plan should also consider the various crops that farmers wish to harvest from a tree. Multipurpose tree species can meet a number of domestic and market needs. For example, a farmer can harvest leucaena and then

- transport the large stems to sell as sawn wood and smaller stems as chips for pulp
- keep or sell the young leaves, flowers, and pods for human consumption
- include the leaves and pods in animal feed
- apply older leaves to the soil around other crops as green manure.

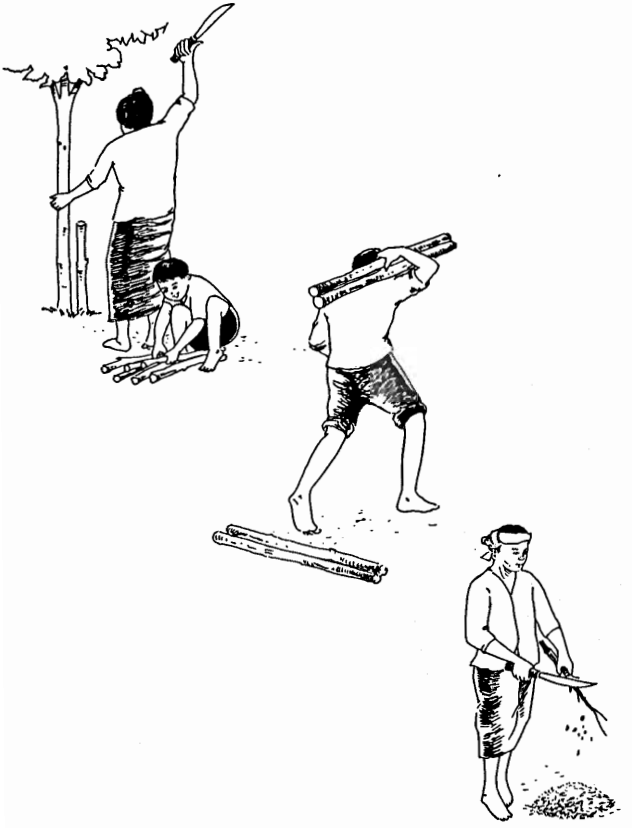

Figure 36.

Multipurpose trees can yield a number of different crops if harvesting is planned carefully.

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A small farm woodlot or tree farm with species that yield many types of crops will help farmers adapt to market changes and farm conditions.

Sketch Map

The harvesting plan should include a sketch map. This is a map that indicates where each species is planted, terrain features, boundaries, slopes, and how the different tree plantings will be managed. If logs are to be harvested as timber, the sketch map should also indicate how to get to the planting site and what type of vehicle is needed (Figure 37).

Timing

The harvesting plan should describe the best time for harvesting the different tree crops. To fix the harvesting season for each tree crop, flowering and fruiting time should be discussed with experienced tree growers in the area. The timing of other farm operations should also be considered to avoid time conflict and higher seasonal wages.

Although harvesting logs is easier in the dry season, the hot weather means that work will be slow and food for animals may be in limited supply.

Inventory for Wood Harvest

As the trees begin to reach full maturity and the time for harvesting logs approaches, conduct an inventory of the stock of each species as well as the total plantation. This will be invaluable in estimating income and productivity. A number of factors must be considered.

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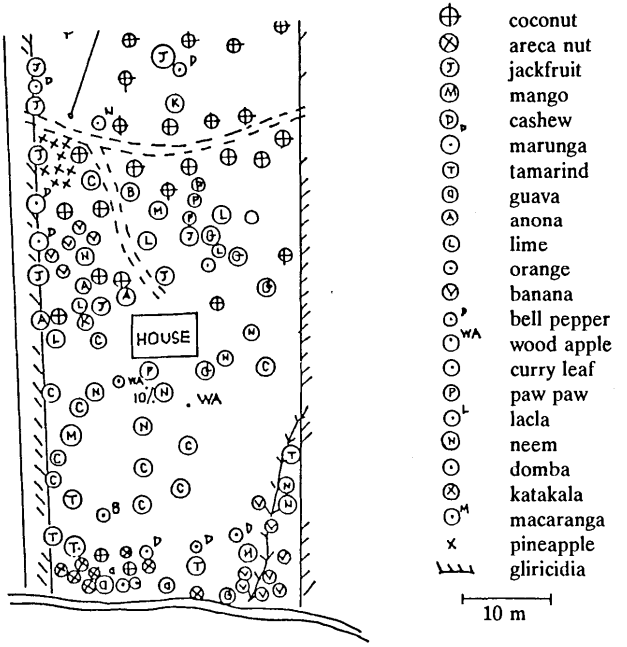

Figure 37.

A harvesting plan should include a sketch map showing where each species is planted, terrain features, boundaries, slopes, and how the different tree plantings will be managed.

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Volume

Farmers should sample 2-10 areas that represent the various types of soils and species being grown. For larger planting areas, more sample plots are needed. The information from these sample plots will be useful in estimating the volume of wood to be harvested. Farmers should refer to the volume tables developed for each tree species. Forest Department officials or staff at a Forest Research Institute or Faculty of Forestry in a university should be able to provide volume tables.

To use volume tables, the following characteristics have to be measured:

- **Diameter at ground level (d_{10}):** usually measured at 10 cm above ground level with a specially gauged diameter tape or caliper. If a tape or caliper that calculates the diameter (distance across the stem) is not available, a standard measuring tape can be used. The circumference (distance around the stem) should be divided by 3.14. For trees with more than one stem, each stem is measured separately and summed.
- **Diameter at breast height (dbh):** is the diameter of the main stem at 1.3 m above ground level. This is a common tree measurement among foresters.
- **Height (h):** is also an important measurement when taking an inventory and evaluating site quality. Total height is the vertical distance from ground level to the tip of the stem. Poles or bamboo culms are commonly used to measure height growth of small MPTS. For commercial sawn wood, industrial buyers measure height along the stem from the ground level

to the first point at which the diameter measures 15 cm.

- **Number of branches:** is used to determine stem quality. Timber has a higher value if it does not have many knots in the wood. Generally, good timber trees have few and small branches, with branches at an angle of more than 90° to the main stem. Trees with big branches are generally not good for sawn wood, veneer, or plywood. However, such trees can be good for fuelwood or other uses.
- **Bark:** thickness is measured by carefully cutting the bark with a knife or axe. This measurement is useful because estimates of wood volume sometimes require use of stem diameter without the bark (ib).

These measurements, which are taken in several sample plots in conjunction with volume tables, determine the volume of wood per hectare (Figure 38).

Log Size

Farmers should know the optimum log length for each intended end use. Generally, the best log length for most commercial wood uses, such as sawn wood and plywood, is 2 m.

Poles

If poles are going to be sold, the trees should be evaluated on the basis of the number of poles of the required length and diameter that can be cut from them. It is not specific volume that matters, but the number of poles, since they are sold by the piece.

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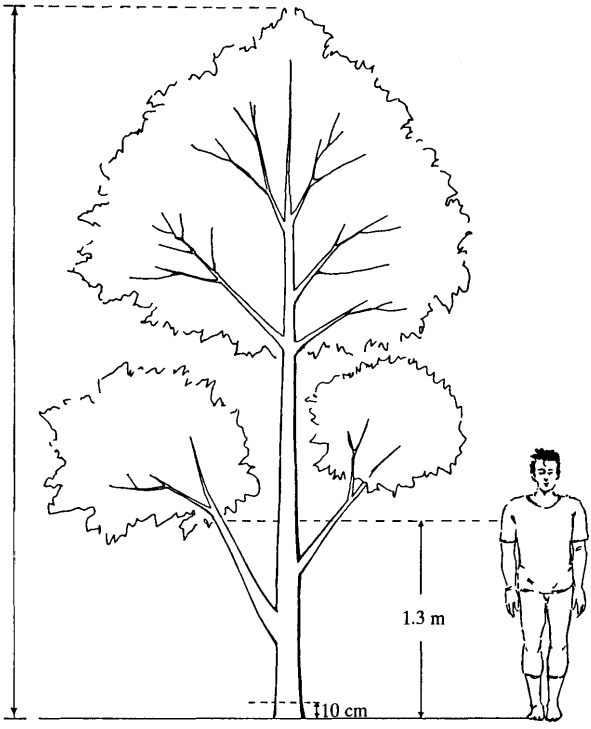

Figure 38.

Using measurements of basal diameter and diameter at breast height, farmers can refer to volume tables to estimate the amount of wood to be harvested.

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Chipwood

For chipwood, total biomass is more important than straight logs. Most chip mills purchase on the basis of green weight, so there is little advantage in sending high-value bole wood to the chip mill. However, transport costs are cheaper if relatively straight material is selected.

Wood Density

For fuelwood, charcoal, and some processed products, it is useful to know wood density (foresters use the term *specific gravity*). High-density wood can be put to more uses than low-density wood. To determine wood density, it is best to consult a specialist in wood utilization at a nearby university or forest research station.

Selecting and Marking Trees

Why Mark Trees?

There are several good reasons for marking trees to be felled:

- If trees are sold on the stump (stumpage sales), farmers, cutters, and buyers will all know exactly which trees are to be harvested.
- If farmers hire extra labor to cut the trees, the work can be carried out even if the farmers are absent.
- By measuring and recording the trees at the time that they are marked, farmers can more easily keep track of which trees have been measured.

How To Mark Trees

If the trees are to be cut a short time after they are marked, charcoal or lime whitewash can be used.

Otherwise, paint is an excellent way to mark trees. This is better than using an axe because the trees are not damaged.

The mark should be placed at eye level. It is best to place the mark always on the same side of the tree. For example, in a block-type plantation, one could start at the back and mark the trees on the side that faces the front of the plantation. This way the farmer can look back from any point and see which tree he or she has marked.

Site Considerations for Harvesting Logs

Topography

If trees are planted on flat land as homestead trees or on small farms, harvesting is relatively simple. On hilly sites, topography affects both manpower and equipment needs and limits the ways that logs can be removed. On steep slopes, moving logs is difficult and expensive. Slope also dictates the number of trees that can be felled.

Table 5. Classification of Slopes

Slope class	Slope gradient (%)	Prevailing ground conditions for road construction
Level	0 - 15	Unfavorable, if drainage poor
Gentle	15 - 30	Favorable
Moderate	30 - 50	Favorable
Steep	50 - 70	Difficult
Very steep	70	Very difficult

Soil Strength

Soil strength is directly related to terrain. If the terrain is flat and has few rocks and stumps, soil strength has no influence on transportation of

wood and other tree crops. However, if the terrain is difficult, there is increasing risk that the vehicle used for transporting the wood will sink into the soil. This imposes a load limit. Soil conditions on slopes affect the cost of harvesting logs. If they are particularly difficult, it can mean that it may not be economically feasible to grow commercial timber on that site.

In areas prone to flooding, the soil will not support some logging operations. During dry periods, ground skidding might be possible. Also, since farmers are often busy with other agricultural crops during the wet season, it is often preferable to harvest logs in the dry season.

Quality of Roads

The quality of roads should be considered when planning wood harvesting, even before planting the trees. Road quality affects the cost of harvesting. In remote areas, provincial or national authorities might provide assistance for building roads.

Even small-scale farmers should consider the quality of roads when growing trees for commercial uses. When an area is cleared to make a road, a combination of heavy rains, steep slopes, and soil composition can result in soil erosion. During heavy rains, splash erosion causes soil to be carried down the slope. This is another reason for planning road construction carefully. It may be wise to develop a water discharge system and plant a cover crop or grass on roadside banks as part of the road construction process.

If farmers can afford it, they might consider placing a layer of gravel several centimeters thick over the road to extend its serviceable life. Road

repair is best done during the dry season (Figure 39).

Access to Markets

Before harvesting trees for wood, farmers should identify exactly where their tree crops will be taken for sale. (See Module 7.)

The greater the distance that trees are transported, the more expensive transport costs are. Higher transport costs make it harder for farmers to cover their investment at sale time.

Equipment and Labor

Appropriate Tools for Workers

Where labor is not readily available and there is enough money to buy machines, mechanization has greatly changed harvesting methods. In some places, tractors and skidders have replaced animal power. But machines still cannot do all the work. The best approach is to equip workers with locally available tools.

It is easier for tree-grower cooperatives to buy equipment than for individual growers. However, the need for training in equipment use must be considered. Small-scale farmers might find it more economically feasible to use animals than machines for transporting logs over short distances.

Training Needs

Training people in safe harvesting methods can save money and prevent accidents. Budget and time should be set aside for training workers if they are inexperienced. Workers should be paid according to skill and experience.

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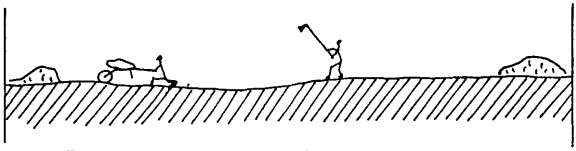
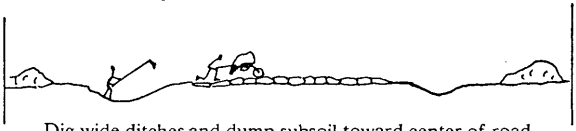
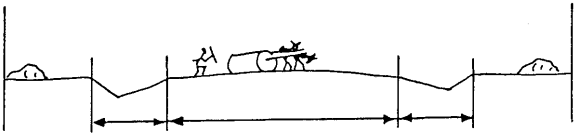


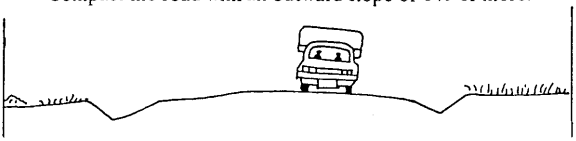
Remove topsoil for at least 8 m from center of road.



Dig wide ditches and dump subsoil toward center of road.



Compact the road with an outward slope of 5% or more.



Lay topsoil on ditch slopes and plant cover grass to prevent erosion.

Figure 39

Roads are expensive to build and must be planned carefully for long-term use.

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Basic Tools

All equipment should be in good condition. It might be possible to rent or borrow chainsaws. For harvesting small trees or collecting fuelwood, fodder, or fruit, farmers can use a locally available saw, axe, or knife.

Purchasing the following equipment might be considered:

Axe: is usually used for tree felling and removal of branches. Many types of single-bit axe heads are available. Any one of them is suitable. Most axe heads weigh 1-2 kg and have a 60 cm-long handle. For efficiency and safety, the axe blade should be kept sharp and properly tapered. A dull axe is more dangerous to use than a sharp one.

Bowsaw: is particularly appropriate for cutting trees with a stem diameter of 15-35 cm. Though more labor intensive than the chainsaw, it is more efficient than an axe. Use of a bowsaw also means that much less wood is wasted than when using an axe or knife (Figure 40).

Chainsaws: felling direction should be planned before the engine is started. The working space should also be cleared to allow easy movement.

Handsaw or chainsaw: can be used for limbing and bucking. Logs should be cut into sizes appropriate for the particular end use. An axe, adze or knife can be used to remove the bark.

Pulp hook, two-hand log tong: can be used for rolling logs and piling them by the roadside. Of course, this can also be done simply using one's hands for small logs.

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Figure 40.

The bow saw requires less than half the labor that an axe requires, and wastes less wood.

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Locally Made Tools

Many of the tools used in harvesting trees can be made domestically or in small rural workshops. Blacksmiths and small metalcraft shops can easily make bolos, hoes, scythes, sickles, spades, pick-mattocks, shovels, and grub hoes to order.

Making use of local resources helps promote rural employment and community involvement in tree growing.

Harvesting Operation

Harvesting small-stemmed, fast-growing trees is easier than harvesting large, slower-growing trees.

Felling and Limbing

A chainsaw, axe, or bowsaw can be used to fell trees and remove limbs. Accuracy in the direction of felling can improve efficiency and enhance safety when there are many workers in the area. The undercut should be made first to define the angle of the "hinge." The hinge is the portion of wood remaining after making the back cut. It helps the specific direction which the tree will fall.

Debarking

Bark is removed from the logs either at the cutting site, roadside, processing plant, or not at all.

Piling

Small trees can be bunched into groups for transporting. When the logs are in piles, the farmer can better estimate total log volume. This is necessary for arranging for transport and determining selling price. Animals can sometimes be used to pile large logs at the roadside. It is best to transport logs as soon as possible after

harvesting. For pulpwood or chipwood, bunch logs before skidding or hauling.

Transport

Terrain Transport

This immediately follows cutting and precedes road transport. Terrain transport involves the following steps:

- Full trees or crosscut trees are "skidded" or dragged by tractor, animal, or workers to a loading point (Figure 41). In most large-scale tree-planting operations, skidding using a farm tractor is customary. The tractor engine should be at least 35 kW (48 hp) and preferably 60 kW (82 hp). A hydraulic three-point hitch can be attached to the tractor for skidding of reasonably-sized trees.
- Pulling the load mechanically to a separate winch or to the winch of a tractor.
- "Forwarding" which is transport on wheels or sledge runners drawn by animals or machines. A farm tractor with a semitrailer and hydraulic grapple loader is suitable for forwarding. The tractor should also be equipped with a winch and tire chains. Generally, a farm tractor cannot compete with a four-wheel drive skidder for distances over a few hundred meters.
- "Yarding" which calls for the whole load or part of it to be lifted off the ground most of the time, supported and moved by a steel cable. This is a difficult operation, requiring

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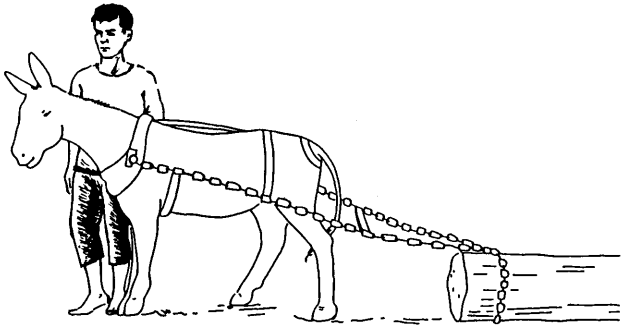

Figure 41.

Animals can be used to drag logs to the roadside.

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detailed planning and engineering and a highly skilled crew. Because fixed costs are high, cable systems are justified only where slopes are so steep that mobile skidders cannot be used and where a high volume of timber can be extracted per unit area.

- An integrated approach, using manual labor, animals, and a farm tractor equipped with a winch might be considered. Logs can be transported a short distance from the cutting site to a point where four-wheel skidders can transport bunched logs the longer distance to the roadside.
- Site protection and repair is necessary during log removal. This may include making contour strips of branch and root debris left by the logging operation to reduce erosion.

Road Transport

Road transport first involves loading the logs, mechanically or manually, onto trucks or other means. They can then be transported to a conversion depot or directly to a mill or other market outlet.

For long distances, truck, train, and river transportation are possible. Transport by train or water can be more expensive if the logs have to be loaded onto trucks and unloaded twice. In some parts of Asia, river transportation is difficult because there are many dams.

Means of Transport

- Animals can also be used to transport wood and other tree crops. They must be trained to obey commands and accept a work harness. Oxen, buffalo, horses, and

elephants are often used in Asia. A single forehead yoke, double-head yoke, or neck yoke is used in most of Asia.

- Tractors can be used for transporting logs, fruit, or fodder. If roads are good, trucks can transport a large volume of tree crops.
- Animals with log trailers or a four-wheeled cart can reduce friction and allow logs to be transported over longer distances.
- Some consideration should be paid to ergonomics. This means knowing how much energy is required to do a particular task. Working time should be set. Clear, written instructions can prevent confusion and save a lot of time and expenses.

Workers' Safety

Harvesting trees, logging in particular, is hazardous. The work is hard. Sometimes the climate is poor and the terrain difficult. Safety measures, such as protective helmets and visors, should be provided, particularly to riggers and workers who use chainsaws. Safety measures pay for themselves through higher worker morale, higher productivity, and fewer doctor and hospital bills.

Harvesting Fruit

Some varieties of fruit trees have a shorter juvenile stage and yield more abundant fruit than other varieties of the same species. Farmers should know which variety they will be growing before planting so they can estimate the yield.

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Bagging Young Fruit

For high-value fruits farmers might want to bag young fruits on the tree. Bagging has the following advantages:

- protects fruits from pests and diseases
- reduces the need for using expensive and hazardous pesticides
- helps in making quick and accurate estimates of harvest
- helps prevent bruises and wounds during harvest
- bagging materials provide a cushion during initial packaging and transport.

Many locally available materials can be used for bagging fruit, including paper bags, newsprint, jute, synthetic sacks or even plastic bags.

Timing of Bagging

Timing of bagging depends on the species. Mangoes should be bagged 10-15 days after fruits set. Jackfruit can be bagged when they are the size of an adult's fist. Guava should be bagged right after fruit set. Cacao should be bagged when fruits or pods are at least 4-6 cm long.

Equipment

To harvest fruits, use a stable ladder on firm ground. Place harvested fruit in a rigid container such as a box to avoid bruises and preserve fruit quality. Some fruits such as mango can be collected using a small rattan basket attached to the end of a long bamboo pole.

Transporting Fruits

For fruit, as with timber, nearby markets are more desirable. Unless the fruit is preserved in some

way (for example, pickled, sun-dried or fermented), it will spoil during extended transport.

Some bicycles can be loaded with up to 250 kg of fruit. They can also be used to transport fodder and fuelwood. A tricycle can carry even heavier loads and is more comfortable over longer distances. In most Asian countries, public transport is widely used for rapid transport of valuable fruits.

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Remember

Early planning can mean the difference between a successful harvest and one that will waste precious resources. Consideration must be given to species and types of tree crops to be harvested. Community involvement should be encouraged.

Sustainable use is the principal objective of a good harvesting plan.

A sketch map should indicate the location of each species, stage of growth, key terrain characteristics, and best time for harvesting.

An inventory will help farmers estimate possible income and the productivity of their tree farms. It will also help them determine the markets and optimum time of sale for their tree crops.

Trees should be selected and marked so that both farmers and laborers will know exactly which trees should be cut.

Site conditions determine which types of machines are appropriate. A thorough site evaluation before harvesting can save money and time.

Workers' safety can be ensured by providing low-cost equipment such as protective helmets and visors. These pay for themselves by reducing "down" time and avoiding medical care costs.

This module was prepared by Dr. Suree Bhumibhamon, Associate Professor, Department of Silviculture, Faculty of Forestry, Kasetsart University, Bangkok 10900, Thailand.

Institutional Background

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Growing Multipurpose Trees on Small Farms

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Module 4:
Small Plantations of Multipurpose Trees

Module 5:
Tending Multipurpose Trees

Module 6:
Harvesting Crops of Multipurpose Trees

Module 7:
Selling Tree Crops

Module 8:
Principles of Effective Extension

Module 9:
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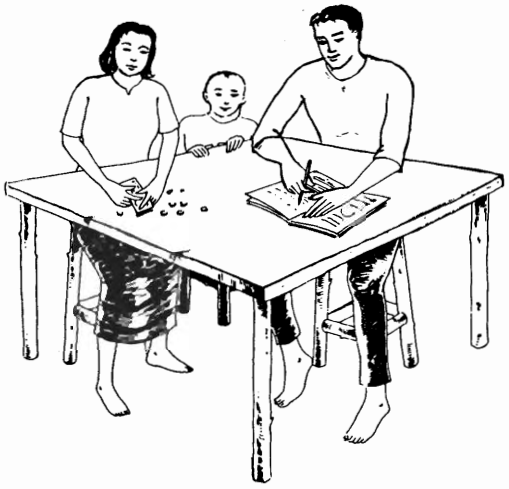
Module 7

Selling Tree Crops



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Module 7
Selling Tree Crops

This module describes some of the principles involved in selling tree crops and products. It provides guidelines on estimating production and marketing costs. It also suggests various marketing alternatives. Particular attention is paid to preparing a marketing plan for different crops farmers wish to sell. A "marketing checklist" is provided to help tree growers monitor their success.

The Farm as an Enterprise

Careful Planning

Farming is a means of earning a livelihood. Crops are produced either for the farm family's own consumption or to sell or exchange for other goods.

Farmers must plan carefully to minimize the effects of unforeseen problems. Many things can go wrong. Drought or insects can severely damage the crop or crop prices can fall suddenly because of changes in market conditions. Illness in the family or unavailability of hired help can spoil the best of plans. Good planning, however, can reduce the number of surprises.

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Benefits of Growing Multipurpose Trees

Growing multipurpose trees on a small farm can result in extra income, less soil erosion, and protection against total crop failure.

Growing trees is often done in conjunction with cultivating agricultural crops. Systems of growing crops and trees together in different ways are called "agroforestry."

Working with Other Farmers

As with all farming, growing multipurpose trees on small farms involves risks. For one thing, trees compete with other crops for nutrients and water. Unless agroforestry is managed properly, neither the trees nor the agricultural crops will perform well.

Farmers are accustomed to doing things on their own. Though there are advantages in being able to make their own decisions, there are times when "pooling" of land and labor resources helps distribute risk. Working together with other farmers in a cooperative or even joining with other farmers to form a small company can mean a more cost-effective tree growing enterprise (Figure 42).

The Economics of Growing Multipurpose Trees

Types of Tree Crops

Multipurpose trees can yield fuelwood, timber, fodder, and fruits. In selecting which species to grow, farmers should have a clear idea about which tree crops they wish to obtain. (See Module 1.)

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Figure 42.

Working together with other farmers in a cooperative or even a small company can mean more resources and fewer risks for the individual.

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Estimating Costs

It is important that farmers estimate how much it will cost to produce their tree crops and bring them to market. This requires, in part, knowing the value and carrying capacity of the land. Farm land can be put to many uses, from growing different types of crops, to raising animals, or stocking fish in ponds.

Farmers usually have a good idea of how much it costs to buy fertilizer, hire labor, rent equipment, and so on. However, they sometimes do not calculate the cost of their own labor, that is, the time they and other family members put into planting, tending, and harvesting. Farmers should not forget to include the cost of their own time when planning their farm operations (Figure 43).

Demand for Tree Crops

The demand for tree crops influences the price at which they can be sold. It is important that farmers know why and when people want to buy their tree crops. It will help them understand the market and possibly sell their crops at a higher price. For example, for fuelwood, this means knowing the size of logs or branches that buyers prefer and the burning quality of the charcoal that sells best.

Selling Price

Selling price is determined by how much it costs to produce the tree crops and how much people are willing to pay for them. Many factors are involved in determining selling price. Some, such as general economic conditions and tariffs, are outside the control of farmers.

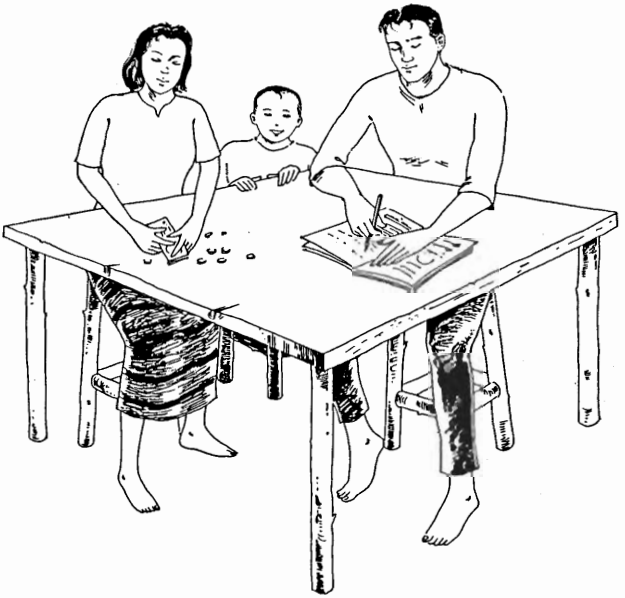

Figure 43.

Accounting is important. Include the value of your family's labor when figuring the costs of producing and marketing tree crops.

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Marketing Tree Crops

What Is Marketing?

Marketing can be thought of as "getting the right product to the right consumer." It consists of matching the ability of the producer to make goods with the ability of the consumer to buy those goods.

Tree farmers might consider marketing as simply putting their trees to use. This can be on their own farm, at a local market, or a distant market. Marketing is especially important when farmers decide to sell their trees or tree products to earn money.

Sellers' Market

In its broadest sense, "market" refers to the process of bringing together sellers and buyers. It is useful to consider the different types of market situations.

The type of market that sellers love best is the "sellers' market." This is where supply is short and demand is high (Figure 44). In this type of market, the farmer (seller) can sell his product at a high price and still find buyers for it. This type of market usually does not last long because new sellers are soon attracted to the handsome profits that can be made and prices fall.

Buyers' Market

A "buyers market" is where supply is high and demand is low. Many sellers and few buyers generally means lower prices for the farmer.

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Figure 44.

A "sellers' market" means there are many buyers, few sellers.

Methods of Marketing

Marketing Plan

A tree farmer needs to have a marketing plan. This is especially important to prepare for changing market conditions.

A good marketing plan should answer the following questions:

- What to sell?
- When to sell?
- Where to sell?
- How to sell?
- What is the final price?

Stumpage Sale

This refers to selling trees before they are cut down, that is, when they are "standing on the stump." The farmer decides which trees he wants to sell, marks them, and invites timber buyers to come and bid on them. The farmer can select the highest bidder.

Advantages

- The farmer does not have to cut and haul trees.
- Price is easier to calculate since there is one cash price for all the trees that are marked.
- The only equipment needed is a can of paint and a brush. The buyer provides everything else.

Disadvantages

- The farmer might receive less money than his trees are worth because the buyer is providing tools, labor, and transport.
- The price offered may not take into account the different sizes of the trees or the

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different values of different parts of the trees.

- The farmer needs to supervise cutting to make certain that only marked trees are cut.

Log and Wood Sale

In this situation, farmers themselves cut the trees. They also grade them into categories such as for timber, pulp, and firewood. Each grade obtains a different price. The farmer must know exactly what buyers want in terms of log length, diameter, degree of straightness, and types of logs. Local roadside sales are easier because buyers tend to be local people whose needs are familiar to the farmer.

Advantages

- Farmers exercise control over the parts of the trees that they want to sell and which they want to retain for their own use.
- Farmers can use their own labor resources during slow times on the farm.
- Total income from sales is likely to be higher than stumpage sales.

Disadvantages

- Buyers will want specific timber characteristics such as size, volume, and moisture content. Farmers have to know about these things or they will be taken advantage of.
- May be expensive, requiring investment in tools, labor inputs, and learning new skills.
- May also involve transport and storage costs.
- Possibility of spoilage if sales are delayed, or of earning less money if market prices slump.

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Processed Products

If the wood is processed into finished products, farmers exercise much greater control over their operation. The "added value" of processed products can make the tree farming enterprise more profitable. For example, making charcoal is a common processing activity. This is sometimes best handled through a cooperative arrangement involving other farmers and people in the community.

Advantages:

- Complete control over the operation from planting to finished products.
- Can add considerable value to the products.
- Provides an incentive to involve other members of the family or the community in income-generating activities.
- Opportunity to learn new skills.

Disadvantages

- Requires additional investments in time, tools, labor, and learning new skills.
- Market conditions are unpredictable. Buyer preferences can change quickly.
- Very competitive.

Types of Products

Fuelwood/Charcoal

Fuelwood and charcoal are used widely in rural areas for domestic cooking. Species selection is an important factor in determining the quality of the fuelwood and charcoal. Consumer preferences have to be considered.

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Fuelwood is generally marketed locally. There are many sellers and buyers. There is often a good market for fuelwood in urban areas that do not have their own sources. Supplying fuelwood for an urban market is more complicated than supplying it for a local market. It involves a chain of distributors and, where such trade is prohibited by law, there may be official opposition. However, profits are attractive and legal constraints usually do not apply to fuelwood produced on tree plantations.

Farmers can limit their operation to growing trees, growing and cutting, or making charcoal and packaging it for the final user. The more complicated the operation, the greater the need for careful planning and organization (Figure 45).

Wood Chips

The pulp and paper industry is a large market for tree plantations. A pulp and paper operation needs many raw materials so that the mill can work continually. This is why pulp and paper mills are usually located in areas with extensive plantations. However, because there is often only one mill nearby, the tree grower may not have much influence over the price he will get. The mill will also have strict standards of wood quality. Farmers may be left with many trees that they cannot sell. These trees can be used for other purposes such as fuelwood and charcoal making, but the income might be less attractive. Usually, the factory will buy at the factory gate and the seller has to make his own arrangements for cutting and transport. This can increase costs considerably.

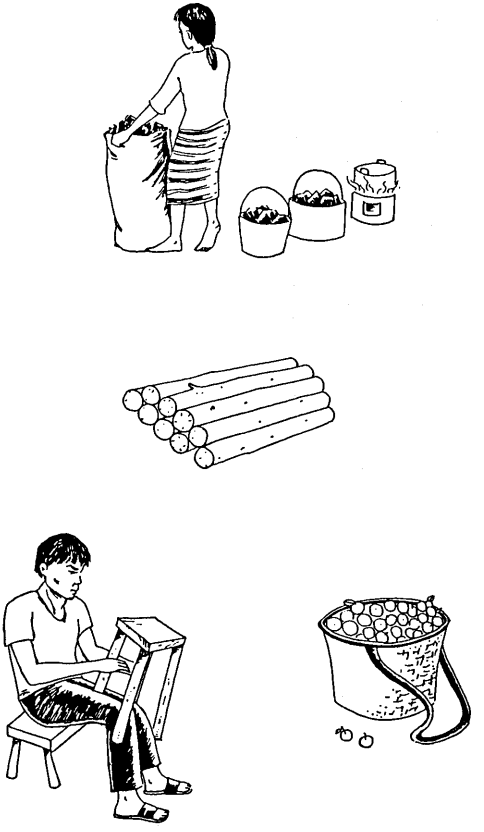

Figure 45.

Multipurpose trees can yield many products that farmers can market.

Timber and Poles

Trees can be sold individually if they are to be used as timber for construction. Poles are sold in pieces. Prices depend on the size of the poles, which means that harvesting time is important. Large trees are usually worth more than smaller ones. Timber wood can also be used for making doors, window frames, and parquet flooring. To make these products, however, farmers need skill and expensive equipment. It also takes more time to make a return on the original investment.

Handicrafts and Other Small Products

Farmers can make a range of wood-based items such as handicrafts, kitchen utensils, toys, and picture frames.

When To Cut

In terms of marketing, tree crops are similar to agricultural crops. Some times are better than others for taking crops to market.

The following will help farmers decide when to cut:

- Determining the types of tree products, their size, and the quality that buyers are looking for.
- Is money needed now? If income from other crops is going to be good, farmers might consider delaying harvesting their trees until they are larger and will bring in more money. If other crop yields are not good, or extra money is needed for school, medical, or other expenses, selling a few trees might be a good idea.

- When is labor available and cheapest? When is the farm family's own labor available?
- If young trees continue to grow for another year or so, will they begin to crowd each other and compete for soil nutrients, water, and sunlight? Sometimes, it is best to do some thinning even if money is not needed right away.
- Finding out what is the best time to harvest trees to encourage coppicing, collect seed and fodder, and reduce possible damage by diseases and insects. (See Module 6.)

A Marketing Checklist

To plan marketing properly, every phase of the operation must be considered. The checklist below (adapted from Kotler and Armstrong, pp. 540-542) can provide some practical guidelines in planning a marketing strategy. Farmers might find that working cooperatively helps maximize benefits. A cooperative of small-scale tree growers may be in a better position to obtain a fair price.

To make use of the checklist, imagine that the tree farmers have formed a tree farmers' cooperative (which we call "The Enterprise") and need to decide how to sell the trees that are now ready for harvesting. They have to decide between stumpage sales or harvesting and processing the wood before selling it.

The checklist can be used as a basis for group discussion. The extension worker should participate but not lead the discussion.

There are four major areas to cover:

1. operation of the tree farm,
2. market environment,

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3. organization of the enterprise, and
4. effectiveness of the marketing plan.

Operation of the Tree Farm

- What is the outlook over the next 10-20 years on land availability, water resources, soil fertility, and rainfall?
- What changes in farming methods could affect the enterprise? Are there new, better species available? Are there new, improved ways of planting, tending, and harvesting?
- Are there ways of increasing productivity without significant new inputs?
- What new, cost-effective inputs might be considered to increase productivity?
- What new laws or regulations could affect the operation of the enterprise? Are there, for example, any changes planned on price control and crop subsidies?
- How does the community feel about the enterprise? Is it supportive? Is it suspicious? Can anything be done to improve community involvement?

Market Environment

- Are there any changes in market prices that the enterprise should consider in its market plan?
- What is the major source of competition? How do buyers compare the products with similar ones being offered by other individuals or companies?
- Is competition among buyers likely to increase in the future?
- What changes are taking place in the market that could affect the enterprise? For

example, are consumers switching from charcoal to another type of fuel?

Organization of the Enterprise

- Are there any difficulties with cash flow or access to credit?
- Are there more efficient ways to get the products to the buyers?
- Are there more efficient ways of storing the products?
- Are significant changes taking place in how the enterprise obtains the materials that it needs such as seeds, seedlings, and fertilizer?

Effectiveness of the Marketing Plan

- Is the enterprise market oriented? Does it know why people buy its products?
- Are the marketing objectives stated clearly? Do these objectives cover everything from species selection to delivering the product to the consumer?
- Do the marketing objectives match resources and market opportunities?
- Are adequate resources allocated to marketing? Are too many resources allocated to marketing?
- Is the costing of the product accurate? For example, is the labor input of the farm family considered?
- Can marketing costs be reduced?

Suggested Readings

Kotler, Philip and Gary Armstrong. 1989. *Principles of Marketing*. 4th edition. New Jersey: Prentice Hall.

Naughton, Gary. 1991. *Tree Farmers Guide: Marketing Farm Grown Timber.* Pakistan: Winrock International.

Tingsabadh, Charit. 1989. *Forest-based Small-scale Enterprises in Rural Development, Report no. 1-88, Participatory Forestry Development through Extension.* (Project THA/86/0/6), Bangkok: Food and Agriculture Organization.

Remember

Multipurpose trees can add to a farm family's income. Farmers should estimate how much it costs to produce tree crops and bring them to market. This requires, in part, knowing about the value of the land and the value of the farm family's labor.

Marketing refers to everything that involves selling the tree crops. This means having good knowledge of local market conditions and sometimes of national conditions.

Determine when to sell your various tree crops. Depending on local conditions, it might be wise to sell the trees even before they are cut. Under some circumstances, it may be wise to form a cooperative. Sorting and/or processing can result in added value for the farmer.

This module was prepared by Dr. Charit Tingsabadh, Deputy Director, Institute for Environmental Research, Chulalongkorn University, Phyathai Road, Bangkok 10200, Thailand.

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Module 8
Principles of Effective Extension

This module discusses the role of extension workers and how they can work effectively with farmers and researchers. The module considers principles for doing effective extension work, guidelines for preparing a good work plan, suggestions for understanding farmers' decisions, hints for effective communication and training methods, help on addressing problems when they arise, and ideas on strengthening local institutions.

If farmers do not adopt a variety, species, or technique that the extension worker recommends, the extension worker may feel that the farmers are stubborn or even ignorant. The real reason, however, is usually because the technology being recommended does not meet the needs of farmers in that locality. This can happen when scientists fail to consult farmers when designing or introducing new technology.

Effective extension involves collaboration between farmers, extension workers, researchers and private enterprises. Together they can they can identify or develop technologies that farmers need and can accept.

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The role of the extension worker is often described as informing potential users about technology and advising researchers of farmers' problems. But that is not all. Active participation by farmers in the design of new technology is important.

Extension workers also provide farmers with information about improved varieties and practices developed elsewhere that may be applied locally. This requires access to information and skill in testing a technology with selected farmers before recommending it for general use. Acquiring this information often involves three components:

- active participation in formal and informal networks
- interaction with research centers
- access to up-to-date information in journals, newsletters, and databases.

Working with Farmers

Extension workers in forestry and agroforestry need to know a lot about trees and people. This means, for example, knowing what men, women, and children do in planting and caring for trees.

As an extension worker, you work with farmers to 1) learn what options farmers have for using their land and earning a livelihood, and 2) develop criteria for helping farmers choose the best options for their particular circumstances.

This involves:

- helping farmers analyze their situation and how this might change in the future
- gaining knowledge and insight into the problems that farmers have and helping them to organize what they already know

- helping farmers acquire the knowledge that they need to solve problems.

Working with Researchers

As an extension worker, you can get research stations to help you do your job by:

- informing researchers about the circumstances under which farmers operate and sharing the knowledge that farmers have
- advising researchers about farmers' problems
- reporting on how well a new technology is working in farmers' fields and why farmers do or do not adopt it
- participating in research by establishing and monitoring on-farm experiments.

Working with Women

The contribution of women to agriculture often is not fully acknowledged. Good extension workers are particularly vigilant in adapting communication methods to reach women farmers and identify their needs. Your success may well depend on this.

Working with Private Enterprises

Linkages with private business and supporting institutions are critical for farmers. A good extension worker can help ensure fair treatment in:

- obtaining credit
- procurement of supplies/inputs
- provision of transport
- marketing of tree crops.

Preparing a Good Work Plan

The following principles can serve to prepare an effective extension plan:

- Write a clear mission statement: what you will do, who your work will serve, how you will operate, what resources you will need, and how you will evaluate your work.
- Review legislation and government regulations related to any new program that you might wish to undertake with individual farmers or community organizations. Be prepared to explain these to farmers.
- Identify and build upon the indigenous knowledge, experience, and practices of farmers.
- Make certain that you involve farmers in determining which problems to be addressed, planning which new technologies will be tested, conducting tests, and evaluating the results. Involve family members in ways that are culturally acceptable.
- Work with and through groups for more efficient and longer lasting results.
- Establish good working links with farmers, local organizations, research stations, suppliers of seed and other inputs, markets, and community leaders. Help suppliers to time their activities so that inputs are available when farmers need them.
- Draw on research-tested technology that has proved appropriate for specific sites and farmer circumstances.

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Implementing an Extension Plan

Implementation of the extension plan calls for the following set of related tasks and attitudes:

- Improve your technical, communication and organizational skills.
- Improve your ability to diagnose problems under farm and field conditions.
- Use a variety of methods for communicating and instructing.
- Monitor how farmers selectively adopt new practices. Adapt the practices to local conditions as necessary.
- Follow-up with farmers who adopt new technology. Help them to identify and solve unexpected problems (for example, pest attacks or adverse effects on other crops). Seek explanations for difficulties encountered, and adapt practices as needed.
- Be responsive to new problems that arise from use of new technology. For example, farmers could experience difficulties with storage, processing, marketing, or social issues related to the needs of different community members.

How Farmers Make Decisions about New Technology

It is important to consider how farmers decide if they will grow the new crop or select the recommended variety and practice. Close and continued interaction with farmers will help you gain knowledge and appreciation of how farmers make decisions. It is also important to study what farmers are doing that works and what they consider to be their most important problems.

Perception of Risks and Costs

When farmers adopt a new variety or species, it usually requires some change in the way they farm. How farmers perceive the cost, effort, or risk associated with the new practices often determines their acceptance of a new variety or species.

Generally, farmers have to be convinced of the following before they will accept a new practice:

- **Relative advantage**: the innovation will increase profits or lower costs, compared to the current practice. It can also reflect farmer perception of the new technology as meaning less work, fewer risks, or more social prestige.
- **Reliability**: the innovation will result in consistent minimum yields that are needed to feed the farm household and provide essential income.
- **Simplicity**: the new technology is easy to use.
- **Compatibility**: the innovation suits farmers' values, experiences, and current practices.
- **Visibility**: the results of the new practice are clearly apparent to the farmer and others.
- **Divisibility**: the farmer can try the innovation on a limited basis (for example, a small area).
- **Independence**: the farmer can adopt the new technology without consulting landlords, credit institutions, or the community. For example, a farmer might not be able to obtain irrigation for growing fruit trees unless enough other farmers agree to help develop and use the system.

Remember, whether farmers accept or reject an innovation depends much more on how they perceive it rather that its actual physical and economic characteristics. Until the farmer has seen other farmers use the new technology or have tried it themselves, the extension worker must pay close attention to the perceptions of farmers. Changing those perceptions may be your first, and possibly, only communication task.

Need To Inform Many Groups

If you want farmers to consider accepting a new technology, identify the different audiences that have to be informed. It is not enough to tell only the farmers. Also inform their families, landlords, money lenders, the people who buy and process their crops, and the people who handle transport and storage. If they have not received the same initial information, they might be skeptical or negative. If the crop is consumed or used locally, you must also inform the general public.

It is increasingly important to involve community-based non-government organizations (NGOs) in extension work. Good community organization is necessary for ensuring support for effective farm-forestry programs.

Need for Patience

To introduce a new tree-growing technology a 3-5 year campaign may be needed. Although a new variety may be "big news" when it is first announced, adoption generally requires several years and many adjustments.

How To Learn from Farmers

Specialists who know how to learn from farmers won't offer solutions until they have thoroughly explored, with the farmer, what the problem is. By

asking questions, you can help farmers solve their own problems.

For example (adapted from French & Gecolea, 1986):

- Ask farmers to describe the contrasting characteristics of good and bad trees for growing on their farms.
- Ask farmers about the steps they are taking to protect their farms from erosion.
- Ask farmers what they think should be done to protect the watershed and other common property.
- Ask farmers why their ideas have not been implemented.
- Organize group discussion to seek consensus on priority problems and possible solutions.

How To Communicate Effectively

Most extension methods are really ways to communicate. There are many good references (see Suggested Readings). The following are adapted from French and Gecolea:

- Know your target audience's attitudes, interests, and goals.
- Be clear about what you want to achieve. That is, what change(s) do you expect from your target audience?
- Make certain that what you want to say is in line with what the villagers feel they need.
- Select a means of communication (informal discussion, method demonstration, radio, etc.,) that is suited to your message. For example, detailed technical instructions over the radio are not effective. On the

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other hand, radio can create awareness of a new technology and how to get it.

- Choose the most suitable time and place for communicating your message.
- "Listen" with your eyes as well as your ears to check how villagers react to your ideas.

Some Useful Training Methods

- **Method demonstrations**: hands-on training for small- to medium-sized groups in a technique; for example, outplanting.
- **Result demonstrations:** highlighting visible results of improved technologies. For example, side-by-side plots of fertilized and unfertilized trees, or pruned and unpruned trees.
- **Group discussions and practice:** on-farm locations are ideal.
- **Lectures with appropriate media**: videos, handouts, filmstrips.
- **Study tours and field visits:** visits to farms of innovative farmers are particularly instructive.
- **Case studies:** use descriptions of the experiences and problems of others to give an idea of what they may face.
- **Role play:** can be an entertaining way to dramatize problems and draw out farmers' views on them.
- **Games/competitions:** can be a fun way to get farmers to share their results with others and draw attention to successful farming methods.
- **Apprenticeships:** working with other experienced persons can be a practical and

cost-effective training approach if numbers of trainees are small.

How To Respond To Problems that Arise

Until farmers have used a new practice for some time, one can expect some difficulties. When this happens, take the following steps:

- Indicate that, though difficulties may arise on occasion, you will do everything possible to help the farmer find a solution.
- Identify and help state the problem clearly.
- Collect information. This means getting complete information on symptoms through discussions with the farmer and through field visits. Ask other extension workers and research station or university staff for information.
- List possible solutions.
- Work with the farmer in selecting the best solution or combination of solutions.
- Test and implement the solution.
- Follow-up with the farmer.

Some Ways To Strengthen Local Institutions

Provide training in:

- communication skills for group leaders
- technical skills
- accounting and record keeping
- how to get help from government and private agencies
- work planning and monitoring of progress

Help provide access to:

- credit
- seedlings
- fertilizer
- improved livestock
- technical advice

Provide or clarify legal status regarding tree or land ownership and use by drafting a cooperative charter.

Suggested Readings

Buck, Louise. 1989. *Agroforestry Extension Training Sourcebook*. Nairobi, Kenya: CARE, Regional Technical Advisory Committee.

Capistrano, Lyn N., Janet Durno, and Ilya Moeliono. 1990. *Resource Book on Sustainable Agriculture for the Uplands*. Cavite, Philippines: International Institute of Rural Reconstruction.

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Remember

Failure of farmers to adopt a new technology is likely because of the **inappropriateness of the technology**. Work closely with farmers to adapt it to local conditions.

The extension worker plays a key intermediary role by communicating new technology to farmers and reporting to researchers on how farmers respond to that technology.

An effective work plan is essential. Determine exactly what it is that you need to do, how you want to do it, and the resources that you need.

Identify what farmers are doing already. This will help you to understand the constraints they face and what they will accept.

Extension is about communication. Carefully select the means of communication, study your audience's reaction, and be prepared to adapt how you communicate.

Problems will arise. When a problem arises, note as much information about it as possible. Seek advice from other extension workers and researchers. Work closely with farmers on possible solutions.

This module was prepared by Dr. Francis C. Byrnes, Senior Associate, Winrock International, Arlington, Virginia and Mr. David Taylor, Winrock International, Forestry/Fuelwood Research and Development Project, Bangkok, Thailand.

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Institutional Background

The **Forestry/Fuelwood Research and Development Project, (F/FRED)**, funded by the **U.S. Agency for International Development (USAID)**, is designed to help scientists address the needs of small-scale farmers in the developing world for fuelwood and other tree products. As an outcome of collaborative meetings in the region, a ***Multipurpose Tree Species Research Network*** was established through which scientists exchange research plans, methods, and results. Research and development activities center on the production and use of multipurpose trees that meet the household and market needs of small farmers.

F/FRED is being executed by the **Winrock International Institute for Agricultural Development**. Winrock is a private, nonprofit U.S. organization working in agricultural development around the world. It was established in 1985 through the merging of the Agricultural Development Council (A/D/C), the International Agricultural Development Service (IADS), and the Winrock International Livestock Research and Training Center. Winrock's mission is to improve agriculture for the benefit of people, help increase agricultural productivity, improve nutrition, and advance the well-being of people throughout the world. Winrock's main areas of emphasis are human resources, renewable resources, food policy, farming systems, and agricultural research and extension.

Growing Multipurpose Trees on Small Farms

Module 1:
Selecting Multipurpose Trees

Module 2:
Nurseries and Propagation

Module 3:
Mulitpurpose Trees in Agroforestry

Module 4:
Small Plantations of Multipurpose Trees

Module 5:
Tending Multipurpose Trees

Module 6:
Harvesting Crops of Multipurpose Trees

Module 7:
Selling Tree Crops

Module 8:
Principles of Effective Extension

Module 9:
Species Fact Sheets

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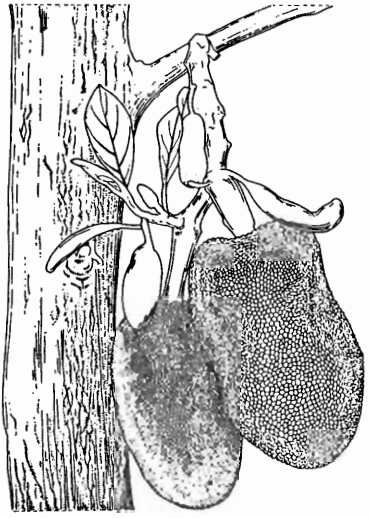
Module 9

Species Fact Sheets



Growing Multipurpose Trees on Small Farms

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Species Fact Sheets

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Species Fact Sheets

This Volume is designed for quick reference by field workers. Information is presented in a simplified form to make it as compact as possible yet still allow readers to make decisions on the suitability of specific species for growing in their conditions. It also serves as companion material to the volumes on establishing and managing multipurpose trees. An *Index of Species Names* which are commonly used in Bangladesh, India Indonesia, Nepal, the Philippines, Sri Lanka, and Thailand is included to save time in searching for specific *Species Fact Sheets.*

The fact sheets describe 58 multipurpose tree species that have high potential in Asia. They cover a wide range of climatic and site conditions. Descriptions are classified into 10 headings: These are: **origin**, the natural range of the species; **ecology**, typical climatic and soil requirements; **characteristics of the species**, giving normal mature size, tree stem and branching form, average growth rate, and coppicing ability; **products**, including wood, fodder, food and others. Four categories cover cultivation of the trees. These include **propagation techniques, seed treatment, management**, and **agroforestry uses.** There are also brief summaries of their **primary advantages** and **disadvantages**.

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58 Selected Species

The following species have been selected for inclusion. Although this is not a comprehensive list for all locations, it is a good place to start when considering options. See the matrix in this section and index at the end of this volume for common names.

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Common Names of Multipurpose Tree Species

Scientific Name	United States	Bangladesh	India	Indonesia	Nepal	Philippines	Sri Lanka	Thailand
Acacia auriculiformis	wattle	akashmani	akshmoni	akasia, auri	—	auri	acacia	kra thin narong
Acacia catechu	cutch tree	khoir	kair	—	kattha	—	—	Seesiat neua
Acacia mangium	mangium	mangium	—	mangium	—	mangium	acacia	kra thin tepa
Acacia mearnsii	black wattle	—	—	—	kalo siris	—	—	acacia
Acacia nilotica	Egyptian thorn	babla	babul kikar	—	babul	—	—	acacia
Acacia senegal	gum arabic tree	—	kuuiat	—	—	—	—	acacia
Acacia tortilis	umbrella thorn	—	Israeli babul	—	—	—	—	acacia

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Adansonia digitata	baobab	kalabogh	baob	—	—	—	—	—
Albizia lebbek	East Indian walnut	kala koroi	kala siris	kitoke, tekik	kalo siris	langil	hurimara	phruek
Albizia procera	white siris	sil koroi	safed siris	weru	seto siris	akleng parang	—	thing thon
Albizia saman	raintree	raintree	—	thrembesi	—	—	para mara	chaam churee
Alnus nepalensis	Indian alder	utis	—	—	utis	—	—	—
Anacardium occidentalis	cashew	kazu badam	—	jambu mente	kaaju	kasui	kadja	mamuang himma phaan
Artocarpus heterophyllus	jackfruit	kathal	kathal	nangka	katahar	nangka	kos	khanun
Azadirachta indica	neem	neem	margo	mimba, mene, nim	nim	neem	kohomba	sadao
Butyrospermum parkii	shea butter tree	—	—	—	—	—	—	—

(continued)

Scientific Name	United States	Bangladesh	India	Indonesia	Nepal	Philippines	Sri Lanka	Thailand
Cajanus cajan	pigeon pea	arhar	—	kacang kayu	rahar	kadios	thora parippu	thua rae
Calliandra calothyrsus	calliandra	—	—	kaliandra	—	calliandra	calliandra	—
Cassia siamea	Thailand shower	minjiri	kassod	johar	casia	robles	wa	khee lek
Casuarina equisetifolia	sea oak	jhau	saru	cermara laut	—	agoho kasa	kasa	son thale
Cocos nucifera	coconut	narikel	narival	kelapa	nariwal	niyog	pol	maphraao
Dalbergia sissoo	rose wood	sisso	shisham	sono keling	sisam	—	—	praduu khaek
Durio zibethinus	durian	—	—	durian, duren	—	durian	durian	thurian
Erythrina poeppigiana	erythrina	mandar	—	dadap, nonfui	faledo	dapdap	dadap	thong laang

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Eucalyptus camaldulensis	river red gum	eucalyptus	—	ekaliptus	masala	—	turpentine	yuukhaalip
Eucalyptus grandis	flooded gum	—	—	—	masala	—	—	yuukhalip
Faidherbia albida	winter thorn	—	African babul	—	—	—	—	—
Gliricidia sepium	gliricidia	—	—	gamal	—	kakawati	gliricidia	khae farang
Gmelina arborea	gmelina	gamar	gambar, melina	gemelina	khamari	yemane	eth demata	soh
Grevillea robusta	silver oak	—	—	salamandar	kangiyo phul	—	sabukku	son india
Hevea brasiliensis	rubber tree	rubber	—	karet	rubber	para rubber	rubber	yaang paaraa
Inga vera	Inga, guaba	—	—	—	—	—	—	—
Leucaena diversifolia	leucaena	—	—	lamtoro	ipil-ipil	—	—	—

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(continued)

Scientific Name	United States	Bangladesh	India	Indonesia	Nepal	Philippines	Sri Lanka	Thailand
Leucaena leucocephala	leucaena	ipil-ipil	subabul	lamtoro gung	ipil-ipil	ipil-ipil	ipil-ipil	kra thin yak
Mangifera indica	mango	aam	kam	mangga	aanp	mangga	amba	mamuang
Melia azedarach	China berry	bokain, ghora neem	bakain, dek	mindi	bakainu	paraiso	lunumidella	lian
Moringa oleifera	horseradish tree	sajna	sainjana	kelor	—	malunggay	murunga	marum
Morus alba	mulberry	tut	shahtut	murbai, besaran	kimbu	—	malbery	mon
Paraserianthes falcataria	falcataria	falcataria	—	sengon, albisia	—	moluccan sau	albizia	—
Parkia speciosa	parkia	—	—	petai, pete	—	—	—	sator
Paulownia tomentosa	paulownia	paulownia	—	—	—	—	—	—

Pinus caribaea	Carribean pine	pine	—	pain	—	—	—	son
Pinus radiata	monterey pine	—	—	pain	—	—	—	son
Pinus roxburghii	chir pine	—	chir pine	pain	khote salla	—	—	son
Pithecellobium dulce	Madras thorn	—	—	asam keranji	—	makam tet	katu andara	makhaam thet
Populus deltoides	black poplar	—	poplar	—	lahare pipal	—	—	poplar
Prosopis cineraria	prosopis	—	—	—	—	—	—	—
Prosopis juliflora	mesquite	—	—	—	—	—	—	—
Psidium guajava	guava	beyara	amrud	jambu biji	amba	bayabas	pera	farang
Pterocarpus indicus	red sandalwood	padauk	—	linggod, sena, angsena	—	Narra	—	pradoo baan

(continued)

Scientific Name	United States	Bangladesh	India	Indonesia	Nepal	Philippines	Sri Lanka	Thailand
Robinia pseudoacacia	black locust	—	false acacia	—	robinia	—	—	—
Sclerocarya birrea	namabu	—	—	—	—	—	—	—
Sesbania grandiflora	sesbania	—	dhaincha, agathi	turi	turi	katurai	kathuru murunga	khae baan
Shorea robusta	sal	gazari	sal	—	sal	—	—	saa la
Tamarindus indica	tamarind	tetul	imli	asam jawa	imali	sampalok	siyambala	makhaam
Tectona grandis	teak	segun	—	jati	sagwan	teak	tekka	sak
Terminalia catappa	terminalia	kat badam	—	ketapan	—	talisai	kottama	huu kwaang
Zizyphus mauritiana	Indian jujube, Chinese date	boroi	ber	bidara, kabuka	—	—	—	phut saa

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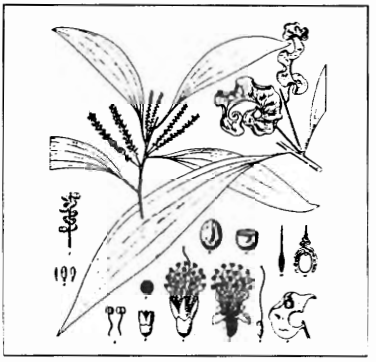
Acacia auriculiformis (wattle)



Origin

Australia and Oceania, including Papua New Guinea.

Ecology

Annual rainfall: 1000-3000 mm.
Normal temperature range: 22-32 °C.
Altitude range: 0 - 700 m.
Seasonal adaptability: 4-6 months dry season.
Soils: Can grow on soils ranging from highly acid to alkaline; from shallow clay soils to deep sandy loams.
Light requirement: Strong.
Other site limitations: Low wind tolerance.

Description

Height at maturity: 15-25 m.
Diameter at breast height (1.3 m) at maturity: 50-60 cm.
Form: Poor; crooked stem, heavy branching.
Coppicing ability: Poor-Fair.
Growth: 15-18 m. in height, 15-20 cm in diameter in 10-12 year rotation.
Other: Fixes nitrogen, produces high levels of nitrogen even on poor soils.

Primary advantages

Good pulp production on highly infertile sites with pH as low as 3.0 or on soils as shallow as 20 cm; also can shade out imperata grass (*Imperata cylindrica*).

Primary disadvantages

Has strong allelopathic effects that limit tree-crop interactions.

Products and Yields

Wood products: Poles, pulp, timber; 12-15 m^3/ha/year on 10-12 year rotation, higher or lower yields depending on rainfall and soil type.

Fuelwood: 4600-4800 kcal/kg, yields of 16 tons/ha/year; branches and leaves are a good source of small diameter fuelwood, yielding 4-6 tons/ha/year.

Fodder: Unpalatable for livestock after first year.

Other: Shade tree, tannin and gums.

Propagation

Planting seedlings is the best method but it is possible to direct seed.

Seed treatment

Some scarification of the seed is needed, hot water scarification is best.

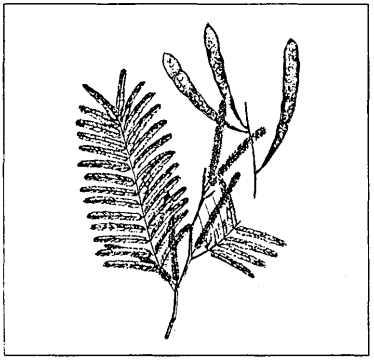
Management

Pruning, coppicing, pollarding. For fuelwood and pulp, usually planted at 2x2 m up to 4x4 m. For better coppicing, cut stumps at 1 m. above ground. Removing lower branches of young plants may improve stem form.

Agroforestry Uses

Limited by the allelopathic effects of prolific leaf litter. Some uses include hedgerows on steep denuded lands. Used as firebreak species in orchards, shades out imperata grass, thus reducing fire danger. Not recommended for growing close to food crops.

Acacia catechu (cutch tree)



Origin

From the southern Himalayas to Andhra Pradesh in India and eastwards to Thailand.

Ecology

Annual rainfall: 500-2000 mm.
Normal temperature range: -1-39 °C.
Altitude range: Upto 1500 m.
Seasonal adaptability: Dry season of 3-4 months.
Soils: Sandy, gravely alluvium, loamy and sandy clay soils. Can grow on poor shallow calcareous soils. Does poorly on clay or poorly drained soils.
Light requirement: Strong light demander.
Other site limitations: Seedlings are intolerant of frost.

Description

Height at maturity: 20 m.
Diameter at breast height (1.3 m) at maturity: upto 60 cm.
Form: Poor, short stem and spreading crown.
Coppicing ability: Good in full light at young age.
Growth: On a good site about 1 m in height, 1 cm in diameter per year for the first 10 years, then slows considerably.
Other: A small or medium-sized deciduous thorny tree, with peeling dark grey bark. Flower clusters

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white to pale yellow, 5-10 cm long, in leaf axils. Leaves bipinnate 15-20 cm long. Thorns in pairs, curved, 8 mm long at the base of each leaf.

Primary advantages

Ready market for products in certain areas.

Primary disadvantages

Slow growth, poor stem quality.

Products and yields

Wood products: Main products are cutch, used for tanning and dyeing, and katha, which is chewed with betel nut. These are extracted from the heartwood by boiling. The strong durable timber is used for house posts, tools, wheels etc., fuelwood and charcoal, hardboard. Yield 1-5 m^3/ha/yr. Yield of heartwood 50-75 m^3/ha at 60 years, yielding 4-6 tonnes of cutch. Wood density 0.8-1.2.

Fuelwood: 6127 kcal/kg.

Fodder: Leaves (13-19% protein).

Other: Medicinal use for the bark to treat diarrhoea, dysentry and wounds, the seeds for antibacterial action. The tree is also a host for lac cultivation.

Propagation

From seed or cuttings. Seedlings are grown in a nursery, transferred to bags and planted out when 30-50 cm tall. Direct seeding possible in moist areas.

Seed treatment

Collect pods as soon as ripe and extract seeds when dry. Viability 6-8 months. Pretreatment: immerse in boiling water, allow to cool for 24 hours, or soak in concentrated sulphuric acid for 20-30 minutes.

Management

Young trees require weeding and protection from fire and grazing. Plant 3-6 month old seedlings at 2x4 or 4x6 m spacing. Trees with girth of 60-120 cm are suitable for harvesting.

Agroforestry uses

Intercropping, field margins, trees-on-farm.

Acacia mangium (mangium)

Origin

Australia and Oceania, including Papua New Guinea.

Ecology

Annual rainfall: 1000-4000 mm.

Normal temperature range: 17.5-31 °C.

Altitude range: 0 to 720 m.

Seasonal adaptability: Poor drought tolerance

Soils: pH from 4.5-8.0, grows well on red-yellow podsols, even if heavily eroded. Can tolerate some waterlogging.

Light requirement: Strong, as it is a pioneer species.

Other site limitations: Performs poorly with less than 1200 mm annual rainfall; does not tolerate strong wind.

Description

Height at maturity: 25-30 m.

Diameter at breast height (1.3 m) at maturity: 40-60 cm.

Form: Good, self pruning, straight bole without knots, especially when grown in plantation.

Coppicing ability: Only in young stems, poor in old trees.

Growth: In a 13-year plantation, can reach 23-25 m height, 27-30 cm diameter at breast height (1.3 m).

Other: Fixes nitrogen.

Primary advantages

Provides timber and other wood products; can quickly suppress imperata grass (*Imperata cylindrica*) on degraded acid soils.

Primary disadvantages

Some damage has been reported in young stands due to pinhole borers; some damage in nursery due to mildew and molds; wood has a high degree of 'spring' in milling test, a potential defect; heart rot can be a problem in older stands.

Products and Yields

Wood products: Timber, pulp, plywood, particle board. Yields range from 14 m^3/ha/year at 4 years to 44 m^3/ha/year at 10 years. Its timber has nice, close grain.

Fuelwood: 4800-4900 kcal/kg, produces high quality charcoal.

Fodder: Generally considered a poor fodder tree.

Other: Shade and ornamental planting.

Propagation

By seed.

Seed Treatment

Pour boiling water over the seed, 1 part seed to 10 parts water. After 30 seconds to 1 minute remove seeds and place in cold water, then soak overnight, remove, and dry.

Management

Commonly planted at 3x3 m spacing. For timber, prune every six months, up to age 2 years, and thin stands at ages 2, 6, and 10 years. To avoid heart rot, harvest at 5-7 years.

Agroforestry Uses

Used in taungya systems. Closes canopy quickly, however, and must be planted at wide spacing (greater than 3x3 m) to allow more than one year of annual inter crop.

Acacia mearnsii (black wattle)

Origin

South and East Australia.

Ecology

Annual rainfall: 400-1600 mm.

Normal temperature range: 2-26 °C.

Altitude range: up to 2500 m.

Seasonal adaptability: 2-3 months dry season and moderate frost resistance.

Soils: Well-drained, moist, valley alluvial, forest podzols, sandy loams of acid to neutral pH and low to moderate fertility. Does not do well on calcareous soils.

Light requirement: Light demander, shade tolerant when older.

Description

Height at maturity: 6-20 m.

Diameter at breast height (1.3 m) at maturity: 40 cm.

Form: Short bole with crooked stem and low branching when open grown, straighter in plantations.

Coppicing ability: Poor.

Growth: On a good site 1 m/year in height and 2.5 cm/year in diameter for first 10 years.

Other: A small to medium-sized evergreen tree with dark fissured bark in older trees. Flower clusters

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pale yellow and globular, 10-20 clusters per stem, in leaf axils or terminal. Leaves feathery bipinnate, 8-15 cm long.

Primary advantages

Nitrogen fixing, fast growth, good fuelwood and tannin source. Suitable for soil protection on poor soils.

Primary disadvantages

Fire sensitive when young, invasive, not windfirm, not suitable for alkaline soils.

Products and yields

Wood products: Fuelwood and charcoal, mine props, poles, low quality pulp. Production 10-25 m^3/ha/yr. Wood density 0.55-0.85.

Fuelwood: 4690-7800 kcal/kg.

Other: Bee forage, ornamental, tannin from bark (35-40% tannin).

Propagation

Seedlings, direct seeding, natural regeneration.

Seed treatment

Store dry, cold and airtight. Pretreatment: mechanical scarification, or immerse in boiling water then allow to cool.

Management

Pollarding on 8-10 year rotation. Coppicing is weak.

Agroforestry uses

Shelterbelts, erosion control on poor soils and steep slopes, homegardens, live fence, intercropping when young, pastoral systems, green manure, shade tree for tea.

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Acacia nilotica (Egyptian thorn)

Origin

Africa and South Asia.

Ecology

Annual rainfall: 600-1200 mm.
Normal temperature range: 9-40 °C.
Altitude range: 15 to 600 m.
Seasonal adaptability: Withstands drought extremely well.
Soils: Prefers alkaline to neutral soils, deep soils, and alluvial loams; grows on heavier clay soils as well.
Light requirement: Requires full sun.

Description

Height at maturity: 10-15 m.
Diameter at breast height (1.3 m) at maturity: 40-60 cm.
Form: Spreading crown, heavy branching and crooked stem. Variety cupressiformis has a narrow crown and broom-like ascending branches.
Coppicing ability: Fair; responds well to pollarding.
Growth: At 20 years, up to 12 m in height, 20 cm diameter.
Other: Fixes nitrogen; thorny.

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Primary advantages

Excellent fuelwood species and good shade tree; grows well on a range of sites from dry to moist; can withstand periodic heavy flooding and saline soils.

Primary disadvantages

Thorns prevent optimum use of foliage for fodder; can become a weed if not managed, particularly under irrigated conditions; susceptible to leaf defoliators, beetles, and damping off.

Products and Yields

Wood products: Small timber, fuelwood; up to 80 m^3/ha in 15 years.

Fuelwood: Caloric value of 4800-4950 kcal/kg; planted in irrigated plantations to provide fuel to power locomotives, boilers, and other industrial uses.

Fodder: Leaves and pods are palatable; thorns are a problem. Pods may contain up to 15% protein.

Other: Tannin production, (bark and pods 12-20% tannin content), good-quality honey; fair-quality edible gum.

Propagation

Commonly direct seeded; young trees must be protected from browsing animals and need weeding.

Seed Treatment

Fresh seeds can be planted directly. Older seeds need hot water treatment. Seeds may also be mixed with fresh cow dung and left in heaps for four to five days.

Management

Pollarding, lopping, or pruning on a regular basis provides fodder to animals and keeps tree size desirable.

Agroforestry Uses

Its open crown and pod production make this very good for livestock grazing systems.

Acacia senegal (gum arabic tree)

Origin
Sahel.

Ecology
Annual rainfall: 100-800 mm.
Normal temperature range: 14-43 °C.
Altitude range: 100-1700 m.
Seasonal adaptability: Dry season of 8-11 months.
Soils: Grows on sandy soils and also clay if no waterlogging. Optimum pH 5-8.
Light requirement: Strong demander.

Description
Height at maturity: 2-13 m.
Form: Poor, short bole and wide spreading crown.
Coppicing ability: Good.
Growth: 0.3 m in height and 1.4 cm in diameter per year.
Other: Small thorny, branchy tree with light grey to light brown scaly bark. Thorns black 3-7 mm long, in triplets and claw-like. Flower clusters cylindrical, 2-10 cm long, at leaf nodes. Leaves bipinnate 2-6 cm long, shorter than flower clusters.

Primary advantages
Highly drought resistant, easy to propagate.

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Primary disadvantages

Susceptible to grazing damage in early years. Can spread rapidly in fallow areas, becoming a weed.

Products and yields

Wood products: Good quality fuelwood. Poles and agricultural tools. Timber yields are about $5m^3/ha/yr$ from natural forest. Where gum is harvested wood yields drop to about $1m^3$ or less in plantations.

Fuelwood: 3200 kcal/kg.

Fodder: Leaves and pods have high protein content. Seeds are also eaten by humans.

Other: The major source of gum arabic. Root fibres are used to make ropes and fish nets. Bee fodder. Suitable for erosion control and soil improvement, especially in desert conditions.

Propagation

Seed, either in plastic pots or by direct seeding.

Seed treatment

Pretreatment: soak in concentrated sulphuric acid for 20-30 minutes or soak in cold water for 48 hours.

Management

Needs protection from grazing, weeds and fire for 2 years.

Agroforestry uses

Intercropping, at wide spacing (10x10 m), live fences and pastoral systems when established.

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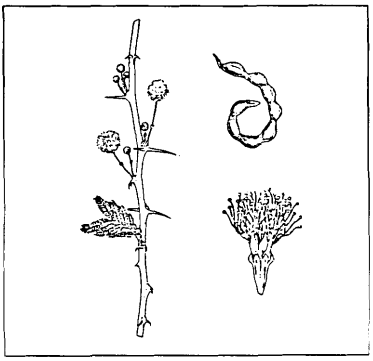
Acacia tortilis (umbrella thorn)



Origin

Sahel, Middle East to Yemen.

Ecology

Annual rainfall: 50-1000 mm.
Normal temperature range: 0-45 °C.
Altitude range: up to 1000 m.
Seasonal adaptability: Dry season 6-9 months, moderately frost resistant after about 2 years old.
Soils: Well-drained eroded sites, sandy loams, lateritic gravel of neutral to alkaline pH. Also grows on shallow and saline soils.
Light requirement: Light demanding.
Other site limitations: Young plants are frost sensitive.

Description

Height at maturity: 4-20 m.
Form: Poor, multistemmed trees are common; crowns spreading.
Coppicing ability: Good.
Growth: 1 m in height and 1.3 cm in diameter per year.
Other: Stem and branches dark brown, bark deeply furrowed and scaly. Has long, white paired thorns 2-10 cm long and also short paired prickles outside leaf axils. Pods 5 mm wide, 8-12 cm long, curved and twisted or spirals. Flower clusters white, cream

or pale yellow, globular, 1-4 at leafbase. Leaves bipinnate, 1.5-3.5 cm , long.

Primary advantages

Drought resistant, multipurpose tree with relatively good growth for arid regions.

Primary disadvantages

Seeds can be attacked by insects. Susceptible to livestock grazing when young. Timber attacked by wood borers. The tree can become a weed.

Products and yields

Wood products: Fuelwood, charcoal, poles, household utensils.

Fuelwood: 4400 kcal/kg. Can yield 54 tonnes/ha in 12 years at 3x3 m.

Fodder: Leaves (15-20% protein), pods (19% protein)/seeds are an important fodder source. Production about 900 kg/ha/yr.

Other: Bee forage, tannin from bark, medicinal use for leaves/bark, soil conservation, dune fixation, ornamental.

Propagation

Mainly from seed, also coppicing, direct seeding, natural regeneration.

Seed treatment

Store at ambient temperature. Pretreatment: dip in hot water then soak overnight, or soak in concentrated sulphuric acid for 20-30 minutes. Digestion by animals also helps germination.

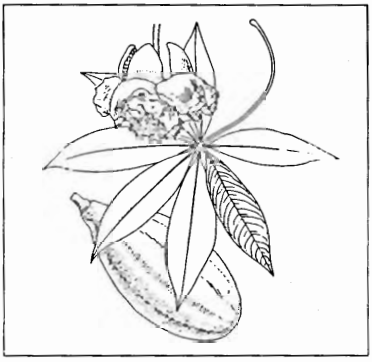
Management

Establishment requires weeding, wide spacing (10x10) on shallow soils and protection from grazing for 3-5 years. Coppicing, lopping and pollarding are used for harvesting. Rotation is 10 years for fuelwood.

Agroforestry uses

Homegardens, pastoral systems, living fences, trees-on-farm.

Adansonia digitata (baobab)



Origin

Africa, south of the Sahara in semi arid to subhumid tropical areas.

Ecology

Annual rainfall: 100-1500 mm.

Normal temperature range: 16-36 °C.

Altitude range: up to 1500 m.

Seasonal adaptability: Tolerates long dry season.

Soils: Grows on a wide variety of soils but prefers deep moist calcareous soils. Tolerates seasonal flooding but not on heavy clay soils.

Light requirement: Light demanding.

Description

Height at maturity: 20 m.

Diameter at breast height (1.3 m) at maturity: 200-600 cm.

Form: Poor, short bole, heavy branching and umbrella shaped crown.

Coppicing ability: Poor.

Growth: 12 m in height in 15 years.

Other: Deciduous tree with smooth silvery grey bark. Branches curve downwards and resemble large roots when leafless. Flowers are pendulous and creamy white, on long stalks, extending up to 1 m

when the fruit develops. The species is dioecious, male and female flowers are roduced on separate trees.

Primary advantages

Drought and fire resistance, and multiple uses.

Primary disadvantages

Not a timber or fuelwood tree.

Products and yields

Wood products: Timber not normally used, but can be made into canoes, trays, fishing floats, utensils and can be chewed to provide drinking water.

Fodder: Leaves are an important source in the early rainy season.

Other: Leaves, flowers, seeds, fruit are edible for humans. Bark of young trees provides fibre and can regenerate. Trunks can be reservoirs of large quantities of water. Multiple medicinal uses from every part of the tree. Roots give a red dye, bark is a source of tannin and fruit pulp is an insect repellant when burnt.

Propagation

From seed sown in bags/pots, stake cuttings, direct sowing.

Seed treatment

Viable for several years if stored under normal conditions. Immerse in boiling water, remove immediately and cool. Digestion by animals also breaks dormancy.

Management

Suitable for individual planting only. No major pests or diseases. Young trees can be damaged by fire or grazing.

Agroforestry uses

Homegardens or pastoral systems.

Albizia lebbek (East Indian walnut)

Origin

South Asia.

Ecology

Annual rainfall: 355-2500 mm.

Normal temperature range: 10-37 °C.

Altitude range: 0 to 1600 m.

Seasonal adaptability: Tolerates 2 to 6 months dry season.

Soils: Grows well on a variety of soils but best where pH is 5.5-7.5. Prefers deep, well-drained soils.

Light requirement: Moderate.

Other site factors: Some problems with wind but strong resistance to frost damage.

Description

Height at maturity: Up to 30 m.

Diameter at breast height (1.3 m) at maturity: 100 cm maximum.

Form: Fair (in rain forest) to poor (in open pasture).

Coppicing ability: Fair to good.

Growth: 1-1.5 m/year in height and 4-6 cm/year in basal diameter.

Other: Fixes nitrogen well.

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Primary advantages

Excellent fodder tree, open canopy allows light through for good grass yields; high yields even in low rainfall areas.

Primary disadvantages

In open areas the stem is too crooked for high timber yields. Animals browse seedlings.

Products and Yields

Wood products: Timber is valued for ornamental work; pulp is suitable for writing and printing papers; fuelwood. In rotations of 10-15 years yields 5 m^3/ha/year. Wood density 0.55-0.60.

Fuelwood: Good quality, 5200 kcal/kg.

Fodder: In best usage, yields 1700 kg/ha/yr from pruning on a three-year rotation. Grass yields can increase by up to 100% under this trees tree in open spacing.

Other: Good flowers for honey production; hosts lac insects, which secrete a resin used in making shellac.

Propagation

By seedlings, stem cuttings, or direct seeding.

Seed Treatment

Does not require scarification. For greater germination, boil for 3 seconds and then allow the water to cool and soak for 24 hours. Remove and dry seeds. Viability of four years is possible at room temperature storage.

Management

Open spacing favors greater grass production, tighter spacing will yield greater digestible foliage. Tolerates both pollarding and lopping.

Agroforestry Uses

Used in intercropping, hedgerows for forage and fuel production, and often in systems combining trees and pasture also used as shade tree in tea, coffee, and cardamom plantations.

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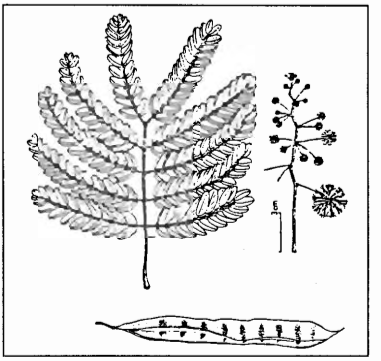
Albizia procera (white siris)



Origin

Australia and Oceania, including Papua New Guinea, Southeast Asia, South Asia.

Ecology

Annual rainfall : 500-300 mm.

Normal temperature range: 21-32 °C.

Altitude range: 0 to 1300 m.

Seasonal adaptability: Tolerates 6-8 months dry season.

Soils: Moderately acid-tolerant to alkaline soils, pH 5.5-7.5; grows well on shallow soils but prefers alluvial soils.

Light requirement: Moderately demanding.

Other site limitations: Easily damaged by frost; branches of mature trees break readily in high wind.

Description

Height at maturity: 25 m.

Diameter at breast height (1.3 m) at maturity: 35 cm.

Form: Good; clear stem but often curved; open canopy.

Coppicing ability: Fair to good.

Growth: On good sites, 12-year-old trees reach 0.9-1.1 m in diameter and 15 m tall.

Other: Fixes nitrogen.

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Primary advantages

Good-quality timber; grows well in shallow stony soils and areas with a long dry season.

Primary disadvantages

Its frost susceptibility limits planting at higher elevations.

Products and Yields

Wood products: Timber. Yields of 10 m^3/ha/year are reported on good sites. Wood quality is good; used for cabinets and veneer.

Fuelwood: Fair quality; 4900-5000 kcal/kg.

Fodder: Leaves provide good forage.

Other: Wood is used as a substitute for walnut and general construction. In Nepal, leaves used as insecticide.

Propagation

Easily by seedlings, cuttings, stumps, root suckers or direct sowing.

Seed Treatment

Place seeds in boiling water, remove water from heat, let cool over night, then dry and store.

Management

Can be heavily lopped or pollarded to provide forage. In open stands, prune to improve stem quality.

Agroforestry Uses

Used in hedgerows, pastures, fuelwood plantings.

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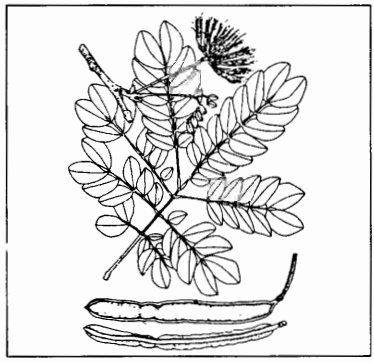
Albizia saman (raintree)



Origin

Central and South America.

Ecology

Annual rainfall: 600-2500 mm.
Normal temperature range: 20-35 °C.
Altitude range: 0 to 1000 m.
Seasonal adaptability: Tolerates 2-4 months dry season.
Soils: Acidic to alkaline, pH 5.5-8.5, clay or sands, can even withstand seasonally waterlogged soils.
Light requirement: High.

Description

Height at maturity: 40 m.
Diameter at breast height (1.3 m) at maturity: 2 m.
Form: Fair (plantations) to poor (in open pasture); large crown.
Coppicing ability: Fair to excellent.
Growth: Can attain a diameter at breast height of 18 cm in 5 years.
Other: Fixes nitrogen.

Primary advantages

Good-quality timber for carving; ideal shade tree, with a high tolerance to a wide variety of sites.

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Primary advantages

Good-quality timber for carving; ideal shade tree, with a high tolerance to a wide variety of sites.

Primary disadvantages

Top heavy and shallow-rooted; spreading crown can occupy a wide area; foliage is sometimes attacked by defoliators.

Products and Yields

Wood products: Timber for carving and furniture is high quality, with production of 10-25 m^3/ha/year under a 10- to 15-year rotation. Wood density is 0.6-0.7. Wood can be carved when green.

Fuelwood: 5200-5600 kcal/kg, high quality charcoal, but wood burns with a lot of smoke even when very dry.

Fodder: Pods contain 12-18% protein, are 40% digestable, and are favored by cows and goats. Leaves are also palatable.

Other: Used to rear lac insect. Tannin, gum, and honey from prolific flowering. Pulpy pods are edible.

Propagation

By seed. Seedlings should be transplanted using containers.

Seed Treatment

Place seeds in hot water for 3 minutes, then soak overnight in cool water.

Management

Can be pollarded, lopped heavily, or coppiced to provide fuel.

Agroforestry Uses

Used as a shade crop for coffee, vanilla, nutmeg, and cacao. Good shade tree in pasture systems and can be grown as a hedge tree if lopped heavily.

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Alnus nepalensis (Indian alder)

Origin

South Asia.

Ecology

Annual rainfall: 800-3700 mm.
Normal temperature range: 0-26 °C.
Altitude range: 100 to 3000 m.
Seasonal adaptability: Tolerates 4-8 months dry season.
Soils: Prefers loamy, deep soils but can grow on sands, clays and gravel soils that are not too dry or compacted. Soils acidic or neutral. Withstands waterlogging for short periods.
Light requirement: Low.
Other site limitations: Wind sensitive.

Description

Height at maturity: 30 m.
Diameter at breast height (1.3 m) at maturity: 80 cm.
Form: Fair to good, but persistent branching.
Coppicing ability: Fair to good; best if cut in rainy season.
Growth: Rain dependent; on a good site, a 9-year-old stand can reach 24.3 m in height; less on drier sites.
Other: Fixes nitrogen.

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Primary advantages

Can grow at high elevations; fixes nitrogen; can stabilize slipping slopes; good for green manure.

Primary disadvantages

Susceptible to defoliators and stem borers. Seedlings susceptible to frost.

Products and Yields

Wood products: Poles and fuelwood in 5 years, small saw timber in 10 years. Boxes, matches, splints, and pulp.

Fuelwood: 4600 kcal/kg; dries rapidly and burns very fast.

Fodder: Leaves provide a low-quality fodder for sheep and goats. Good bedding material.

Other: Sometimes used for tannins and dyes.

Propagation

Containerized seedlings grown from seed. Seedlings planted after 4-5 months in low elevations, 10-11 months in higher elevations. Seedlings can be easily damaged by ants and frost. Fresh seed can be sown directly on bare mineral surface.

Seed Treatment

No pretreatment needed. Seeds can be stored up to one year if dried well and placed in sealed containers. Seeds germinate 1-2 weeks after planting; then transplant into containers.

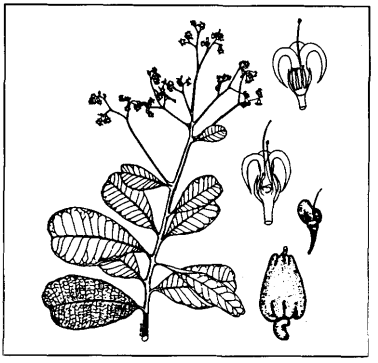
Management

In plantations, spacing of 2.5x2.5 m is common. Pollarded for pole and fuelwood production.

Agroforestry Uses

Intercropped with cardamon, chili peppers, barley, and pumpkin. Used in boundary plantings.

Anacardium occidentalis (cashew)



Origin
South and Central America.

Ecology
Annual rainfall: 500-3500 mm.
Normal temperature range: 22-35 °C.
Altitude range: 0 to 1200 m.
Seasonal adaptability: Good drought tolerance. Sensitive to frost.
Soils: Sandy soils with good drainage, pH of 4.5-6.5.
Light requirement: Strong light demander.

Description
Height at maturity: 12 m.
Form: Short bole, spreading crown, evergreen.

Primary advantages
Produces edible nut marketable as cash crop; can grow in drought-prone locations; suitable for deep sandy soil.

Primary disadvantages
Some diseases, such as Anthracnose, can infest cashew and reduce nut yields considerably. Requires good tap root and deep soil for good growth.

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Products and Yields

Nuts and peduncles: About 45 kg/tree/year; 450-850 kg/ha in plantations.

Wood products: Small timber, fuelwood.

Other: Young shoots may be eaten as a vegetable. Cashew nut shell liquid has many industrial uses from high-temperature paints to clutch pads. Fruits (peduncles) used to make jam, vinegar etc.

Propagation

Usually by seedling. Plant multiple seeds per bag. For better yields, use grafting of improved variety. Pots must be tall enough to allow good tap root development.

Seed Treatment

Select seeds that sink in water or in a sugar-water solution. Seeds of high density produce much better seedlings. Seeds should be scarified.

Management

Plant at 8x8 m spacing; may be thinned later if needed. Weeding is necessary for about 3 years. Remove branches to about 1 m height of trunk for easier management.

Agroforestry Uses

Sometimes used in intercropping systems during establishment phase, for example, with pineapple.

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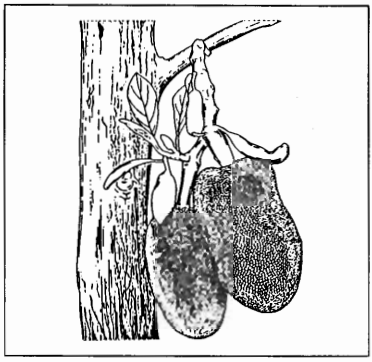
Artocarpus heterophyllus (jackfruit)



Origin
South Asia.

Ecology
Annual rainfall: 1100-2400 mm.
Normal temperature : 16-35 °C.
Altitude range: 0 to 1000 m.
Seasonal adaptability: Can tolerate 3-4 months dry season.
Soils: pH of 5.0-7.5, deep well drained soils, clay-loams, sandy-loams.
Light requirement: Medium.
Other site limitations: Does not withstand flooding.

Description
Height at maturity: 10-25 m.
Diameter at breast height (1.3 m) at maturity: 30-60 cm.
Form: Good, straight bole, but branching begins quickly; fruits borne from trunk and branches.
Coppicing ability: Poor.
Growth: Can reach 5 m height in 5 years.

Primary advantages
Fast-growing fruit tree able to grow in a range of climates. Straight-stemmed variety provides good

timber and does not shade nearby crops. Generally not prone to disease or pest infestation.

Primary disadvantages

Fruit production decreases after 35-40 years. After 40 years, some holes may develop in the trunk, affecting wood quality.

Products and Yields

Fruit: Fruiting starts after about 5 years; earlier for grafted trees. Fruits require several months to mature, yields vary but 8-12 fruits/tree/year is normal for 5-year-old trees. Immature fruits used as vegetable in cooked dishes such as curries.

Wood products: Fuelwood and small timber; 3-5 m^3/ha/yr when grown at a density of 80 stems/ha. Also used to manufacture guitars.

Fuelwood: Good, with wood density of 0.5-0.7 and calorific value of 4600 kcal/kg.

Fodder: Not good, but leaves and fruit rinds usable.

Other: Latex and dye. Dye is produced by boiling the sawdust. In Nepal, the root is used to relieve diarrhea and unripe fruit as a laxative.

Propagation

From seed. Spacing in plantation is usually 8x8 m or greater.

Seed Treatment

Seeds are recalcitrant and cannot be stored long; should be planted when fresh. Store for short periods in airtight plastic bags or in dry sand. Seeds lose viability after 1 month.

Management

Pruning. Rotations are normally 20-30 years, after which fruit production decreases dramatically.

Agroforestry Uses

Intercropping in homegarden systems.

Azadirachta indica (neem)

Origin

South and Southeast Asia.

Ecology

Annual rainfall: 450-1500 mm.

Normal temperature range: 9.5-37 °C.

Altitude range: 0 to 1500 m.

Seasonal adaptability: Excellent; withstands 7-8 dry months dry season.

Soils: pH 5-7, grows well on most soils but does not tolerate seasonally waterlogged soils or deep sands with a deep water table. Does not grow on saline soils.

Light requirement: Medium to high, although prefers partial shade in first growing season.

Other site factors: Can grow with as little as 150 mm. annual rainfall on sites with an accessible water table.

Description

Height at maturity: 15-20 m.

Diameter at breast height (1.3 m) at maturity: Up to 100 cm.

Form: Bole of 2-5 m, canopy rounded or erect.

Coppicing ability: Good.

Growth: Height of 5-11 m in 8 years.

Primary advantages

Durable wood and good fuelwood; uses for all parts of the tree, including organic pesticide; grows on a wide variety of poor sites and arid conditions with significant wood yields.

Primary disadvantages

Seedlings can be damaged by fire; seeds lose viability quickly.

Products and Yields

Wood products: Fuelwood and timber. Eight-year-old trees yield 108-137 m^3/ha, although yields on drier sites may be much lower. Very durable wood.

Fuelwood: Very high quality (wood density of 0.56-0.85), charcoal is excellent.

Fodder: Generally poor, but valued in parts of India.

Other: Leaves used in medicine. Seeds produce insecticide and industrial, non-edible oils. Bark has high tannin content (12-14%). Young shoots of *var. siamensis* eaten as a vegetable.

Propagation

From seedlings, outplant to field at 3-4 months, or 30-50 cm in height. Weed during the first growing season.

Seed Treatment

Remove leathery endocarp, especially for seeds that have been stored. Sow seeds into nursery pots.

Management

Can be planted at 2.5x2.5 m in fuelwood plantations, on a 5-year cutting cycle. Rotations for fuelwood are 8-10 years; for saw timber, 15-30 years.

Agroforestry Uses

Commonly used in windbreaks (4x2 m spacing) and hedgerows, or left as single trees in cropland. Often grown for shade.

Butyrospermum parkii (shea butter tree)

Origin

Southern Sahel.

Ecology

Annual rainfall: 600-1500 mm.
Normal temperature range: 14-35 °C.
Altitude range: up to 1200 m.
Seasonal adaptability: Tolerates a long dry season.
Soils: Dry sandy clay soils with humus, though can tolerate stony and lateritic sites. Does not like wet sites or seasonal flooding.
Light requirement: Light demander.
Other site limitations: Generally grows in open sites in parkland savannas. Requires extensive root system to survive dry season.

Description

Height at maturity: 10-15 m.
Form: Poor, short bole, round crown.
Coppicing ability: Good.
Other: Deciduous tree with thick corky rectangular-fissured bark. Bark, twigs, petioles secrete a white latex when damaged. The leaves are spirally arranged on the end of stout twigs. They are rusty red and hairy when young, dark green and shiny when mature. Flowering occurs Dec-Mar when the

tree is almost leafless. Flowers are green-yellow, in clusters of 30-40 on the branch tips. Fruit are 5-8 cm long by 3-4 cm wide berries, with yellow-green or yellow shiny skin. The seed is covered by a thick butter-like layer.

Primary advantages

Nuts in high demand in Africa.

Primary disadvantages

Needs care in establishment. Yields nuts only after about 15 years.

Products and yields

Wood products: Hard termite-resistant timber, fuelwood and charcoal.

Fodder: Leaves and young sprouts.

Other: The main product is shea butter (an edible oil) from the nuts. The demand is so high that the tree is rarely used for its wood in Africa. Bee forage, dye from wood ash, and medicinal uses for the butter, bark, leaf.

Propagation

From seed sown immediately after harvesting in seedbeds or pots. Seedlings should be out-planted at 14-24 weeks from pots and after 12 months from seedbeds.

Seed treatment

None. Sow immediately after harvesting.

Management

Wide spacing, good site preparation and protection from weeds, fire and grazing are essential. The plant has slow juvinile growth so needs early care.

Agroforestry uses

Pastoral systems, intercropping, tree-on-farm.

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Cajanus cajan (pigeon pea)

Origin
South Asia.

Ecology
Annual rainfall: 400-2500 mm.
Normal temperature range: 15-40 °C.
Altitude range: 0 to 3000 m.
Seasonal adaptability: Excellent drought tolerance.
Soils: Tolerates poor fertility, sandy soils, and low moisture. Does not like saline soils or soils waterlogged for more than 3-4 days.
Light requirement: High.
Other site factors: Poor growth on acidic soils.

Description
Height at maturity: 3-4 m.
Form: Many major forms — dwarf, tall, open, compact, and bushy.
Coppicing ability: Fair to good.
Growth: In perennial crops, 2-10 tons/ha/yr of woody stalks.
Other: Fixes nitrogen well, annual or perennial crop varieties.

Primary advantages

Fast growing in dry climates, produces food and fuelwood.

Primary disadvantages

Susceptible to many pathogens and pests; rarely survives into third year. Seed production decreases over time; some nutritional problems in use as fodder. Difficult to establish in non-agricultural settings.

Products and Yields

Wood products: Low-quality but useful household fuel. Sticks used for weaving baskets in India.

Fuelwood: Low specific gravity and high moisture content. 4600 kcal/kg.

Fodder: Very good. Crude protein is 15-24%. Good dry-season forage. Deficiencies in some amino acids and in foliar factors limit its use as a sole source of animal feed.

Food: Mature split pods widely used as pulse. Green pods may be eaten as a vegetable.

Propagation

Direct seeding is best. Can be stored up to 4 months in humid tropics, longer in drier regions.

Seed Treatment

No treatment is needed.

Management

Plant at high densities if monocropping, 50,000+ seeds/ha. Seeds should be sown on well-prepared fields. Gaps may be filled later with seedlings grown from containers.

Agroforestry Uses

Excellent hedgerow and intercropping species with potential in alley-cropping. May be used in many systems due to its multiple varieties: either as perennial shade tree, annual intercrop, or perennial firewood, vegetable, and seed crop.

Calliandra calothyrsus (calliandra)

Origin
Central America.

Ecology
Annual rainfall: 800-4000 mm.
Normal temperature range: 14-31 °C.
Altitude range: 0 to 1900 m.
Seasonal adaptability: Tolerates 3-6 months dry season. Sensitive to frost.
Soils: pH 5.5-7.5, acid to neutral soils. No waterlogging of soil for longer than 1-2 weeks.
Light requirement: High.
Other site factors: May become a weed due to its vigor.

Description
Height at maturity: 10-12 m.
Diameter at breast height (1.3 m), at maturity: 20-30 cm
Form: Poor; many branches, short stem.
Coppicing ability: Excellent.
Growth: At 2 years old, can attain 2.6-6.0 m in height and 2.6-1.6 cm diameter at breast height.
Other: Life span of 10-12 years. Fixes nitrogen.

Primary advantages

Rapid fuelwood production; fixes nitrogen; easy to propagate. Small diameter makes fuelwood easy to harvest. Shades out imperata grass (*Imperata cylindrica*) with its fast growth.

Primary disadvantages

Stem is too small for timber use; can become a weed.

Products and Yields

Wood products: Fuelwood or pulp, up to 20 m^3/ha/year.

Fuelwood: Excellent (wood density of 0.5-0.8); 4500-4700 kcal/kg for fuelwood and 7200 kcal/kg for charcoal.

Fodder: High protein content but also high in tannins, so digestability is low (35-42%).

Other: High honey yields due to prolific flowering.

Propagation

Seedlings, stumps, or direct seeding. Transplant seedlings at 20-25 cm height. Or allow stumps to grow to 1.0 m (or 4-6 months), then prune roots and top to 25 cm height (shoot of 25 cm, root of 25cm) and plant.

Seed Treatment

Place in boiling water, leave overnight.

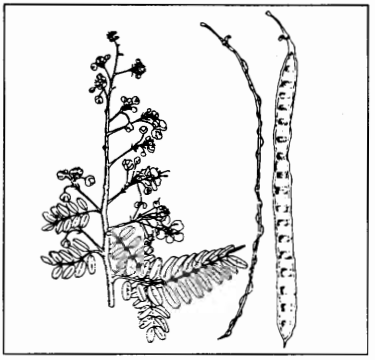
Management

Plant at 1x1 m or 1x2 m spacing for fuelwood. Start cutting in the first or second year. Coppicing is the usual management practice. May need weeding in the first growing season. Useful for direct seeding on steep slopes.

Agroforestry Uses

Used in hedgerows, improved fallow intercropping, fuelwood plantings. Also used in rotational cropping (Calliandra for 4 years, sugar cane for 4 years, maize for 2 years). In areas with heavy grass it can be used in firebreaks to shade out imperata grass.

Cassia siamea (Thailand shower)



Origin
Southeast Asia.

Ecology
Annual rainfall: 500-2800 m.
Normal temperature range: 14-36 °C.
Altitude range: 0 to 1300 m
Seasonal adaptability: 4-8 months dry season.
Soils: pH of 5.5-7.5, likes a deep well drained soil, can grow in laterites or limestone if drainage is good.
Light requirement: High.
Other site limitations: Cannot withstand frost. If grown in dry climates roots need access to ground water.

Description
Height at maturity: 20 m; 5 m in arid conditions.
Diameter at breast height (1.3 m) at maturity: 50 cm.
Form: Spreading crown, bole of 2-3 m.
Coppicing ability: Good.
Growth: 15 m in height and 15 cm diameter at breast height for 10-year-old trees.
Other: Does not fix nitrogen.

Primary advantages
Grows fast and is widely used; good roadside tree and in alley cropping.

Primary disadvantages

Needs weeding for the first one or two growing seasons. Pods, seeds, and leaves toxic to pigs. Does not tolerate frost.

Products and Yields

Wood products: Poles, small timber, fuelwood; wood yields of 10-15 m^3/ha/year.

Fuelwood: Good (wood density of 0.6-0.8), but wood produces much smoke when burning.

Fodder: Leaves and seeds used, but toxic for pigs.

Food: Young leaves and flowers are used in curry.

Other: Honey, tannins.

Propagation

By direct seeding, seedlings, and suckers. Transplant seedlings at 10-12 months.

Seed Treatment

None needed for fresh seeds. Otherwise, place in boiling water, leave in water to cool, then dry seeds.

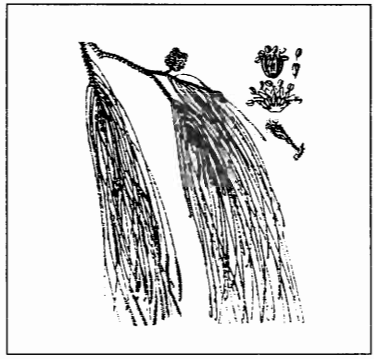
Management

Coppicing, lopping, or pollarding. For shelterbelts, plant at 3x3 m. Fuelwood can be harvested in 6-8 years. Thin multistem coppice growth to one or two shoots for better pole production.

Agroforestry Uses

Intercropping, hedgerows, windbreaks, and shelterbelts. Used to shade cocoa, coffee and tea.

Casuarina equisetifolia (sea oak)



Origin

Australia, Pacific islands and Southeast Asia.

Ecology

Annual rainfall: 200-5000 mm.
Normal temperature range: 7-35 °C.
Altitude range: 0 to 1500 m.
Seasonal adaptability: Tolerates 6-8 months dry season.
Soils: pH 5.0-8.0, does not like clayey soils. Grows on moderately poor soils.
Light requirement: Strong.
Other site limitations: Cannot withstand waterlogging for long periods of time. Grows best in coastal areas.

Description

Height at maturity: 25-35 m.
Diameter at breast height (1.3 m) at maturity: 0.5-1 m.
Form: Poor to fair. Tall trees with variable stem qualities. Good potential to improve form.
Coppicing ability: Poor to fair.
Growth: At 10 years, 20 m in height and 20 cm in dbh.
Other: Fixes nitrogen; inoculation with *Frankia* improves N fixation greatly where no casuarina have grown before.

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Primary advantages

Among the best fuelwood species; wood burns when green; resistant to wind, salt and drought.

Primary disadvantages

Fire-sensitive, not compatible with some crops due to highly competitive nature.

Products and Yields

Wood products: Poles, fuelwood, posts and tools, heavy construction, pulp for writing and printing paper. 6-18 m^3/ha/year until age 20, declining after that. On a 7-10 year rotation yields 75-200 tons/ha.

Fuelwood: Excellent (wood density of 0.8-1.2); calorific value of 5000 kcal/kg; burns when green.

Fodder: poor, but browsed by cattle. Young trees can be damaged by heavy browsing.

Propagation

By seedling; raise seedlings until 5-10 cm in height, then transplant to containers for growing to a height of 30-50 cm before field planting.

Seed Treatment

None needed. Store seed in dry conditions; viability is low.

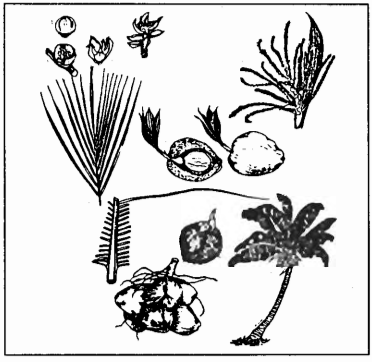
Management

Rotation periods for fuelwood is 7-15 years. Plant plantations at 2x2 m or 3x3 m. As with most other tree species, plant after rains have started; young seedlings need soil moisture.

Agroforestry Uses

Living fences, shelterbelts in windy zones. Will suppress most undergrowth, so it should not be used with annual crops in agroforestry systems. Used as a shade tree for coffee and cardamon in Papua New Guinea.

Cocos nucifera (coconut)



Origin

Southeast Asia and Oceania.

Ecology

Annual rainfall: 600-2500 mm.
Normal temperature range: 16-34 °C.
Altitude range: 0 to 1000 m.
Seasonal adaptability: Tolerates 3 months dry season.
Soils: Deep, well-drained soils, pH 5.0-8.0. Coastal sandy soils.
Light requirement: Medium to high.
Other site limitations: No prolonged waterlogging of soil.

Description

Height at maturity: 20-25 m.
Diameter at breast height (1.3 m) at maturity: 20-40 cm.
Form: Palm.
Coppicing ability: None.
Growth: 20 cm/year after juvenile stage.

Primary advantages

Fruit has a variety of uses; stems may be used for low-quality finishing planks; widely known.

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Primary disadvantages

Slow growth; high labor cost to remove edible portion of the fruit.

Products and Yields

Nuts: 45-120 nuts/tree/year.
Copra: 2.5-3.5 tons/ha/year.
Wood products: Low quality timber; pestles.
Fuelwood: Poor to fair; makes better charcoal.
Other: Beverage, oils, fats; medicinal uses. As medicine for livestock, as a dewormer, and to relieve bloat and constipation. With slow-release fertilizer, husk from old coir makes good lightweight potting medium. Fibre from nut used to make mattresses, door mats. Nut shell used to make handicrafts. Young green stem eaten as a vegetable.

Propagation

By seed. Transplant from nursery at about.5-6 months after the shoot is well established. No need to shade the nursery.

Seed Treatment

Cut a hole in the thick exocarp and mesocarp. Soak in water for 1-2 weeks. Seed viable for up to 2 years.

Management

Irrigation during dry period increases fruit yields. Planting cover crops of nitrogen fixing legumes under the canopy also increases yields.

Agroforestry Uses

Intercropping with yams, cassava, taro, coffee and spices is very common. Interplanting with bananas for the first two years of production or in mixed fruit plantations with mango (*Mangifera indica*), cocoa, rubber (*Hevea brasiliensis*), citrus (*Citrus* spp.), and others. Cattle may be grazed under the canopy in plantations older than 6-8 years, usually 2-3 head of cattle per ha.

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Dalbergia sissoo (rose wood)

Origin

Himalayan foothills of South Asia.

Ecology

Annual rainfall: 500-2000 mm.
Normal temperature range: 9-36 °C.
Altitude range: 0 to 1500 m.
Seasonal adaptability: 4 months.
Soils: pH 5.5-7.5; pure sands to rich alluvial bottomlands. Likes well-drained soils, but can withstand some water-logging. Performs poorly on poorly drained clay soils.
Light requirement: High.
Other site limitations: Fire sensitive.

Description

Height at maturity: 15-30 m.
Diameter at breast height (1.3 m) at maturity: 80-100 cm.
Form: Fair.
Coppicing ability: Very good.
Growth: In 5 years, can attain 9 m height on good sites, 13 cm diameter at breast height.
Other: Fixes nitrogen.

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Primary advantages

Quality timber for carving, furniture; can tolerate a wide range of temperatures.

Primary disadvantages

Trees are browsed heavily by animals. Fire sensitive and can lose vigor after three cuttings. Root suckers can be weedy. Heartwood susceptible to root rot.

Products and Yields

Wood products: Carved items, farm tools, poles, timber, furniture, fuelwood; wood yields of 61-99 m^3/ha/year in a 10-year rotation.

Fuelwood: Excellent (wood density of 0.64-0.7); 4900-5200 kcal/kg. Charcoal is also of good quality.

Fodder: Good quality leaves, pods, and branches; 12-24% protein and 12-26% crude fiber.

Other: Honey and tannins.

Propagation

By cuttings, direct seeding, seedlings, and natural regeneration. Shade is needed in the nursery. Grow stumps 6-12 months in bed; pull up carefully; prune shoot to 5-10 cm and roots to 20 cm length. Plant in container; outplant at site when stem diameter reaches 1-2.5 cm.

Seed Treatment

Break the seed pod into several pieces, each containing 1-2 seeds. Soak pods in room temperature water for at least 24 hours before sowing. Seeds can be stored for 2-4 years in a cold (5°C) room.

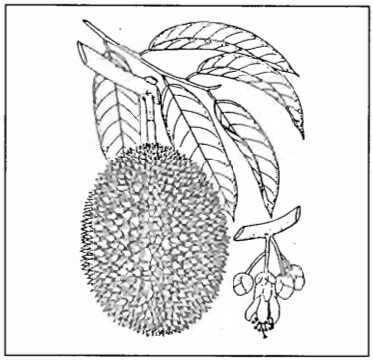
Management

Coppice for fuelwood, lop or pollard for forage. Planting at close spacing yields more fuelwood and better stem quality. Weeding should be done for the first 3 years. Thin regularly for timber production

Agroforestry Uses

Taungya systems, along canals, and irrigated plantations.

Durio zibethinus (durian)



Origin

Southeast Asia.

Ecology

Annual rainfall: 1000-2000 mm.

Normal temperature range: 22-36 °C.

Altitude range: 0 to 800 m.

Seasonal adaptability: Tolerates 3-4 months dry season.

Soils: Moist, light, and high fertility.

Light requirement: Medium, can be shaded when young.

Other site limitations: Cannot tolerate waterlogged soil. Needs constant soil moisture to grow well.

Description

Height at maturity: 25-40 m.

Diameter at breast height (1.3 m) at maturity: 50-120 cm.

Coppicing ability: Poor.

Other: Does not fix nitrogen.

Primary advantages

Fruits are sought after in Southeast Asian countries; easily harvested; branches and fruit rinds provide fuelwood.

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Primary disadvantages

Long time required before first harvest (6-10 years for seed-grown tree; 5-6 years for grafted trees).

Products and Yields

Fruit: Fruit takes about 3 months to mature. Fruit pulp cannot be stored for more than 1-3 days at room temperature. Mature tree yields 50-150 fruits annually (or 70-200 kg/tree).

Wood products: Wood used for furniture and indoor construction.

Fuelwood: Branches and fruit rinds provide fuel.

Fodder: Fruits are said to restore health of some animals.

Propagation

Bud grafting or seedlings. Bud grafting maintains the benefits of improved varieties for better fruit taste and quality, and shortens the juvenile stage.

Seed Treatment

Sow seed fresh, as it loses viability quickly.

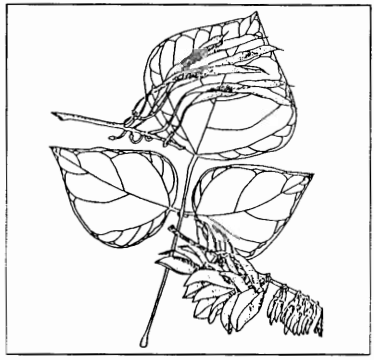
Management

Requires intensive management to control branching, flowering, fruit set, diseases and to maintain soil moisture, for commercial production.

Agroforestry Uses

Can be intercropped with other crops, such as pineapple, langsat (*Aglaia domestica*), mangosteen (*Garcinia mangostana*), and rambutan (*Nephelium lappaceum*).

Erythrina poeppigiana (erythrina)



Origin
Central America.

Ecology
Annual rainfall: 1500-4000 mm.
Normal temperature range: 18-26 °C.
Altitude range: 0 to 1900 m.
Seasonal adaptability: Up to 6 months.
Soils: Light (sand), preferably well drained; tolerates waterlogging.

Description
Height at maturity: 30 m.
Diameter at breast height (1.3 m) at maturity: 50 cm.
Form: Rarely straight; spreading crown.
Coppicing ability: Good.
Other: Fixes nitrogen (12-40 kg/ha/year when planted for coffee shade — 150-300 trees per ha).

Primary advantages
Good for shade and green manure for improved soil fertility.

Primary disadvantages
Poor fuelwood; wood is very light, white to yellow in color; has many thorns.

Products and Yields

Wood products: Tools and utensils; poles; sometimes used for pulpwood.

Fuelwood: Poor, wood density of only 0.25. Thorns limit utilization.

Fodder: Good, leaves are high in protein (25-30%) and digestibility (50-80%). Readily eaten by cattle. Swine can suffer hair loss from eating leaves. Pods may also be dangerous.

Food: Flowers are used in salad or soups.

Other: Honey, medicinal, tannin.

Propagation

By cuttings or seedlings. Plant leafless cuttings 2-3 m long and 8-12 cm in diameter.

Seed Treatment

Seeds may remain viable for several years. Boil seeds for 1 minute and leave in water to cool to room temperature. Further soaking in concentrated sulfuric acid for 15 minutes improves germination.

Management

Pollarding, lopping, or coppicing. Tree can be totally pollarded once or twice a year and branches used for green manure.

Agroforestry Uses

Used as shade crop for species like coffee and cocoa, as well as in living fences, shelterbelts, pasture improvement, and alley cropping with maize, beans, and cassava.

Eucalyptus camaldulensis (river red gum)

Origin

Australia.

Ecology

Annual rainfall: 250-2500 mm.

Normal temperature range: 13-28 °C.

Altitude range: 0 to 2000 m.

Seasonal adaptability: 2 to 8 months.

Soils: Acidic to neutral (pH 4.5-7.0); can withstand some waterlogging, slightly saline soils and infertile sites.

Light requirement: Strong.

Other site limitations: Poor growth on alkaline soils, dry sands, shallow soils. Important to match seed source with site.

Description

Height at maturity: 25-40 m.

Diameter at breast height (1.3 m) at maturity: 60-100 cm.

Form: Straight bole in plantation, narrow crown.

Coppicing ability: Good to excellent.

Growth: 18 m height and 17 cm in diameter at 10 years.

Primary advantages

Fast growth on poor sites with low rainfall if free from initial weed competition; good for fuelwood and poles; resistant to most diseases.

Primary disadvantages

Leaves are not palatable to livestock; grows so fast it is difficult to intercrop with this species; may be attacked by termites in seedling stage; Northern Australian provenances (seed sources) are rather frost-sensitive.

Products and Yields

Wood products: Poles, posts, charcoal, fuelwood, timber, and pulp. Yields of 17-30 m^3/ha/year on fair-good sites.

Fuelwood: Very good; wood density of 0.6-0.7; 4800 kcal/kg.

Fodder: Not palatable.

Other: Honey.

Propagation

By seed or cuttings; seedlings most common. Plant seedlings in the field when they are 3-4 months old.

Seed Treatment

No pretreatment needed. Seeds can be stored for over three years if storage space is cold and dry, and containers are sealed.

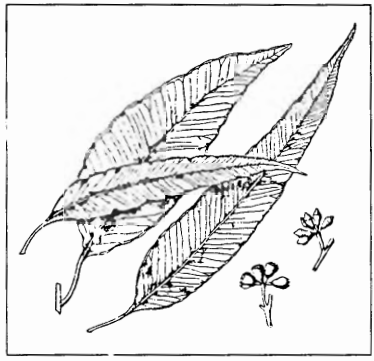
Management

Coppicing and pollarding. Plantations are usually planted at 3x3 m or 4x4 m spacing or wider between rows for intercropping. Weed for first two growing seasons.

Agroforestry Uses

Used in taungya systems, shelterbelts, and windbreaks. Competes with crops very effectively for water, so planting location must be considered.

Eucalyptus grandis (flooded gum)



Origin

Coastal eastern Australia.

Ecology

Annual rainfall: 1000-4000 mm.

Normal temperature range: 5-35°C.

Altitude range: 0-2100 m.

Seasonal adaptability: tolerates 3 month mild dry season and occasional mild frost.

Soils: Deep well-drained soils from loamy to sandy texture.

Light requirement: Strong demander.

Other site limitations: Vulnerable to fire and frost. Sensitive to boron deficiency.

Description

Height at maturity: 45-55 m.

Form: Good, long straight bole.

Coppicing ability: good.

Growth: 2 m in height, 2-3 cm in diameter per year.

Other: Bark is white, grey or green, sheds in strips and is smooth except for lower 1.5 m which is scaly. Leaves are drooping, 10-20 cm long 2-4 cm wide, with slender stalks 12-20 mm long. Flowers in clusters of 5-12.

Primary advantages

High growth rate and yield of timber on suitable sites.

Primary disadvantages

Not fire tolerant. Timber susceptible to splitting.

Products and yields

Wood products: Timber is used for house construction, packing cases, fuelwood, charcoal, pulp, poles etc. The timber has a tendency to split. Production 24-55 m^3/ha/yr. Density 0.5.

Fuelwood: 4700 - 4 800 kcal/kg

Other: Honey.

Propagation

Seed and clonal planting from coppice shoots.

Seed treatment

No treatment necessary, though insecticide/fungicide can be applied.

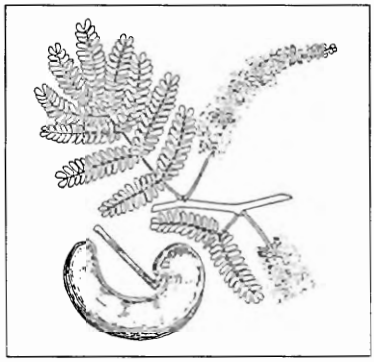
Management

Planted at 2.5-3.5 m spacing. For fuelwood 4-10 year rotations have been used. Response to fertilizers can be good, but depends on site. Response to irrigation has been good on dry sites.

Agroforestry uses

Pastoral systems, intercropping.

Faidherbia albida (winter thorn)



Origin

Tropical and subtropical Africa from Egypt and Senegal to the Cape.

Ecology

Annual rainfall: 100-1800 mm.

Normal temperature range: 6-35 °C.

Altitude range: 0-2000 m.

Seasonal adaptability: Can withstand several years of drought.

Soils: Alluvial or sandy soils, well-drained but with high water table and neutral pH. Can withstand flooding for several weeks.

Light requirement: Light demanding.

Description

Height at maturity: 15-20 m.

Diameter at breast height (1.3 m) at maturity: 100-150 cm.

Form: Poor, short bole.

Coppicing ability: Good.

Growth: 30-90 cm/year in height for five years. Growth is slow until roots reach ground water.

Other: Grey deeply fissured bark. Leaves blue green, shed in rainy season, flush in the dry season. The flowers are cream colored on dense spikes 7-10 cm

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long. Pods 10-15 cm long, orange-reddish brown and twisted. Thorns straight, paired, white with brown tip and wide base. Strong deep tap root.

Primary advantages

Drought resistant, leafless in wet season when crops are growing. Provides fodder in the dry season.

Primary disadvantages

Susceptible to fire when young.

Products and yields

Wood products: Furniture, boats, implements, general light carpentry, but not common for fuelwood.

Fodder: Leaves, pods/seeds have high food value.

Other: Bee forage, fish poison (pods), tannin, gum, medicine from bark for diarrhoea, eye inflamation, bleeding.

Propagation

Coppicing, direct seeding, seedlings, natural regeneration. Does not transplant well because of deep tap root, therefore pots must be tall - at least 30 cm.

Seed treatment

Store dry, air-tight, cold. Pretreatment: many methods reported - hot water treatment for 24-48 hours; soak in 66% sulphuric acid for 4-5 min. then wash in water; soak in concentrated sulphuric acid for 20-30 minutes; scarification; soak in cold water for 24 hours.

Management

Plant 5x5 to 10x10 m depending on rainfall. Weeding necessary. Prune to half tree height in agroforestry systems. Young plants need protection from livestock.

Agroforestry uses

Intercropping, homegardens, pastoral systems, protein bank, living fence. Trees are leafless in the wet season and give shade, foliage and pods in the dry season.

Gliricidia sepium (gliricidia)

Origin

Central America.

Ecology

Annual rainfall: 650-3500 mm.
Normal temperature range: 19-36 °C.
Altitude range: 0 to 1500 m.
Seasonal adaptability: Tolerates 6-7 months dry season.
Soils: pH 4.5-8.0. Pure sand to heavy clay; shallow, rocky, and eroded soils; slightly saline soils.
Light requirement: Medium to high.
Other site limitations: Light frosts cause dieback, but can resprout. Does not tolerate heavy frost or waterlogging.

Description

Height at maturity: 10-12 m.
Diameter at breast height (1.3 m) at maturity: 30-50 cm.
Form: Poor to fair; trunk twists, multistem.
Coppicing ability: Very good.
Growth: Fast.
Other: Fixes nitrogen.

Primary advantages

Can be planted as large cuttings and pruned to maintain living fences; nitrogen fixer and good shade tree.

Primary disadvantages

Leaves, roots, and seeds are toxic to horses; fast decomposition reduces its effectiveness as a mulch for weed control.

Products and Yields

Wood products: Posts, charcoal; yields 10-15 m^3/ha/year.

Fuelwood: Very good (wood density of 0.5-0.6); 4700-4900 kcal/kg for fuelwood.

Fodder: High protein content (18-30%) and highly digestible (48-77%). Mixed feed of 10-30 fresh weight basis in mix of grass, straw or others.

Green manure: High nitrogen content, decomposes quickly. Yields vary from 500-3000 kg/ha (dry weight) per cutting.

Other: Edible flowers, good-quality honey.

Propagation

By cuttings, seedlings, or direct seeding. For cuttings, take a mature, branch, 2-6 cm in diameter, 30-200 cm long. Plant to a depth of 20-50 cm.

Seed Treatment

None for fresh seed. Otherwise soak in tepid water overnight. Inoculate with rhizobium to ensure nodulation.

Management

For living fence, plant in rows at 1-2 m spacing, or 20 cm for a thick hedge. Woodlot rotations are about 5 years, coppicing every 2-4 years.

Agroforestry Uses

Living fences, hedgerows, alleycropping, shelterbelts, and fuelwood plantings. Used to shade coffee and cocoa, and as a support for pepper, yams, and vanilla.

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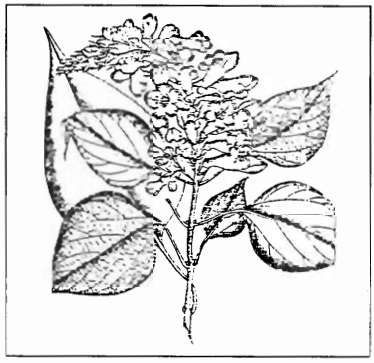
Gmelina arborea (gmelina)



Origin

South and Southeast Asia.

Ecology

Annual rainfall: 750-4000 mm.
Normal temperature range: 9-36 °C.
Altitude range: 0 to 1200 m.
Seasonal adaptability: Up to 6 months.
Soils: Grows best on deep, well-drained, base-rich soils, pH between 5.0-8.0. Poor on thin, highly leached acid soils.
Light requirement: Medium.
Other site limitations: No impenetrable soil layers.

Description

Height at maturity: 30 m.
Diameter at breast height (1.3 m) at maturity: 60 cm.
Form: Fair to good; 6-9 m of branchless, often crooked trunk; large, low-branched crown.
Coppicing ability: Good.
Growth: On a good site, can reach 20 m height in 5 years.
Other: Does not fix nitrogen.

Primary advantages

Good for pulp; fast growth on good sites; well known and easy to propagate; foliage is very palatable to animals; needs very little tending.

Primary disadvantages

Grows too fast for more than 1-2 seasons of intercropping with annual crops; on poor sites, does not grow as well as other species; leaf litter can become a fire hazard; susceptible to some defoliating insects and *Loranthus* species.

Products and Yields

Wood products: Pulp, charcoal, plywood, timber, construction poles. Can yield 18-32 m^3/ha/year.

Fuelwood: Its charcoal is reported to be better than fuelwood. Fuelwood has a wood density of 0.42-0.64 and provides 4800 kcal/kg.

Fodder: Good.

Other: Good-quality honey.

Propagation

Cuttings, direct seeding, seedlings. Sow young seedlings in transplant beds, then move to containers when leaves first show. Transplant to the field when seedlings reach 30 cm tall.

Seed Treatment

Soak seed for one or two days before sowing. Seed remains viable less than one year.

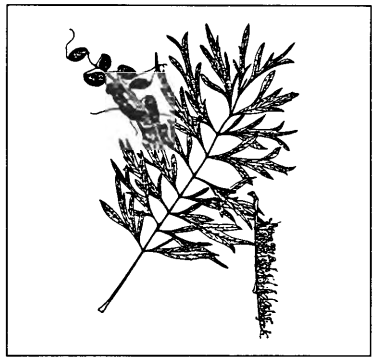
Management

Coppicing is common after clear cutting. Fuelwood plantings are usually cut after 5-10 years; timber cut after 20 years, but needs thinning and pruning to produce quality timber. The rotation for pulp is generally about six years.

Agroforestry Uses

Used in taungya systems with short cropping rotations. Also planted in hedgerows and as a shade tree.

Grevillea robusta (silver oak)



Origin
Australia.

Ecology
Annual rainfall: 500-2500 mm.
Normal temperature range: 13-27 °C.
Altitude range - tropics: 1000 to 2400 m.
Altitude range - subtropics: 0 to 1200 m.
Seasonal adaptability: 6 months dry season maximum, less on shallow soils.
Soils: Deep soils with medium to high fertility important for good long-term growth; pH range from 4.5 - 8.5; does not tolerate waterlogging, heavy clay, or cracking clay soils.
Light requirement: Strong.

Description
Height at maturity: 35+ m on best sites; 20-25 m on average sites.
Diameter at breast height (1.3 m) at maturity: 100 cm.
Form: Good, straight bole without branches if grown at close spacing or pruned, 15 m to crown; crown is rather open.
Coppicing ability: Poor.

Growth: On a good site managed for timber, can reach 19 m height and 80 cm diameter at breast height in 14 years.

Primary advantages

Good timber tree; can grow at high altitudes and in a wide range of climatic conditions.

Primary disadvantages

Can become a weed; sometimes severe growth reduction or dieback after age 20 years.

Products and Yields

Wood products: Timber, pulp, fuelwood, plywood, and flooring. Yields 10-15 m^3/ha/yr.

Fuelwood: Good (wood density of 0.57); makes satisfactory charcoal.

Other: Gum; attractive ornamental; nectar/pollen for honey.

Propagation

Seedlings, either in containers or bare-rooted. Transplant to field when seedlings are 20-40 cm high. Can be grown from cuttings.

Seed Treatment

None needed. Seed life is short, but can last more than two years if dried below 10% moisture content and stored at low humidity and constant temperature (20°C or lower).

Management

Pollarding and pruning. Usually grown in single- or double-row plantings 2-3 m apart. Rotations for poles of 6-10 years; fuelwood yielded from pruning or pollarding every 3-5 years.

Agroforestry Uses

Intercropping, farm boundaries, woodlots. Good shade tree for tea, coffee, and pepper.

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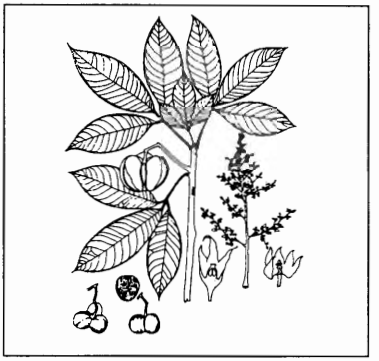
Hevea brasiliensis (rubber)



Origin
Brazil.

Ecology
Annual rainfall: 1200-4000 mm.
Normal temperature range: 23 to 33 °C.
Altitude range: 0 to 1000 m.
Seasonal adaptability: can tolerate 3-4 months dry season, but selected varieties needed to give resonable rubber production in seasonal climates.
Soils: Ranges from clay-loamy soils to clay soils. Acidic to neutral pH is good. Drainage should be good with a deep soil.
Light requirement: Strong.
Other site limitations: Does not grow on shallow soils. Plants propagated by cuttings have low wind resistance.

Description
Height at maturity: 25 m.
Form: normally poor, straight bole is possible with improved varieties.
Coppicing ability: None.
Other: Does not fix nitrogen.

Primary advantages

Yields valuable rubber; when no longer productive, provides wood for fuel and furniture etc.

Primary disadvantages

Rubber tapping labour intensive and must be done at night.

Products and Yields

Rubber latex: Exudes by wounding the stem; yields 1500-1800 kg/ha/yr in plantations.
Wood products: Furniture, fuelwood, pulp.
Fodder: No.
Other: Honey from leaf stalk nectary and flowers.

Propagation

By seedlings, grafting on seedling rootstock, or cuttings (not wind-resistant). Two weeks after seedlings sprout they should be transplanted to containers. After one year, top the seedlings and prune roots to 45-60 cm; then transplant to the field.

Seed Treatment

No pretreatment; very short viability period (about one month). Seeds should be sown laying flat.

Management

For the first few years to ensure good growth. Tapping starts after five to seven years. Planting at 3 m x 8 m is normal, although spacing varies considerably. Wider spacing allows longer intercropping period.

Agroforestry Uses

Good for intercropping with pineapple, beans, and other crops. Cattle grazing under mature crop. Can be a shade crop for coffee and cocoa.

326

Inga vera (inga)

Origin
Caribbean, Central and northern South America.

Ecology
Annual rainfall: 1300-2700 mm.
Normal temperature range: (Humid tropics).
Altitude range: Up to 1000 m.
Seasonal adaptability: Poor.
Soils: Grows on a wide range of soils.

Description
Height at maturity: 20 m.
Diameter at breast height (1.3 m) at maturity: 30-60 cm.
Form: Poor.
Growth: 2.5 in diameter per year.
Other: An evergreen tree with spreading crown and lightly fissured grey-brown bark. The leaves are pinnate, 17-30 cm long, leaflets are stalkless and 5-15 cm long, 2.5-7 cm wide. Flowers are in clusters of 1-4, at the leaf base. They are 6-7.5 cm long and 7.5-9 cm wide. The long thin stamens are white, emerging from a narrow tubular greenish yellow corolla with 5 short lobes.

Primary advantages
Fast growth, workable wood.

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Primary disadvantages

Timber not durable.

Products and yields

Wood products: Fuelwood, charcoal, light carpentry

Other: Honey, fruit. Widely used as shade for plantation crops.

Propagation

Seed.

Seed treatment

Macerate pods and separate seed. Viability is short. No pretreatment reported.

Agroforestry uses

Used extensively as a shade tree for coffee and cocoa.

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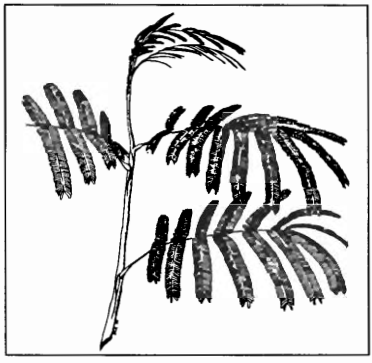
Leucaena diversifolia (leucaena)



Origin
Central America.

Ecology
Annual rainfall: 600 to 2800 mm.
Normal temperature range: 18 to 30 °C.
Altitude range: 500 to 2000 m.
Seasonal adaptability: Not good; no long periods of drought.
Soils: Wetter soils than *Leucaena leucocephala*.
Light requirement: Strong.

Description
Height at maturity: 20 m.
Diameter at breast height (1.3 m) at maturity: 20 cm.
Form: Good, fairly straight bole for several meters is possible.
Coppicing ability: Excellent.
Growth: Fast.
Other: Fixes nitrogen.

Primary advantages
Fast growing for light poles and fuel; grows at higher altitudes and generally with higher rainfall levels than *Leucaena leucocephala*.

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Primary disadvantages

Not as useful at low altitudes; fodder quality not as high as *L. leucocephala*, although lower mimosine content.

Products and Yields

Wood products: Poles, timber, and fuel. Poles are of poor quality.

Fuelwood: Wood density of 0.4-0.5, provides 4,500-4,600 kcal/kg.

Fodder: Can be mixed as feed ingredient.

Propagation

By planted seedlings. New hybrids with *L. leucocephala* have been developed in Taiwan and Hawaii, U.S.A.

Seed Treatment

Soak in hot water for 2-3 minutes, then in room temperature water for 2-3 days. Sow soon after treating.

Management

Coppicing, lopping, pollarding. Rotations of 6 months for small fuelwood to 10 years for poles. Fodder can be harvested after 2-4 months in hedgerow systems.

Agroforestry Uses

Hedgerows, alleycropping, intercropping. Hedgerows produce valuable green manure, fodder, and small fuelwood and increase soil nitrogen. Commonly intercropped with cassava, papaya, and sweet potato.

330

Leucaena leucocephala (leucaena)

Origin
Central America.

Ecology
Annual rainfall: 600-2500 mm.
Normal temperature range: 10-33 °C.
Altitude range: 0 to 1000 m.
Seasonal adaptability: 5-6 months.
Soils: Soil pH of 6.8-9.0. Cannot grow well on acid soils.
Light requirement: Strong.
Other site limitations: Yields decline rapidly at higher elevations; unsuitable above 500 m.

Description
Height at maturity: 10-20 m.
Diameter at breast height (1.3 m) at maturity: 40 cm.
Form: Poor to excellent.
Coppicing ability: Excellent.
Growth: 8 m in height and 5 cm in diameter in 3 years.
Other: Fixes nitrogen.

Primary advantages
Fast growth on good sites; coppices well; wood used for poles, pulp, and fuel; leaves are good fodder supplement.

331

Primary disadvantages

Leucaena psyllid (*Heteropsylla cubana*) is an important defoliating pest, although new varieties offer resistance. Because the foliage contains the toxin mimosine, non-ruminants should consume only 5-10% leucaena in total diet. Can become a weed.

Products and Yields

Wood products: Fuelwood, post, poles, pulp, small timber; typically yields 20-40 m^3/ha/year.

Fuelwood: Good; 4200-4600 kcal/kg, wood density 0.7-0.8. With its fast growth, this makes it a good species for short-rotation fuelwood plantations, though heavy seeding can reduce yields

Fodder: Good feed supplement (25-30% protein), except that it contains mimosine. Ruminant bacteria can be provided to ruminants to detoxify mimosine. High digestibility.

Other: Young shoots and leaves may be eaten, in some countries seeds are also eaten after cooking.

Propagation

Planted seedlings or direct seeding. Seedlings must be weeded. Hedgerows are commonly planted in double rows, starting from seed sown 20 cm apart. New hybrids with *L. diversifolia* developed in Taiwan and Hawaii, U.S.A.

Seed Treatment

Soak in boiling water for 2-3 minutes, then leave in water at room temperature for 2-3 days. Sow soon after treating.

Management

Coppicing, lopping, pollarding. Rotations of 6 months for small fuelwood, up to 10 years for poles. Fodder can be harvested at 2-4 months in hedgerows, lopping at height of 70 cm - 1 m.

Agroforestry Uses

Hedgerows, alleycropping, intercropping. Commonly intercropped with cassava, maize, papaya, and sweet potato.

Mangifera indica (mango)

Origin

South and Southeast Asia.

Ecology

Annual rainfall: 300-2700 mm.
Normal temperature range: 9-36 °C.
Altitude range: 0 to 1600 m.
Seasonal adaptability: tolerates 6-8 months dry season
Soils: Most soils, deep sandy loams-heavy clays; must be well drained.
Light requirement: Strong.

Description

Height at maturity: 15-25 m.
Diameter at breast height (1.3 m) at Maturity: 60-100 cm.
Form: Spreading crown, short bole 2-3 m in height.
Coppicing ability: None.
Other: Does not fix nitrogen.

Primary advantages

Good fruit tree that grows well on poor soils and dry sites; also produces wood and adequate fodder.

Primary disadvantages

Does not fruit well without a pronounced dry season.

333

Products and Yields

Fruit: Five-year-old trees can yield 20 fruits/year; at 10 years, 500 fruits/year; at 15 years, 1,500 fruits/year; at maturity, over 2000 fruits/year. In a plantation, this can mean almost 60 tons/ha/year.

Wood products: Furniture, fuelwood, utensils; plywood, wood density 0.48-0.58.

Fodder: Not good, but young leaves can be eaten by some animals.

Other: Trees are pollinated by bees, so honey production can be good but seasonal.

Propagation

Grafting, seed, shield budding. Grafting from good varieties ensures a high-quality fruit tree with known qualities.

Seed Treatment

Store seed for up to 3 months in charcoal, sealed in a plastic bag at room temperature. Do not cool seeds.

Management

Pruning improves form and removes dead growth and weak shoots. Prune or thin plantations as the trees mature.

Agroforestry Uses

Intercropping systems and homegardens.

334

Melia azedarach (China berry)

Origin
South and Southeast Asia.

Ecology
Annual rainfall: 600-2500 mm.
Normal temperature range: 3-37 °C.
Altitude range: 0 to 2000 m.
Seasonal adaptability: Poor.
Soils: Well drained, fertile, with slight acidity (pH of 5.5-6.5) is best.
Light requirement: Medium to strong.

Description
Height at maturity: 10-25 m.
Diameter at breast height (1.3 m) at maturity: 1-1.5 m.
Form: Fair.
Coppicing ability: Good.
Other: Does not fix nitrogen.

Primary advantages
Good for veneer and plywood.

Primary disadvantages
Short lived and has a brittle crown.

Products and Yields

Wood products: Fuelwood, timber, tools. Yields of 5-10 m^3/ha/year are normal; large diameter trees are often hollow.

Fuelwood: Wood density of 0.45-0.66 and calorific value of 4600-5200 kcal/kg is normal.

Fodder: Generally not used, but goats are sometimes fed the leaves.

Other: Oils and insecticides from the fruit.

Propagation

From seed or cuttings. Transplant at about 1 month of age.

Seed Treatment

Remove seed from fruit and soak in water for a few days to speed germination. Seed remains viable for up to one year.

Management

Manage for fuelwood by coppicing. Short rotations of 10-15 years are recommended.

Agroforestry Uses

Used in boundary plantings and as a shade tree.

336

8

Moringa oleifera (horseradish tree)

Origin
South Asia.

Ecology
Annual rainfall: 750-2500 mm.
Normal temperature range: 9-37 °C.
Altitude range: 0 to 1000 m.
Seasonal adaptability: Good.
Soils: pH 5.5-7.5; can grow on soils with low fertility; best on alluvial soils.

Description
Height at maturity: 12 m.
Form: Small tree, umbrella shaped, light crown.
Coppicing ability: Good.
Other: Does not fix nitrogen.

Primary advantages
Has a number of food, fodder, and fuel uses; grows well on poor, dry soils.

Products and Yields
Fuelwood: Has wood density of 0.32 (air dry) 4600 kcal/kg. Burns very fast.
Fodder: Leaves are used.

337

Food: Young pods are eaten; dried seeds eaten like peanuts; root from seed-grown trees used as horseradish substitute.

Other: Oil from seeds is known in trade as Ben or Behen oil and used locally as an edible oil, illumination, lubrication and cosmetics; bark and leaves reported to be medicinal.

Propagation

Seedlings, cuttings, direct sowing.

Seed Treatment

None required.

Management

Can be coppiced, lopped, pollarded, or pruned for fuelwood.

Agroforestry Uses

Light crown density allows it to be interplanted with many kinds of annual crops.

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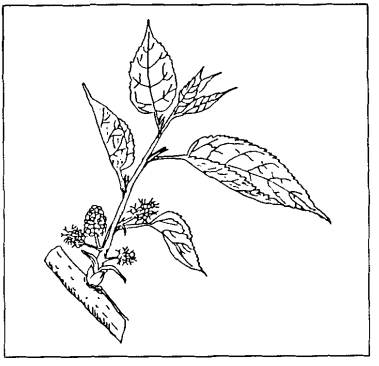
Morus alba (mulberry)



Origin
Asia.

Ecology
Annual rainfall: 600-1400 mm.
Normal temperature range: 8.5-37 °C.
Altitude range: 250 to 2200 m.
Seasonal adaptability: Can withstand 6 dry months.
Soils: Slightly acidic soils are good, soils with pH 5.8 - 6.5 are best. Does not like alkaline soils. Prefers soils deeper than 80 cm, with poor yields on soils shallower than 30 cm.
Light requirement: Strong.

Description
Height at maturity: 12 m.
Form: Short with branching beginning at the base of the tree.
Coppicing ability: Excellent.
Growth: 2 m tall in 3 months from coppice.

Primary advantages
Provides main food source for silkworms; berries for jams and jellies.

Primary disadvantages

Not compatible with many crops. Damaged by browsing animals. Fields need to be manured or fertilized to maintain productivity.

Products and Yields

Timber: Excellent wood for sports industry.

Fodder: For silkworms, rabbits, swine, and cattle.

Food: Berries eaten fresh and cooked as jellies and jams.

Propagation

Cuttings, layering, grafting. Cuttings are the easiest; pick shoots about 4 months old, and select 20 cm of the stem for cutting (3-5 nodes); may be planted in the field after root growth is initiated, about 5,000-9,000/ha. Good rains should be available for growth.

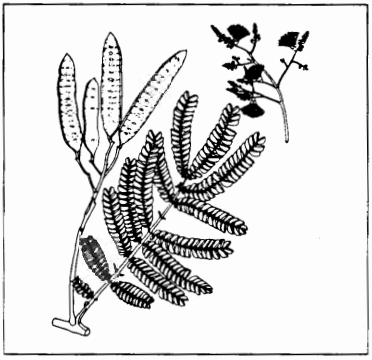
Management

Lopping, pollarding, pruning, or coppicing. May be cut at waist height to allow easy picking of leaves and to maximize yield/ha. 15 kg of leaf is needed to produce 1 kg of silkworm cocoon. Mulch should be plowed into the soil at a depth of 30 cm. Weeding is necessary.

Agroforestry Uses

Limited due to its need for direct sunlight and large area to produce enough leaves for a silkhouse. However, mulberry can be used in hedgerows and windbreaks. Planted as an understorey to irrigated *Dalbergia sissoo* in Pakistan.

Paraserianthes falcataria (falcataria)



Origin

Southeast Asia.

Ecology

Annual rainfall: 2000-4000 mm.
Normal temperature range: 22-38 °C.
Altitude range: 0 to 1600 m.
Seasonal adaptability: Not good; tolerates 0-2 months dry season.
Soils: Mildly acid to alkaline, deep soil is important for good growth. Best is thick topsoil layer with good organic matter content and exchangeable potassium.
Light requirement: Strong.
Other site limitations: Easily damaged by wind.

Description

Height at maturity: 35-45 m.
Diameter at breast height (1.3 m) at maturity: 80 cm.
Form: Fair to good; clear bole but often bent; open canopy.
Coppicing ability: Fair.
Growth: Fast on good sites; 3-6 m/year in height and 5-7 cm in diameter at breast height. In 10 years, can reach 30 meters tall.
Other: Fixes nitrogen.

341

Primary advantages

Pulp yield is very high; grows very fast on good sites; useful for intercropping in plantations and for agroforestry; can coppice and regenerate naturally from seeds after harvest.

Primary disadvantages

Wood quality is poor, wood density is 0.25-0.50; generally not strong or durable. Tree is easily damaged by wind. Wood can be attacked by fungi if exposed. Susceptible to gall rust disease.

Products and Yields

Wood products: Pulp, fuelwood, fiberboard, core veneer. Volume yields of 20-40 m^3/ha/year are possible.

Fuelwood: Charcoal is good quality; wood yields only 2900-3400 kcal/kg.

Fodder: Not used, though seedlings are browsed by cattle.

Other: Leaves used as green manure; also planted to provide shade and in ornamental plantings.

Propagation

Seedlings. Plant at 3-4 months, when 30-35 cm in height.

Seed Treatment

Soak overnight in water. For best results, wrap seeds in cloth, place in boiling water for 20 seconds, then allow seeds to cool before sowing. Germinates after four or five days.

Management

For pulpwood, plant at 3x3 m spacing and coppice on 8-year rotations. Thin to 6x6 m if sawtimber is desired and cut at age six to eight years.

Agroforestry Uses

Used in intercropping and for shade in cocoa, coffee, banana, and tea plantations. Also used in taungya systems.

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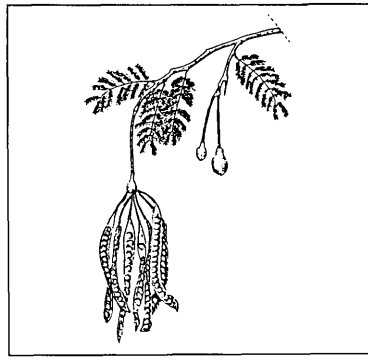
Parkia speciosa (parkia)



Origin
Southeast Asia.

Ecology
Annual rainfall: 1000 to 2000 mm.
Normal temperature range: 24 °C.
Altitude range: 0 to 200 m.
Seasonal adaptability: tolerates 2-3 months dry season.
Soils: Prefers well-drained loam or clay-loam soils.
Light requirement: Medium.
Other site factors: Requires shade during early growth.

Description
Height at maturity: 15-35 m.
Diameter at breast height (1.3 m) at maturity: 50-100 cm.
Coppicing ability: Poor.
Other: Fixes nitrogen.

Primary advantages
In Southeast Asia, the seed is popular for food. Branches are used as fuelwood.

343

Primary disadvantages

Pods may be difficult to harvest; first harvest requires 7-8 years if grown from seed, or 4-6 years if grown from stem cuttings.

Products and Yields

Fruits: Young seeds are eaten raw or cooked. Seeds may also be pickled.

Wood products: Wood of 15-20 year-old trees is good for furniture.

Fuelwood: Branches are used for fuel.

Fodder: Pods can be fed to swine.

Other: Edible seeds.

Propagation

By seedlings, stem cuttings, air-layering and bud grafting.

Seed Treatment

None required.

Management

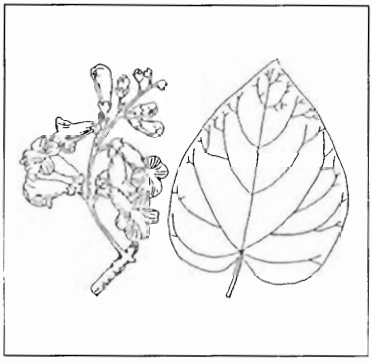
Requires little or no maintenance.

Agroforestry Uses

Can be planted in combination with other fruit crops, including coffee (*Coffea* species), mangosteen (*Garcinia mangostana*), and pineapple.

344

Paulownia tomentosa (paulownia)



Origin

Western Hupeh and Eastern Szechuan in China.

Ecology

Annual rainfall: 500-1500 mm.

Normal temperature range: -5-20 °C.

Altitude range: Above 800-1000 m in warm temperate zones.

Seasonal adaptability: Dry season of 3-9 months.

Soils: Heavy sandy and clayey soils. Prefers deep, loose, moist and well aerated soil. Sensitive to salinity and high water table.

Light requirement: Light demanding.

Description

Height at maturity: 40-50 m.

Diameter at breast height (1.3 m) at maturity: up to 200 cm.

Form: Good, long straight bole.

Coppicing ability: Very strong, growth 5-6 m in first year, but coppice growth is susceptible to disease.

Growth: 1-2 m in height, 2.5-4 cm in diameter per year.

Other: Grey, brown or black, smooth bark, with prominent lenticels when young, gradually developing vertical fissures. Leaves sparse, and crown umbrella-shaped.

345

Primary advantages

Fast growth and valuable timber.

Primary disadvantages

Not tolerant of flooding. Needs moisture during growing season to do well. Sensitive to shading.

Products and yields

Wood products: High value general carpentry and fine timber, but not for strength. Also pulp.

Fuelwood: Timber main crop but pruned branches used for fuel. One 10 year old tree can supply 350-400 kg of branches.

Fodder: Leaves make good fodder for pigs, sheep and rabbits. An 8-10 year old tree can produce 100 kg of fresh leaves per year.

Other: Medicinal uses for leaves, fruit and wood.

Propagation

Seed, and root and stem cuttings of 1-2 year old seedlings or root cuttings of mature trees.

Seed treatment

Gather fruit in autumn when slightly opened. Air-dry in sunlight for 5-7 days, put in sacks and keep in a cool, dry, well-ventilated place. Pretreatment: soak in warm water (40 °C) for 10 minutes, in cold water for 24 hours then dry for 1-2 hours. Keep in a warm place till the radicle begins to emerge, after about 4 days, and sow.

Management

Plant 6x6, 5x5 m or 5x4 and thin out alternate rows after 5-6 years. In strip planting along roadsides etc. plant 4-5 m apart. Needs close management to ensure good growth -- protection from damage, pruning, thinning.

Agroforestry uses

Intercropping widespread in China, at spacings from 5x5 to 5x50 m, with a wide range of summer and autumn crops.

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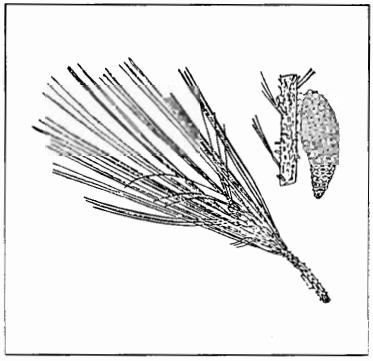
Pinus caribaea (Carribian pine)



Origin

Western Bahamas, Western Cuba, Belize, Guatemala, Honduras, Nicaragua.

Ecology

Annual rainfall: 600-3900 mm.
Normal temperature range: 5-37 °C.
Altitude range: 0-1000 m.
Seasonal adaptability: 2-5 months.
Soils: A wide range, from shallow soils on coral bedrock at pH 8.4 to deep sands, loams, silts, and gravel to acidity of pH 4.
Light requirement: Strong demander.
Other site limitations: No frost.

Description

Height at maturity: 20-30 m.
Diameter at breast height (1.3 m) at maturity: 30-60 cm.
Form: Good, long straight bole, in selected sources.
Coppicing ability: None.
Growth: 0.5-2.3 m in height, 1-5 cm in diameter per year.
Other: Needles 15-25 cm long in bundles of 3 (mainly) crowded on end of branches; shiny, reddish brown

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cones 4-12 cm long and 2.5-4 cm diameter; grey to reddish brown bark, deeply fissured and scaly.

Primary advantages

Fast growth on poor sites, good timber.

Primary disadvantages

Frost tender, acidic leaf litter.

Products and yields

Wood products: General utility timber - construction, furniture, joinery, pulp, particle board, veneer, fuelwood. Production 10-40 m^3/ha/yr. Wood density 0.4-0.55.

Fuelwood: 4200 kcal/kg.

Other: Oleoresin, usually extracted from stumps.

Propagation

Seed.

Seed treatment

Pretreatment: soak in cold water for 24 hours, followed by 2-3 days cold storage at 4-5 °C.

Management

Weed for first year, prune and cull poor trees.

Agroforestry uses

Pastoral systems.

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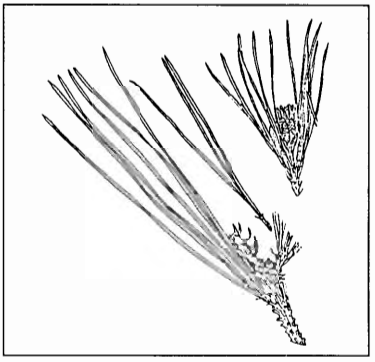
Pinus radiata (Monterey pine)



Origin

Monterey Peninsular, California, USA.

Ecology

Annual rainfall: 650-1500 mm.
Normal temperature range: 2-30 °C.
Altitude range: 1500-3000 m.
Seasonal adaptability: tolerates 2-3 months dry season.
Soils: Free draining, neutral to acid soils of light to medium texture.
Light requirement: Moderate demander.

Description

Height at maturity: 25-35 m.
Form: Moderate.
Coppicing ability: None.
Growth: 2 m in height per year.

Primary advantages

High production of general purpose timber and pulpwood.

Primary disadvantages

Low value timber.

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Products and yields

Wood products: Construction, crates, poles, posts, fuelwood, charcoal, pulp, veneer. Production 12-30 $m^3/ha/yr$.

Fodder: Needles are palatable to sheep.

Propagation

Seed.

Seed treatment

Pretreatment: none or prechill at -2-4 °C.

Management

Weeding, pruning, culling poor trees.

Agroforestry uses

Pastoral systems.

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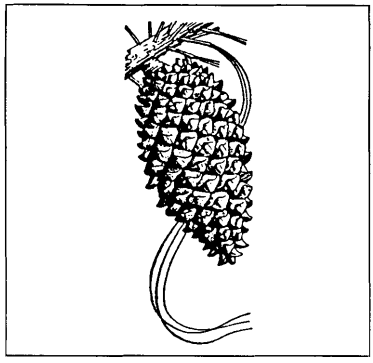
Pinus roxburghii (chir pine)



Origin

Outer Himalayas between 300-2000 m from Afghanistan to Bhutan.

Ecology

Annual rainfall: 750-1750 mm.
Normal temperature range: 4-35 °C.
Altitude range: 450-2500 m.
Seasonal adaptability: 2-4 months dry season.
Soils: Neutral to acid, free draining soils. Can grow on very poor rocky soils.
Light requirement: Strong demander.

Description

Height at maturity: 30 m.
Form: Good.
Coppicing ability: None.
Growth: Upto 0.6 m in height, 1-8 cm in diameter per year.
Other: Needles in threes, 22-30 cm long, light green; bark deeply furrowed, divided into elongated plates.

Primary advantages

Frost resistant, can grow on ver poor soils, produces oleoresin and timber.

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Primary disadvantages

Slow growth, low value timber. Heavy needle fall during summer months increases risk of accidental fire shallow root system results in uprooting of tree growing in open canopy.

Products and yields

Wood products: Light construction, boxes, crates, pulp, posts. Production 7-14 $m^3/ha/yr$.

Fuelwood: 5,500 kcal. Smokes and produces soot

Other: Resin, charcoal from the bark, needles for cattle litter.

Propagation

By seed through nursery-raised seedlings or direct sowing.

Seed treatment

Collect cones March-April, place in hot sun to open the scales and release seeds by threshing. Pretreatment: None needed.

Management

Does not transplant well so direct sowing (1.5x1.5 m) is better for large-scale plantations. Carry out controlled burning of plant litter in winter. The forests regenerate naturally under the uniform system wherever proper seeding felling are carried out. Rotation of 120 years and regeneration period of 30 yrs is followed in India.

Agroforestry uses

Slope stabilization, pastoral systems.

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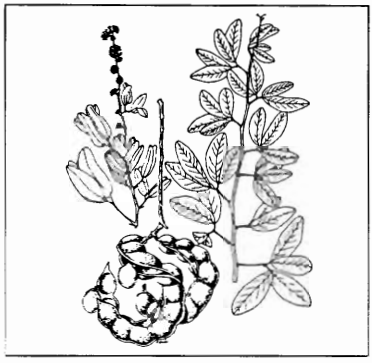
Pithecellobium dulce (Madras thorn)



Origin

North and South America.

Ecology

Annual rainfall: 600-3000 mm.
Normal temperature range: 16-33 °C.
Altitude range: 0 to 1800 m.
Seasonal adaptability: Good dry season tolerance.
Soils: Adaptable to most soil: acidic clays-limestone-sandy soils; grows in waterlogged soils but not well.
Light requirement: Low.
Other site limitations: Does not tolerate strong, constant wind.

Description

Height at maturity: 18 m.
Diameter at breast height (1.3 m) at maturity: 80-100 cm.
Form: Short bole and broad crown, very thorny.
Coppicing ability: Very good.
Growth: Up to 10 m in 5-6 years.
Other: Fixes nitrogen.

Primary advantages

Can endure droughts; tolerates shade and very poor soils; produces good-quality firewood; fruits are eaten fresh or cooked; easily planted from seed; withstands heavy pruning.

Primary disadvantages

May become a weed; bark contains an irritating sap that causes persistent welts on exposed skin; thorns make handling prunings inconvenient.

Products and Yields

Wood products: Firewood, poles, construction.

Fuelwood: Produces smoke; 5200-5600 kcal/kg.

Fodder: Very good from pods. Leaves are browsed by cattle, goats and sheep.

Food: Pods and seeds are eaten raw, in curries, or cooked. The sweet pulp may be turned into an interesting drink.

Propagation

By cuttings or seed. Weed control is not necessary.

Seed Treatment

No pretreatment needed. Seed should be stored in dry, cool conditions. May remain viable for 6 months or more. Seed germinates quickly.

Management

Minimal management needed.

Agroforestry Uses

Road side plantings, living fences, windbreaks. When trimmed, the roots produce many suckers. The thorny stems make an excellent fence. Windbreak in mixtures with other species like *Ziziphus mauritiana* and *Azadirachta indica*.

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Populus deltoides (black poplar)

Origin

The eastern half of the USA, mainly along the plains of Mississipi, Ohio and Missouri rivers.

Ecology

Annual rainfall: 1200-3000 mm.
Normal temperature range: 0-40 °C.
Altitude range: 400-4000 m.
Seasonal adaptability: poor, only tolerates upto 1 month dry season.
Soils: Fertile loams or clay loams.
Light requirement: strong demander.
Other site limitations: Unsuitable for saline or alkaline soils.

Description

Height at maturity: 25 m.
Diameter at breast height (1.3 m) at maturity: 100-130 cm.
Form: Good, long straight bole.
Coppicing ability: Good at young age only.
Growth: 2-3 m in height, 10-12 cm in diameter per year.

Primary advantages

Fast growth on suitable soils; high economic returns.

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Primary disadvantages

Needs good sites for good growth.

Products and yields

Wood products: Sawn timber, crates, chipboard, fibre board. Production 10-40 m^3/ha/yr.

Fuelwood: Waste timber/prunings used as fuelwood. 6,197 kcal/kg.

Fodder: Leaves of some species used.

Propagation

Cuttings from 1-year old cuttings, 1-3 cm diameter, taken in mid January (India). Seed normally used only for tree improvement. The species is dioecious, male and female flowers are formed on separate trees.

Seed treatment

Stored dried to 4-5% moisture content in a sealed container at 10-20 °C remains viable for 3-5 years. Sow in trays on 2:1 mix of wet sterilised soil and river sand. Cover with polythene sheets for 2-3 days till germination starts.

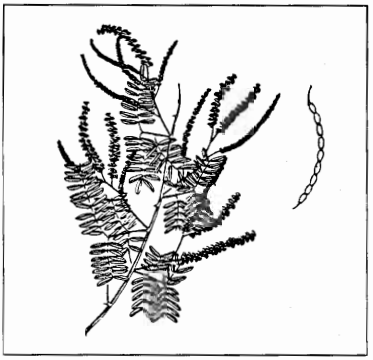
Management

In block planting spacing is 4x3 m, in agroforestry systems 5x4 or 5x5 m to allow machinery to operate. Irrigation needed weekly in first year, every 15-20 days in second year and once a month in subsequent years, during dry periods. Prune lower third of tree starting at 2-3 years old. Debud lower third of stem in first year and remove double leaders.

Agroforestry uses

Intercropping, boundary planting.

Prosopis cineraria (prosopis)



Origin
West Asia.

Ecology
Annual rainfall: 75-850 mm.
Normal temperature range: 4-40 °C.
Altitude range: 15 to 600 m.
Seasonal adaptability: Tolerates 8-10 dry months, and mild frost.
Soils: Neutral to alkaline (up to pH 9.8) soils; coarse-sandy to sandy-loam soils.
Light requirement: Medium to high.

Description
Height at maturity: 10 m.
Diameter at breast height (1.3 m) at maturity: 25-50 cm.
Form: Short, twisted bole.
Coppicing ability: Good in young trees.
Growth: Slow.
Other: Fixes nitrogen.

Primary advantages
Can withstand very hot, arid conditions, moderately alkaline soils; tolerates frost.

Primary disadvantages

Poor initial growth; very thorny and may become a weed if planted in subhumid areas; can be severely damaged by rats, white ants, and defoliators.

Products and Yields

Wood products: Fuelwood, charcoal, poles, small dimension timber. Volume yields of 2.5-2.9 m^3/ha/year are reported.

Fuelwood: Excellent; wood density 0.7-0.9; 5000 kcal/kg. Charcoal is of the highest quality.

Fodder: Leaves and pods are good fodder for goats and camels, but the branches are thorny.

Other: Fruits and gums.

Propagation

From seedlings, root suckers, or direct seeding in moist soils. Plant at the start of the rainy season.

Seed Treatment

Soak seed for 24 hours in warm water, or 48 hours in tepid water before planting.

Management

Coopice for fuelwood; lop for fodder.

Agroforestry Uses

Its deep root systems does not compete with ground crops for moisture. This makes it an excellent tree for intercropping. Also used in fuelwood plantings and in livestock grazing systems.

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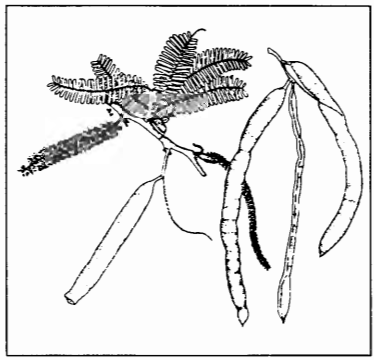
Prosopis juliflora (mesquite)



Origin

Central and South America.

Ecology

Annual rainfall: 70-800 mm.
Normal temperature range: 14-37 °C.
Altitude range: 0 - 1500 m.
Seasonal adaptability: Tolerates 6-8 months dry season.
Soils: Sandy to rocky soils; neutral-alkaline pH.
Other site factors: Complete mortality at -3 °C. Some seedlots can grow in 3.2% seawater.
Light requirement: Strong.

Description

Height at maturity: 15 m.
Diameter at breast height (1.3m) at maturity: 80-100 cm.
Form: Short, thorny, twisted trunk.
Coppicing ability: Very good.
Growth: Can grow 10 m in 12 years; growth declines sharply after age 10.
Other: Fixes nitrogen.

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Primary advantages

Grows fast; good fuelwood; withstands severe cutting and browsing when mature; wood is very durable.

Primary disadvantages

May become a weed; not fire-resistant when young; thornless varieties can be produced only by vegetative propagation. Does not tolerate frost or waterlogging.

Products and Yields

Wood products: Poles, small timber. On a 10-year rotation, can yield 50-60 tons/ha of wood. Its orange/brown color, low shrinkage, and hardness make it a high-quality timber for furniture.

Fuelwood: Excellent, wood density 0.7, 4800 kcal/kg.

Fodder: Leaves and pods. Other: Honey is high quality.

Propagation

By seedlings, root cuttings, grafting, and direct seeding. For cuttings, use stumps of one-year-old seedlings, prune all side roots, plant soon after sprouts appear and new root growth starts.

Seed Treatment

Scarify seed, then place in boiling water, remove seed immediately from heat source and soak for 24 hours.

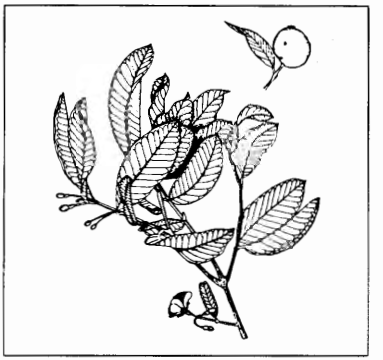
Management

Commonly coppiced on a 3- to 10-year rotation. Reduce weediness by selecting, thinning, and pruning for large trees (30-50 cm in diameter) at wider spacing (10 m). When thinning, 30% of the canopy should be pruned. Coppice growth should be thinned to the one stem with the best form.

Agroforestry Uses

Can withstand heavy browsing in pasture systems. *Panicum maximum* is one of the best understory grass species for a tree-and-livestock system with older trees.

Psidium guajava (guava)



Origin
Central and South America.

Ecology
Annual rainfall: 700-3700 mm.
Annual temperature: 9-33 °C.
Altitude range: 0-200 m.
Seasonal adaptability: Less than six months.
Soils: Prefers acidic soils.
Other site limitations: Susceptible to frost.

Description
Height at maturity: 10 m.
Form: Short or no bole, spreading crown.
Coppicing ability: Good.
Growth: At 20 years, up to 12 m in height 20 cm diameter.
Other: Does not fix nitrogen.

Primary advantages
Bears fruit at 2 years, continues to produce fruit until 30 years old. Tolerates a wide range of soil conditions.

Primary disadvantages
May become a weed.

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Products and Yields

Fruits: Typical yields are 400-500 fruits/tree/year for a 8-10-year-old tree propagated from seed. Grafted trees may yield 1000-1200 fruits at that age.

Fuelwood: Yes.

Other: Leaves used to treat diarrhea.

Propagation

Seedlings, grafted stock, or root suckers. Grafting can be by approach grafting or bud. Transplant seedlings when they are 30cm in height, normally after 5-7 months.

Seed Treatment

Seeds may remain viable for up to 1 year.

Management

Plant at about 6x6 m. Prune to remove suckers and shape the tree.

Agroforestry Uses

Used in homegardens, intercropping, and roadsides.

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Pterocarpus indicus (red sandalwood)

Origin
Southeast Asia to Solomon Islands.

Ecology
Annual rainfall: 1500 mm.
Normal temperature range: 18-33 °C.
Altitude range: 0-100 m.
Seasonal adaptability: tolerates 3-4 months dry season.
Soils: Well-drained loamy soil, neutral pH is best, but tolerates sandy to clay soils.
Light requirement: light demander.

Description
Height at maturity: 33 m.
Diameter at breast height (1.3 m) at maturity: 200 cm.
Form: variable.
Coppicing ability: good.
Growth: 0.5-2 m in height, 1-4 cm in diameter per year.
Other: Trunks fluted and buttressed, bears fragrant yellow flowers. Nitrogen fixing.

Primary advantages
Easy to establish in a wide range of soils. Valuable timber.

Primary disadvantages
Little experience in plantations. Can be invasive.

Products and yields

Wood products: High value furniture timber, poles/posts, fuelwood, charcoal
Fuelwood: 4880 kcal/kg
Other: ornamental planting.

Propagation

Seed or cuttings up to 3 m long by 10 cm diameter.

Seed treatment

Pretreatment: non or soak in hot water for 24 hours.

Robinia pseudoacacia (black locust)

Origin
North America.

Ecology
Annual rainfall: 400-2100 mm.
Normal temperature range: -20-27.5 °C.
Altitude range: 0 to 2200 m.
Seasonal adaptability: tolerates 2-6 months dry season; very frost hardy.
Soils: Most soils (pH of 4.5-8.2) but does not grow well on compacted, waterlogged, or very shallow soils.
Light requirement: High when young.

Description
Height at maturity: 25-30 m.
Diameter at breast height (1.3 m) at maturity: 90 cm.
Form: Fair-good, open canopy; fairly straight bole when grown in plantation.
Coppicing ability: Good.
Growth: At 10 years, can reach 8.2 m height and 8 cm diameter.
Other: Fixes nitrogen.

Primary advantages

Can grow in very cold areas; durable wood; tolerates a wide range of soils; fixes nitrogen; can reclaim degraded slopes.

Primary disadvantages

Subject to attack by stem borers; can become a weed.

Products and Yields

Wood products: Poles, timber, flooring, fuelwood.
Fuelwood: Very good; specific gravity of 0.7-0.8.
Fodder: Leaves.
Other: Very good honey.

Propagation

By seedlings or direct seeding. Direct seeding is very common on slopes.

Seed Treatment

Scarify seeds or pour boiling water (five times the volume of the seeds) over them.

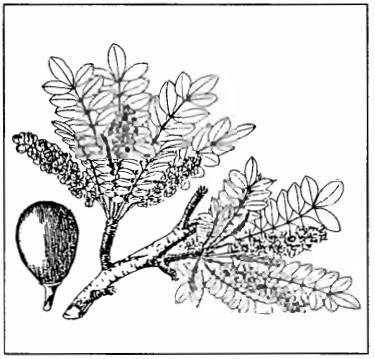
Management

Coppicing, lopping, or pruning. Volume growth stops after about 30 years.

Agroforestry Uses

Rapid growth of root suckers limits the use of this species in tree-crop combinations.

Sclerocarya birrea (namabu)



Origin

Sahel and open savanna from Senegal to East Africa.

Ecology

Annual rainfall: 250+ mm.
Normal temperature range: 11-38 °C.
Altitude range: 0-50 m.
Seasonal adaptability: tolerates long dry season.
Soils: Occurs on sandy, stony or lateritic soil, of acidic to neutral pH. Can tolerate seasonal waterlogging and moderate salinity.
Light requirement: Light demander.

Description

Height at maturity: 15 m.
Form: Poor, short bole.
Coppicing ability: good.
Other: Deciduous tree, flowering before leaves appear. Leaves are pinnate, 15-30 cm long in bunches on the end of the twigs. Male flowers in 5-8 cm long spikes and yellow, female flowers 2-3 together with purple red sepals and green petals. Fruit is orange with shiny skin over a fibrous, juicy flesh covering a stone. Stem bark reddish grey, branches silvery grey and scaly.

Primary advantages

Grows on poor soils, tolerates waterlogging and long dry season.

Primary disadvantages

Young timber of poor quality and limited use.

Products and yields

Wood products: Soft, light wood used for mortars, pestles, bowls, furniture, fuelwood, posts. Splits easily on drying.

Fodder: Leaves are used for fodder, though slightly poisonous.

Other: Fruit and seed edible. Fibre from bark. Medicinal uses for bark, leaves and roots

Propagation

Seed, cuttings or root suckers.

Seed treatment

Soak in water overnight before sowing.

Management

Copice or pollard.

Agroforestry uses

Pastoral systems.

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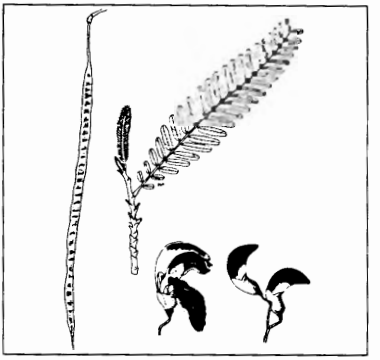
Sesbania grandiflora (sesbania)



Origin

South and Southeast Asia.

Ecology

Annual rainfall: 1000-2600 mm.

Normal temperature range: 17-32 °C.

Altitude range: 0 to 800 m.

Seasonal adaptability: can tolerate only 2-3 months dry season; sensitive to frost.

Soils: Grows well on most soils, even heavy clays; pH 5.5-8.5.

Other site factors: Grows well on sites that experience flooding and waterlogging, such as bunds in paddy fields.

Description

Height at maturity: 10-15 m.

Diameter at breast height (1.3 m) at maturity: 25 cm, maximum.

Form: Good.

Coppicing ability: Poor to good.

Growth: 8 m in height in 3 years with average diameter over 10 cm.

Other: Fixes nitrogen, even in waterlogged soils.

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Primary advantages

Excellent green manure and fodder; grows quickly on a variety of sites; edible flowers and leaves.

Primary disadvantages

Poor quality fuelwood; wood density is low; some susceptibility to insects; coppices poorly in general; does not withstand severe pruning.

Products and Yields

Wood products: Pulp and fuelwood yields of 20-25 m^3/ha/yearr. Wood density is low (432 kg/m^3)

Fuelwood: Poor.

Fodder: Good, leaves and pods.

Other: Gums, tannins.

Propagation

Cuttings, direct seeding, planted seedlings.

Seed Treatment

None needed; rhizobia inoculation improves nitrogen fixation ability. Seeds do not store well after 1-2 years.

Management

For pulpwood, usually grown in three- or four-year rotation; longer for living fences or other uses. Tree should be cropped continually if used as forage for cattle. For fodder, prune lightly at a height of 1.5 meters or higher.

Agroforestry Uses

Excellent green manure and fodder species; good for light shade, hedgerows, living fences. Also used in windbreaks and shelterbelts.

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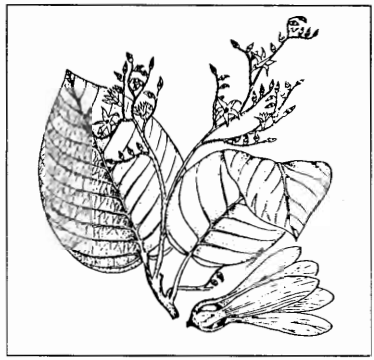
Shorea robusta (sal)



Origin

Bangladesh, India, Nepal.

Ecology

Annual rainfall: under 1000-4600 mm.

Normal temperature range: 1-47 °C.

Altitude range: 100-1100 m.

Seasonal adaptability: Tolerates dry season of 3-4 months.

Soils: Well-drained sandy or clay alluvial soils. Tolerant of alkaline, saline soils and waterlogged soils.

Light requirement: Light demander, but can tolerate light shade.

Other site limitations: Seedlings intolerant of fire, frost and susceptible to insects, fungal and parasitic damage.

Description

Height at maturity: 35 m.

Diameter at breast height (1.3 m) at maturity: 100 cm.

Form: Good, long clear bole.

Coppicing ability: Good.

Growth: 20 m in height, 30 cm in diameter in 30 years.

Other: Bark is thick, dark brown, with deep longitudinal fissures. Leaves 12-25 cm by 10-15 cm.

Flowers are in panicles at leaf base or twig tip. Individual flowers are 2-3 cm wide, with 5 pale yellow pointed petals.

Primary advantages

Good durable timber, produces marketable resin

Primary disadvantages

Does not tolerate arid conditions.

Products and yields

Wood products: Timber for strength and durability: beams, electricity poles, railway sleepers etc. Yield 2.5-3.0 m^3/ha/yr.

Fuelwood: 5400 kcal/kg.

Fodder: Shoot, leaf give medium quality fodder; seeds also edible.

Other: Oleoresin from tapping the trunk, is used for incense, as a fumigant, mixing with industrial waxes, in paints and varnishes, caulking boats, plywood glue, medicine. The oleoresin yields "chua" oil on distillation; oil from the seeds is used for cooking, lighting and making soap; tannin from the bark.

Propagation

Seed, by natural regeneration, direct sowing or nursery-raised; also from seedling stumps.

Seed treatment

Collect in middle of fruiting period and sow immediately as viability is rapidly lost.

Management

Seedlings need protection from fire and frost.

Agroforestry uses

Intercropping. Successful plantations of Shorea robusta have been raised in several states in India through Taungya system under which agricultural crops are raised with the trees for the first 4 to 5
1 years.

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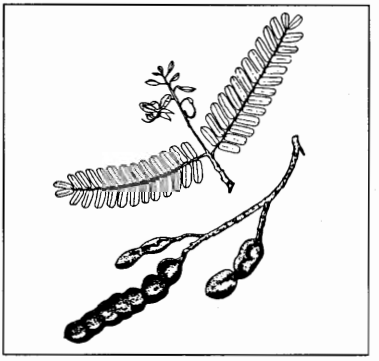
Tamarindus indica (tamarind)



Origin

Eastern tropical Africa.

Ecology

Annual rainfall: 250-2700 mm.

Normal temperature range: 9-37 °C.

Altitude range: 0 to 1500 m.

Seasonal adaptability: Good, tolerates 6-8 months dry season.

Soils: Variety of well-drained soils, acidic or alkaline; does not like heavy clay or very acidic or waterlogged soils.

Description

Height at maturity: 20-25 m.

Diameter at breast height (1.3 m) at maturity: 50-70 cm.

Form: Fair to poor; branching starts about 2-3 m on trunk.

Coppicing ability: Fair to good.

Primary advantages

Fruit is marketed worldwide in sauces, syrups, and processed foods. Improved fruit varieties are available, especially in Thailand. Grows on a wide range of sites and in semi-arid conditions.

Primary disadvantages

Slow growth, fruit can be damaged by insects or browsing animals.

Products and Yields

Fruits: Up to 10-50 kg per tree. Quality depends on the variety and on insect damage.

Wood products: Small timber, excellent charcoal.

Fuelwood: Used for charcoal and fuelwood in some locations.

Fodder: Leaves and young pods are good fodder.

Other: Young leaves, shoots and flowers are sometimes curried or eaten raw. Leaves are used as medicine for livestock, for coughs and colds.

Propagation

Commonly by seed, but improved varieties must be grafted.

Seed Treatment

Pour boiling water over seeds and let cool, or nick seeds with a knife (scarification).

Management

Improved fruit varieties are often grown as single trees. Orchards have been established in Thailand.

Agroforestry Uses

Excellent shade and avenue tree. Common as single tree in cropped fields or home gardens. Also planted as a windbreak.

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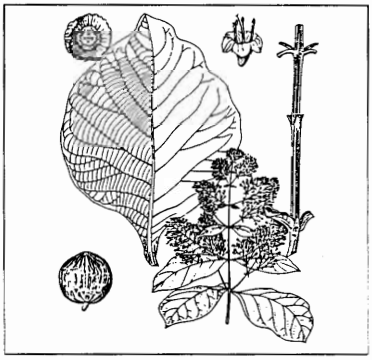
Tectona grandis (teak)



Origin

South and Southeast Asia.

Ecology

Annual rainfall: 1250-3000 mm.
Normal temperature range: 10-40 °C.
Altitude range: 30 to 900 m .
Seasonal adaptability: tolerates 3-4 months dry season.
Soils: Light sandy-loam, well-drained soils, not shallow; pH of 6.5-7.5.
Light requirement: Strong.

Description

Height at maturity: 40 m.
Diameter at breast height (1.3 m) at maturity: More than 2 m.
Form: Good.
Coppicing ability: Good in young trees.
Growth: 10-year-old stand can reach 25 m height.
Other: Fast height growth in young stands.

Primary advantages

High-quality timber; Well understood management systems.

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Primary disadvantages

In pure stands of this species, health and vigor decline rapidly between ages 10-20; epicormic branching is common and insect damage (stem borer) increases. Good quality seed in short supply. Few uses apart from timber.

Products and Yields

Wood products: Timber, poles. Mean annual increment growth of 8-14 on young stands with 3-5 being common in older stands. Heartwood is resistant to rot, decay, and termites.

Fodder: Poor, not commonly used.

Propagation

By seedling stumps, seedlings, direct seeding, cuttings, tissue culture. Remove stumps from the seedbed at the age of 1 year; they can be stored for up to 6-8 months in dry sand with protection from the weather. Survival rate of stumps after storage is usually over 90%.

Seed Treatment

Several methods are used: alternative soaking and drying, removal of the exocarp, air drying, and in China treating with hot sand. Seed can be stored for 1-2 years in dry conditions.

Management

Coppicing and pruning. Frequent thinnings prolong the health and vigor of plantations.

Agroforestry Uses

Used in taungya and other intercropping systems, but only in first two years of growth. If grown at wide initial spacing, good stem quality is lost.

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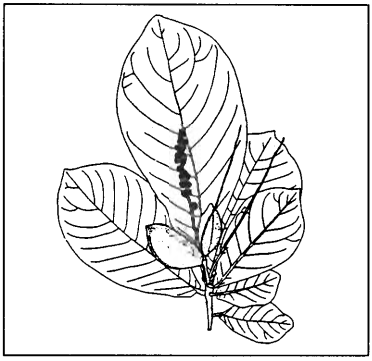
Terminalia catappa (terminalia)



Origin
Southeast Asia.

Ecology
Annual rainfall (mm): 750 to 2000 mm.
Normal temperature range: 20-35 °C.
Altitude range: 0 to 300 m.
Seasonal adaptability: Drought resistant.
Soils: Light sandy or rocky saline soils.
Other site factors: Wind resistant and tolerant to salt spray.

Description
Height at maturity: 25 m.
Diameter at breast height (1.3 m) at maturity: 30 cm.
Form: Medium tree, horizontally whorled branching. Bole is often short and crooked.
Growth: 2 m/year for young trees.

Primary advantages
Can withstand saline sandy soils, and salt spray; good shade tree.

Primary disadvantages
Heavy branching, short bole.

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Products and Yields

Wood products: Firewood, pulp, small timber for boat and house construction etc.; plywood; railway sleepers; yields of 22-36 tons/ha at 10-years.

Fuelwood: Wood density of 0.59; also used for charcoal.

Other: Fruits may be eaten roasted or even raw. A popular ornamental and shade tree. Tannin and dye (black) from bark, leaves, fruit, roots. Medicinal uses. Seed oil is a substitute for almond oil.

Propagation

By seedling, planted when 20-25 cm tall. Seedlings can tolerate shade, so weeding is not needed.

Seed Treatment

None needed; if seed is extracted from the fruit, germination is fast and uniform. Fruit may be planted whole but germination period varies up to 2-3 months.

Management

For fuelwood, commonly managed on a 10-15 year rotation.

Agroforestry Uses

Homegardens, as shade tree, soil stabilization..

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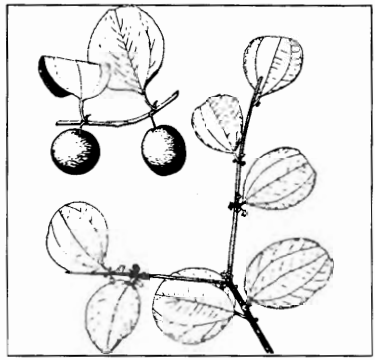
Ziziphus mauritiana (Indian jujube)



Origin
South Asia.

Ecology
Annual rainfall: 250-2000 mm.
Normal temperature range: 9.5-37 °C.
Altitude range: 0 to 600 m.
Seasonal adaptability: Excellent dry season tolerance.
Soils: Most soils, tolerates alkaline soils.
Light requirement: High.
Other Site factors: Can withstand light frost and high temperatures.

Description
Height at maturity: 5 m.
Diameter at breast height (1.3 m) at maturity: 30 cm.
Form: Short tree, spreading crown; branching starts about 1-2 m up trunk.
Coppicing ability: Good.
Growth: Slow initially, but satisfactory once established.
Other: Spiny foliage.

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Primary advantages

Fast growth in low-rainfall areas; multiple uses; fruit is consumed widely throughout the tropics. Excellent fodder and forage.

Disadvantages

Can become a weed; spiny foliage limits some uses; fruit quality is variable. May be damaged by browsing animals when young.

Products and Yields

Wood products: Tool handles, other small timber uses for hard, close-grained wood.

Fuelwood: Good; wood density greater than 0.60, reported up to 0.90.

Fodder: Excellent; leaves sold as fodder in parts of India.

Other: Leaves can host the lac insect, which secretes a resin used in making shellac, and the tasar silkworm.

Propagation

Usually by seedlings. Can be direct seeded. Improved fruit varieties must be grafted.

Seed Treatment

Seeds are usually cracked before sowing.

Management

Coppicing, lopping, pruning, or pollarding. Must be managed to keep root suckers from spreading into pastures and other areas.

Agroforestry Uses

Its thorny nature makes it very useful as a living fence; also in homegardens and border plantings.

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Institutional Background

The **Forestry/Fuelwood Research and Development Project (F/FRED)**, funded by the **U.S. Agency for International Development (USAID)**, is designed to help scientists address the needs of small-scale farmers in the developing world for fuelwood and other tree products. As an outcome of collaborative meetings in the region, a ***Multipurpose Tree Species Research Network*** was established through which scientists exchange research plans, methods, and results. Research and development activities center on the production and use of multipurpose trees that meet the household and market needs of small farmers.

F/FRED is being executed by the **Winrock International Institute for Agricultural Development**. Winrock is a private, nonprofit U.S. organization working in agricultural development around the world. It was established in 1985 through the merging of the Agricultural Development Council (A/D/C), the International Agricultural Development Service (IADS), and the Winrock International Livestock Research and Training Center. Winrock's mission is to improve agriculture for the benefit of people, help increase agricultural productivity, improve nutrition, and advance the well-being of people throughout the world. Winrock's main areas of emphasis are human resources, renewable resources, food policy, farming systems, and agricultural research and extension.

Growing Multipurpose Trees on Small Farms

Module 1:
Selecting Multipurpose Trees

Module 2:
Nurseries and Propagation

Module 3:
Mulitpurpose Trees in Agroforestry

Module 4:
Small Plantations of Multipurpose Trees

Module 5:
Tending Multipurpose Trees

Module 6:
Harvesting Crops of Multipurpose Trees

Module 7:
Selling Tree Crops

Module 8:
Principles of Effective Extension

Module 9:
Species Fact Sheets

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