Agroforestry for the Pacific Technologies

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Intercropping Coconuts With Nitrogen Fixing Tress

The open and well-lit lands under coconut plantations are commonly intercropped with coffee, cacao, and various annual crop combinations-or used for cattle pasture. All coconut (*Cocos nucifera*) intercropping practices take advantage of the extra resources available during the different coconut tree growth stages, substantially increasing the overall productivity of the land under this long-duration crop (Liyanage et al. 1984). Intercropping, like grazing livestock undercoconut, is a traditional practice historically adopted by farm families to increase and diversify farm cash and food production.

Successful intercropping increases returns from coconut plantations. A study in Western Samoa compared the profitability of a coconut monocrop with several intercropping possibilities. Results indicate that in all cases, intercropping more than doubles the returns from coconut (Opio 1986). Often intercropping actually increases coconuts yields. Experiments conducted at the Coconut Research Institute of Sri Lanka demonstrate that intercropping with clove, black pepper, cacao, cinnamon, coffee, and a variety of annuals, increases coconut yields (Liyanage 1984). The likely explanation is that the palms benefit from cultural treatments applied to the intercrops-such as fertilization, weeding and tillage. A cultivated understorey also makes for easier collection of fallen coconuts.

Coconut intercropping and pasture practices that include nitrogen fixing trees are gaining attention as sustainable and productive land-use adaptations. Nitrogen fixing trees add rich organic matter to the often nutrient-poor soils of coconut plantations. At the same time, they provide additional farm products such as fuelwood and fodder. Tree leaf mulch-or "green manure"-builds soil structure and sustains soil fertility in farming systems that include perennial crops such coconut. This is especially important on atolls and in costal areas where nutrient-poor coralbased soils predominate.

The fuelwood produced by these trees can be used by smallholders instead of coconut leaves and husks which can then be returned to the soil. Nitrogen fixing trees also produce nutritious protein-rich fodder that supplements pasture feed, reducing grazing pressure

during periods when pastures are especially susceptible to degradation.

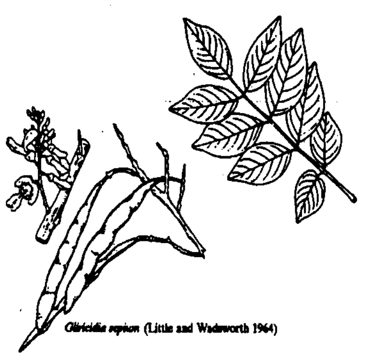
Selecting the Right Tree Species

Tree species must be selected according to soil and climate conditions, understorey shade intensity, land and labor availability, use/product requirements, and marketing possibilities.

- Choose trees that yield locally marketable or useful subsistence products such as fuelwood, fodder, or medicine.
- Choose trees that re-sprout vigorously after repeated pruning or lopping. These trees yield more green manure, fodder, and fuelwood.
- Choose trees that are shade-tolerant. The degree of tolerance required depends on the age and spacing of the coconut trees.
- Choose trees that are adapted to local site conditions such as annual rainfall amount and frequency, soil pH, and soil texture/drainage.

Research and field experience to date illustrates that *Leucaena leucocephala* and *Gliricidia sepium* both perform well in the coconut understorey-yielding useful fodder, fuelwood, and green manure.

Gliricidia sepium continues to yield copious amounts of succulent, high-protein leaf material after repeated lopping. It is moderately shade tolerant and performs well in acid soils where *Leucaena* does not.



Gliricidia sepium (Little and Wadsworth 1964)

Gliricidia is especially suited for introduction into pastures because large cuttings (up to 5 cm in diameter and 2 m in length) can be established rapidly, with little effort. Such cuttings are almost immediately able to withstand browsing by livestock and competition from surrounding pasture plants.

Leucaena leucocephala does not tolerate dense shade but it grows well in most coconut understorey situations (Reynolds 1988). It prefers well-drained alluvial and coralline soils and will not tolerate waterlogging. Common *Leucaena* is losing favor because it is susceptible to the defoliating psyllid insect pest. It also performs poorly in acid soils. Breeding efforts to develop superior, psyllid resistance varieties and interspecific hybrids have produced some promising results.

Prepared by K.R. Dalla Rosa, Program Director for the Pacific, NFTA

L. leucocephala (Vergara 1982)

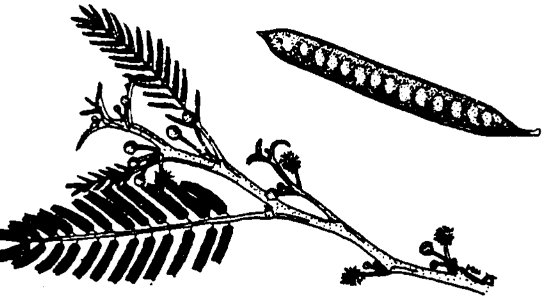
Leucaena diversifolia and *Flemingia macrophylla*, though not yet tested or used to any extent in coconut plantations, would probably also perform well.

Flemingia does not produce as much woody biomass (fuelwood) or as digestible a fodder as *Leucaena* or *Gliricidia.* Where low soil moisture and periodic drought limit coconut production, however, this tree can produce large amounts of water-conserving, soil-enriching mulch.

Flemingia leaves take a relatively long time to decompose. Piled around coconut trees they form a thick layer of rich organic mulch. This layer of mulch prevents weed germination, retains soil moisture, and slowly releases nutrients such as N, P, and K-right on top of the coconut root zone.

Flemingia macrophylla

Leucaena diversifolia is a promising alternative to *L. leucocephala* in certain environments. It is more drought sensitive than its relative, but it shows more psyllid resistance and its leaves contain about half the mimosine content of *L. leucocephala* (Mimosine is a toxic amino acid that can adversely affect the health of some livestock if eaten in large quantities) *L. diversifolia* tolerates partial shade and is especially well adapted to cooler, wetter conditions and higher elevations. It does not appear to tolerate excessively saline or sodic soils so its use in the Pacific is limited to larger islands or interiors. A well known hybrid between tetraploid *L. diversifolia* and *L. leucocephala* has potential.



Leucaena diversifolia (Dr. Diane Ragone 1964)

Nitrogen Fixing Tree Establishment and Management

Spacing and Arrangement Experienced farmers in humid areas recommend planting trees at least 2 m from any coconut palm In dryer areas, trees should be limited to the central meter of any alley between two rows of coconuts. This way, if coconuts are spaced 9 meters apart-as is recommended in drier areas-there will be close to 4 m between a nitrogen fixing tree and any coconut. This is assuming that coconuts are in a triangular arrangement as is recommended by most. Researchers agree that the triangular coconut arrangement makes more efficient use of available resources such as sunlight.

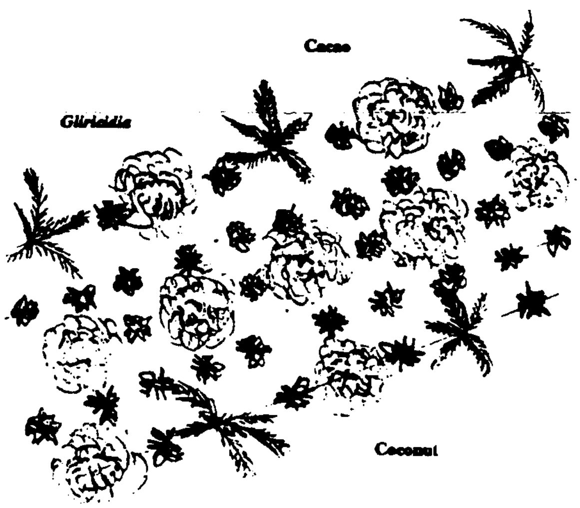
Where soil water is more limiting, opportunities to intercrop nitrogen fixing trees with coconut will be fewer. In the extreme case, it may be best to limit intercrops to shallow-rooted annuals or pastures. However, if there is enough water to grow a healthy coconut crop, nitrogen fixing trees can probably also be included. It is reasonable to assume that if annual rainfall exceeds 1900 mm, competition for water will not be a problem (Plucknett 1974; Liyanage 1984).

Degree of competition for both soil water and nutrients depends upon a number of natural and human-made factors including the water requirements of the different plants. All coconuts require a lot of water to grow and produce. *Leucaena, Gliricidia,* and *Flemingia* do not. They can, however, take up and transpire a lot of water if it is available. In doing so, they can draw the water table down until it is out of reach of the shallower coconut tree roots. Nitrogen fixing tree water consumption may be controlled to a degree with regular harvests of fuelwood, fodder and green manure. A regularly pruned tree win transpire much less than one with a continuously full canopy.

The following examples of well-tested practices illustrate important tree establishment and management considerations. They illustrate that nitrogen fixing trees can provide a wide array of products and services when included in coconut intercropping or pasture systems.

***Casuarina oligodon,* coffee and food crops.** According to Vergara and Nair (1985), farmers in the highlands of Papua New Guinea have been practicing this system since about 1960. It is one of the most promising in the Pacific region. The locally popular annual and perennial food crops, arabica coffee, and *Casuarina oligodon* are all included. Casuarina produces timber for fencing, house construction, and fuelwood. The ground is shaded continuously by a sequence of fast and slow growing species, so there is little need for weeding.

Coconut, cacao and *Gliricidia sepium.* In this system, *Gliricidia* provides shade to cacao plants and also yields fuelwood and fodder. The nitrogen fixing trees are especially useful in newly established plantations, where young coconuts do not provide adequate shade for cacao. Usually, trees are established with cuttings at spacings of 3 x 3 to 6 x 6 m. When the *Gliricidia* trees offer some shade, cacao can be planted in the understorey-typically at 2 x 2 m. The *Gliricidia* trees are periodically pruned to 2 or 3 meters to maintain a uniform canopy and provide mulch and fuelwood.



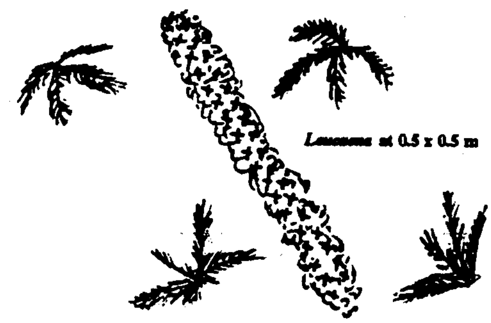
Schematic of coconut cacao and *Gliricidia sepium* arrangement

Coconut, *Gliricidia* sepium and cattle. The use of *Gliricidia sepium* trees in coconut plantations is of ancient origin (Liyanage 1987). Experimental results from Sri Lanka demonstrate that *Gliricidia,* when intercropped with coconut, controls weeds, improves soil structure through leaf fall, increases copra yields and provides fodder and fuelwood.

Schematic of coconut, *Gliricidia* fodder/green manure system

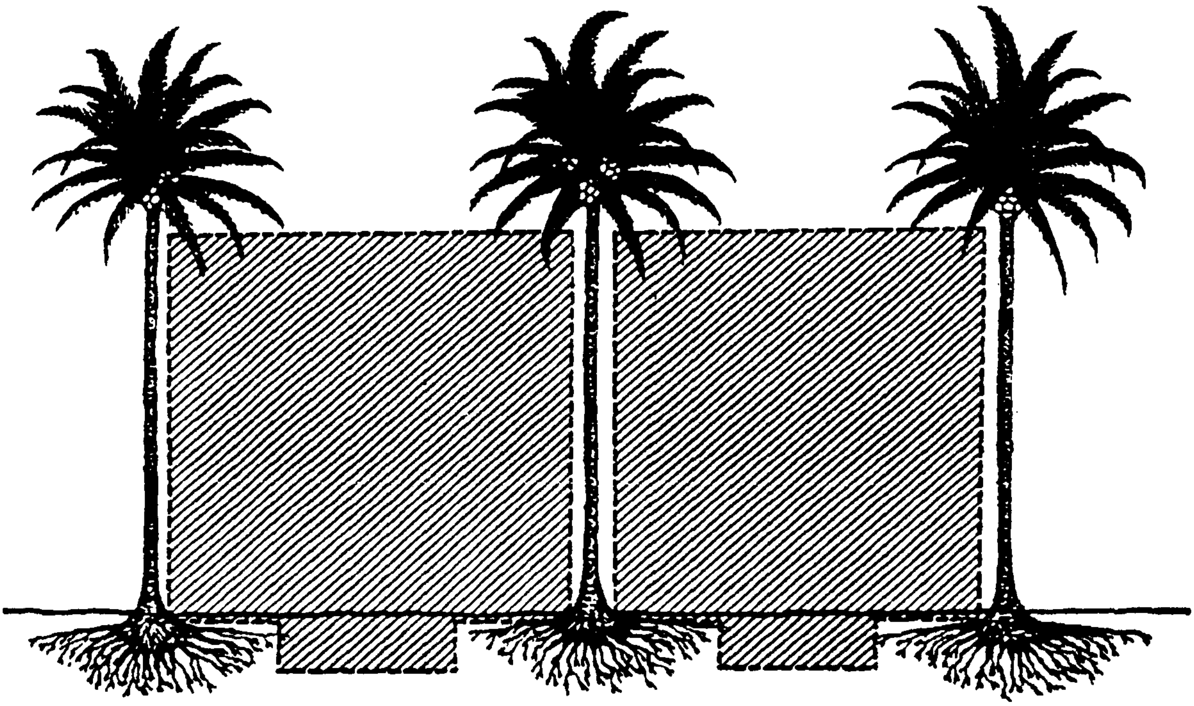
Experimental systems were established in mature coconut plantations in both wet and dry climates. Gliricidia cuttings 1.5 cm long and 2.5 cm in diameter were planted at 2.0 x 0.9 m in double rows in the coconut alleys. Cuttings were lopped one year after planting to 1 m and thereafter every six months. Loppings were dug into circular trenches around coconuts or fed as "cut and carry" fodder to cattle. Digging the leaves into trenches around the coconuts produced significant copra weight increases. A 50%/50% ration of Gliricidia leaves and Cori grass *(Brachiaria miliformis)* produced an average daily live weight gain of 700 g when fed to cattle.

Coconut, *Leucaena leucocephala* and pasture. *Leucaena* is sometimes planted into grass pasture under coconuts to provide supplemental browse.



Schematic of coconut, *Leucaena leucocephala* and pasture

The trees are commonly planted densely (0.5 m) in double rows. This arrangement keeps a good distance between the coconut and *Leucaena* root systems. This is necessary because *Leucaena* roots can be aggressively competitive, especially during dry periods. The *Leucaena* provides high-protein browse to supplement the typically lower-quality tropical grasses. It produces well even in stoloniferous grass pastures where it is difficult to maintain other legumes (Reynolds 1988). It produces best when grazed rotationally to allow recovery after all leaves have been removed.



Schematic representation of available intercropping area in coconut stand (Reynolds 1988)

Research Needs

Research is needed to test the performance of different nitrogen fixing trees as intercrops under coconut. Of particular interest would be a study of how repeated pruning affects the water uptake and root spread on nitrogen fixing trees in the coconut understorey. In addition, studies of different spacings/arrangements and resulting competitive or complementary interactions would be useful.

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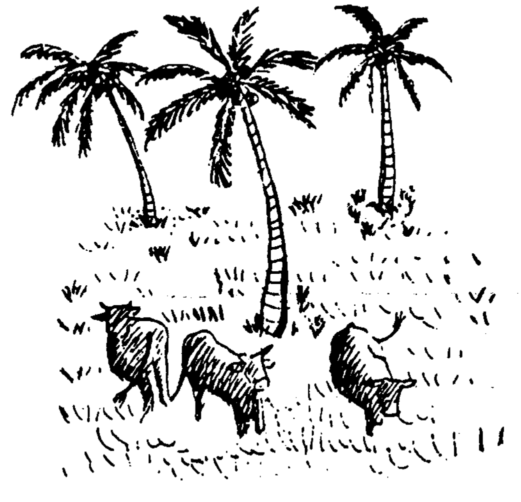
Cattle Under Coconuts : A Pratical Pacific Tradition

Coconuts (*Cocos nucifera*) are the most widely grown perennial crop in the Pacific. Unfortunately, an erratic world copra price and the rising cost of mechanized cultivation have together led to the neglect and poor condition of millions of hectares of land under coconut throughout the region. Large areas of senile plantations are not being replanted primarily because farmers can no longer justify their investment of scarce labor and capital given the risk and uncertainty they now attach to the industry.

Work to address this problem has centered on the breeding of hybrids that can out-yield local "talls" by 3 to 4 times (Opio 1987). The availability of these productive hybrids will surely increase the economic viability of many coconut farms. If farmers continue to focus their efforts only on increasing coconut yield, however, they will remain dependent on a single primary export product subject to an unpredictable international market. Many coconut farmers can increase the profitability of their operations while reducing risks, by adopting or improving upon a common traditional coconut farming practice.



The Coconut Understorey

Traditional methods of increasing the productivity of coconut plantations all consist of alternative uses for the coconut understorey. Coconut trees are fairly long-lived (60 to 80 years), tall and widely spaced. The land beneath the coconuts receives a good amount of sunlight throughout most the plantation's life. Pacific islanders have always used this resource to produce both subsistence and cash crops.

Today's large coconut producers-the primary market suppliers-attempt to simply produce the greatest number of coconuts at the lowest cost possible. Of all the problems faced by these large market suppliers, controlling weeds is by far the most difficult and expensive (Plucknett 1974).

All coconut farmers must deal with the problem of how to manage the land beneath the coconuts. If left untended, the understorey is taken over by shrub and grass weeds, which compete aggressively for limited soil water and nutrients. When weeds takeover, coconut yields decline drastically.

Traditionally, coconut producers used cattle as "sweepers" or "brushers", to keep grass and weeds short-and thus prevent nutrient and moisture competition (Reynolds 1988). The animal protein, manure and income derived from the animals, were considered extra bonuses (Vergara and Nair 1985). Few farmers have managed coconuts and cattle together in an attempt to optimize the productivity of the system as a whole.

Opio (1987) reports that, given world copra prices, income from local "tall" plantations declines rapidly after year 35 and, by year 40, will no longer generate a profit. The opportunity cost of keeping older coconuts outweighs the benefit unless the land underneath is intercropped with short-term cash crops or intergrazed with cattle.

All over the Pacific, cattle graze in the understorey of coconuts. Given the large percentage of land area involved, there is a huge need and potential for the development and improvement of this relatively unexplored traditional technology. The objective of the "cattle-under-coconut" agroforestry strategy should not simply be to reduce coconut management inputs-or to replace nut production with livestock products. The objective should be to optimize the productivity and stability of the whole system. Pacific coconut farmers would benefit tremendously from the development of practices that most successfully integrate pasture, coconut and cattle production.

Pasture Establishment and Management

The establishment and maintenance of an good herbaceous ground cover in the coconut understorey can provide livestock feed, while also preventing the invasion of non-nutritious, yet aggressively competitive weeds.

A healthy ground cover can also reduce soil erosion and increase rainwater infiltration and storage-and thus the supply of water to the entire system. It is true that pasture plants usually deplete soil moisture for a period shortly after their establishment. Average soil moisture

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content then actually tends to rise above previous levels because of reduced runoff and greater infiltration (Plucknett 1974). Leguminous plants offer an additional bonus-they fix atmospheric nitrogen, adding it to the system either as animal feed or as soil-enriching green manure. Many legumes remain green and palatable during drought periods when grasses dry out, providing a more continuous and reliable feed supply. The inclusion and/or encouragement of legumes in any pasture mix is always recommended.

Useful Pasture Species. Forage legumes that do well in the coconut pasture system include centro *(Centrosema pubescens),* calo *(Colopogonium mucunoides)* and cowpea *(Vigna unguiculata).* Recent work in Vanuatu demonstrates that *Desmodium ovalifolium,* a tropical legume commonly used as a cover crop in oil palm and rubber plantations, is also a promising pasture addition.

Grass species suitable for the coconut understorey are relatively short, sod-forming, stoloniferous and, of course, shade-tolerant. They should provide a moderate carrying capacity, allow for quick fallen nut location, are inexpensive and easy to establish from cuttings, compete well with aggressive weeds, maintain a balance with companion legumes under grazing, and do not compete excessively with coconuts (Reynolds 1988). Popular choices are cori grass *(Brachiaria miliformis),* palisade (B. *brizantha),* para *(B. mutica),* koronovia *(B. humidicola),* signal *(B. decumbens)* and guinea *(Panicum maximum).*

Correct species choices are made according to a number of environmental and management factors. In some soils, choices may be very few. On coastal coralline sands and atoll soils, koronovia and siratro *(Macroptilium atropurpureum)* are the only species that have done well under experimental conditions (Gutteridge and Whiteman 1978). Frequency and duration of drought may also limit selection. Centro has proven itself to be especially drought tolerant.

"Local" versus "Improved" Pasture. The conversion of local to improved pasture is usually a very slow and costly process. The extensive site preparation normally required may damage shallow coconut roots. Improved pasture is not a prerequisite for a profitable cattle-under-coconut enterprise. It is true that the productivity and quality of local pastures can be extremely variable, especially during periods of drought. However, where the local pasture contains a high percentage of legumes such as *Mimosa pudica* and *Desmodium heterophyllum,* some fertilizer additional one can make beef production viable (Reynolds 1988).

Yield "Trade Offs". In most cases, the assumed trade-off between pasture (cattle) and coconut yield proves to be rather one-sided.

Pasture herbage production and shade density are closely correlated. A reduction in pasture yield-even forage/grass digestibility-is likely in shaded conditions (Reynolds 1988). On the other hand, intercropping with perennial, short-term, or cover crops rarely affects the yield or growth of the coconut crop adversely. Coconut yield often actually increases when pasture or other crops are cultivated in the understorey. Yield increases are attributed largely to practices that benefit the system as a whole, such as fertilization. A "clean" understorey also makes for easier recovery of fallen coconuts.

Pasture plants do compete for limited soil nutrients and water, particularly N, P and K. This competition can be controlled with proper grazing management and a good pasture mix. Still, regular applications of nitrogen and phosphorus fertilizer are usually necessary.

Pasture yield reductions due to coconut shading can be minimized by selecting grass and legume species that are relatively shade-tolerant. Cori grass appears, in fact, to perform better in the shade than in the open (Reynolds 1988). Shading does seem to affect the growth of tropical grasses more than legumes (Ludlow et al. 1974).

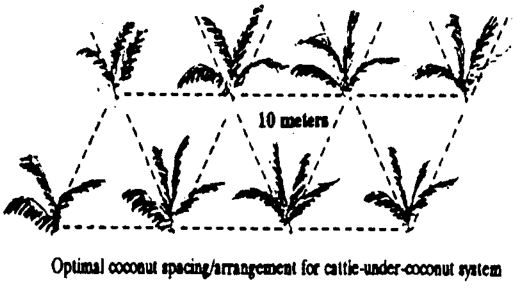
A plowing or disking each fourth year or so is advised for any pasture. This will prevent excessive soil compaction from animal traffic. The shallow cultivation of coconut land-to about 25 cm-also prunes the uppermost coconut roots. This is reported to stimulate the roots which then tend to explore the deeper soil layers (Asghar 1987).

Coconut Establishment and Management

Spacing and Arrangement. The most important management tool in achieving optimal overall system productivity is appropriate coconut spacing. It is the density of coconuts per hectare that determines how much sunlight will get through to the understorey. The optimal spacing for good overall pasture and coconut production is reported to be 10 x 10 m on flat or gently rolling terrain and 9 x 9 m on slopes (Guzman and Allo 1975; Opio 1987). One can compare this to the recommended spacing for maximum nut production alone on flat land which is 8 x 8 m. Nair (1979) estimates that even at this spacing, only 20% of the total soil area under the coconuts is effectively utilized by their roots.

A triangular-as opposed to square-spacing arrangement is now recommended by most experts because it allows for more coconuts, more canopy interlock/overlap, and thus more effective interception of sunlight at any given spacing.

One would suspect, then, that a square arrangement is preferred where pasture production is an objective.With a square arrangement, more light reaches the understorey pasture. However, this extra light is concentrated through wide gaps in the canopy so that some spots in the pasture receive much more light than others. Because uniformity of growth and species mix is one goal of pasture management, the triangular arrangement is still be preferred here. Coconuts in this arrangement, shade the ground more uniformly.



Optimal coconut spacing/arrangement for cattle-under-coconut system

The Age Factor. A stand of coconuts casts varying degrees of shade depending upon its height and thus its age. In young plantations, plenty of light reaches the ground. Shading gradually increases until the palms are about 10 years old. Thereafter, understorey sunlight gradually increases to a maximum level when the palms are approximately 20 years old. It may be best to plant different crops in the understorey at these different coconut growth stages. Options will be discussed later.

Fertilizer. Spot application of potassium (muriate of potash) at the coconut stem is often recommended. This nutrient is much more important to coconut than it is to pasture plants. The usual method is to place the potash in a few shallow holes around the stem of each coconut.

Livestock Management

Cattle do best in cool weather. Heat has a greater affect the well being of most cattle breeds than any other climatic factor (Plucknett 1974). Rising body temperature suppresses animal metabolism causing lack of movement, loss of appetite, and a marked reduction in productivity (Guzman and Allo, 1975). In the tropics, the temperature under coconut shade can be as much as 6° C cooler than in the open. Cattle thus benefit from the presence of coconut palms overhead.

Cattle nutrition. With the appropriate species mix and cattle stocking density, pastures in the partial shade of coconuts can provide adequate feed. Pasture under the relatively open, mature stand, can produce five weight gains and milk yields comparable to those from pasture under open conditions (Reynolds 1988).

Grazing control. Proper grazing control is the key to any productive livestock operation. In the coconut system, grazing can be used both as a tool-both to maximize pasture yield, and to minimize competition between the pasture plants and the coconuts for soil nutrients and moisture. The regular and properly timed grazing of top growth can greatly reduce excessive pasture plant transpiration and thus competition for water. Cattle recycle plant biomass and return nutrients to the system in organic manure.

Grazing control is especially important for "local" pasture. Local pasture vegetation can often prove just as productive as improved pasture mixes, with a well-monitored rotational grazing program, some seeding of leguminous forage species, and an occasional addition of N, P and K fertilizer.

Potential problems. Cattle must usually be kept off coconut plantations until the palms are at least 5 years old. Otherwise the animals will chew fronds, stunting growth. They can also kill a young palm if they damage or remove the growing point.

Another potential problem is the gradual compaction of soil by trampling. One preventative practice is disking every 4 to 5 years (Guzman and Allo 1975). Again, this will also stimulate coconut root function if limited to the upper 30 cm.

The rhinoceros beetle (*Oryctes rhinoceros)* has a tendency to make its home where there is a lot of cattle dung. Free ranging cattle may thus increase the incidence of this serious coconut pest.

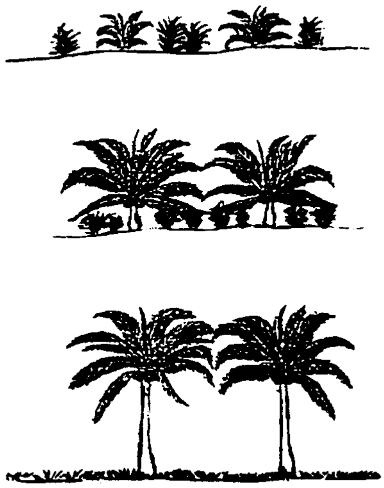
System Design Recommendation

There are periods during the coconut life cycle when grazing and/or pasture production are not feasible due to possible seedling damage or dense shading. For this reason, pasture block rotation is obviously the most suitable management regime. There are basically three stages in the coconut growth cycle. During each of these stages, the understorey can be used differently-to the greatest advantage. In this way, the entire system is steadily maintained at optimal productivity.

- ***Stage 1:*** **0 to 5 years.** Cattle must be kept off to prevent damage to young coconuts. Plenty of sunlight reaches the ground between the coconuts. Sun-loving forage crops can be raised as "cut and carry" animal feed. Alternatively, more light-demanding food crops can be grown, such as chilies, cabbage, cassava and ginger.
- ***Stage 2:*** **5 to 20 years.** Pasture productivity will be relatively low due to dense shading. More shade-tolerant food/cash crops can be grown, such as cacao and kava.
- ***Stage 3:*** **20 years** till coconut replacement. Ideal conditions for pasture and cattle production.

The lengths of these coconut growth phases are determined by the cattle breed and growing environment. They can be shortened or lengthened to suit management goals, size of the herd, size of pasture and other factors.

The farmer can incrementally convert the different blocks to improved pasture or introduce improved coconut hybrids, as able, or in response to market trends and oppprtunities.



Achievable Products and Benefits

The following are achievable returns from the management of coconuts and livestock together, as interacting components of one system:

- Increased overall farm income
- Increased coconut yields
- More efficient use of sunlight, soil and water
- Increased food production
- Understorey weed control
- Organic fertilizer input (manure)
- Stability through diversification
- Prolonged economic life of the plantation
- Better animal health

System Limitations

The management of cattle and coconuts together is a more complex undertaking than simply managing each as a separate enterprise. The farmer must be prepared to address the following possible problems:

- Cattle damage to young palms
- Reduced pasture production
- Soil compaction and erosion
- Coconut root damage
- Introduced coconut pests: rhinoceros beetle
- Lack of adequate management skills

In many areas, there may be other, more appropriate or necessary uses for the coconut understorey. Where population densities are extremely high and land area very scarce-such as on many atolls-food production must be the priority. Many nutritious food crops produce well as coconut intercrops.

On many of the larger islands, however, where coconut plantations cover extensive areas, understorey maintenance is still considered a cost. The successful conversion of this cost into a profit can make many marginally uneconomic operations viable again.

Research Needs

There is a need for research to identify good pasture species combinations, optimal coconut stand densities, and appropriate spatial and temporal arrangements in a variety of environments. Further screening and evaluation of shade-tolerant pasture species that will not compete aggressively with coconut palms would assist interested farmers immensely. Promising species must then be tested under various cutting, grazing and fertilization regimes. Economic studies comparing the cattle-under-coconut system to cattle and coconut production as separate enterprises are also long overdue.

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Fodder Bank Establishment and Management

Livestock play an important role in most small-scale farming systems throughout the world. They provide traction to plow fields, manure which maintains crop productivity, and nutritious food products for human consumption. In most small-scale farming systems livestock graze in pastures or woodlands feeding on grass and other herbaceous plants. During the wet season these lands provide adequate forage to maintain productive animals. In the dry season however, the quantity and quality of forage greatly decreases and is generally low in nutritional value. Livestock sustained on such diets often lose weight and productivity.

To avoid this problem farmers must provide their animals with quality feeds to augment dry-season forages. One option is to supply expensive concentrates or supplemental feeding. For most small-scale farmers this is not possible due to high costs and limited availability of supplements. A more practical option is for farmers to establish fodder banks. Fodder banks are plantings of high-quality fodder species. Their goal is to maintain healthy productive animals. They can be utilized all year, but are designed to bridge the forage scarcity of annual dry seasons. Fodder banks do not provide 100% of feed requirements, but supplement the available dry-season forage.

Fodder bank plants are usually trees or shrubs, and often legumes. The relatively deep roots of these woody perennials allow them to reach soil nutrients and moisture not available to grasses and herbaceous plants. This characteristic enables these plants to retain fresh foliage into the dry season. The ability of some legumes to fix atmospheric nitrogen makes them protein-rich feeds.

ESTABLISHMENT

Fodder banks are valuable crops which support productive farming systems. They should be managed intensively. Thorough site-preparation is necessary to establish fodder banks. This can be accomplished by mechanical or chemical means. Use methods practiced locally for other high-value crops. The goal is a weed-free seed bed, in which plant growth and survival will be maximized. As with all tree planting activities fodder bank establishment must coincide with the rainy season. This assures high plant survival.

Planting material. Direct seeding is normally recommended for fodder bank establishment. Seeds of many fodder bank species must be soaked in water or scarified to assure good germination. Information on these methods is *Agroforestry for the Pacific Technologies, Number 12.*

Sowing depth depends on seed and site characteristics. Most seeds should be sown at a depth equal to 1-2 times their width. In heavy soils, or when seed is small, sowing depth should be shallow. In arid and semi-arid environments sowing depth should be deep. For most seed types, successful sowing methods vary from place to place. Use those methods practiced locally for a similar type of seed.

Fodder bank establishment is also possible with seedlings or cuttings. However, because of the large number of plants needed this is often impractical. When seedlings or cuttings are used wide plant spacing, 50x50 cm or 1x1 meter, is usually recommended. Species that can be established by cuttings include *Gliricidia sepium* and *Erythrina* spp.

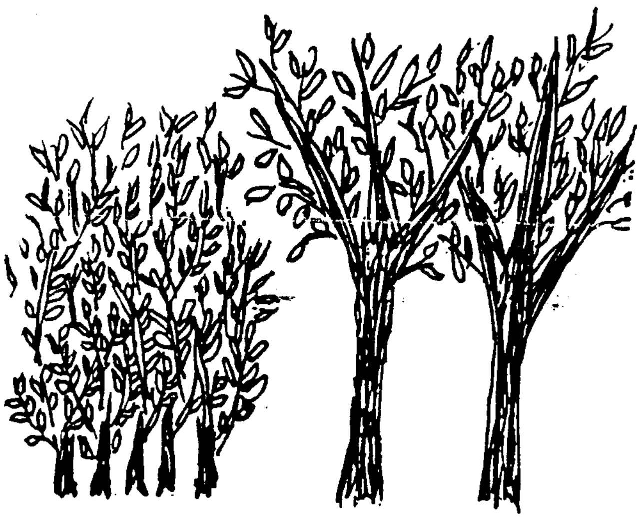
Post-establishment care Although most fodder bank species are considered fast-growing their initial growth is often slow. During this period seedlings are susceptible to weed competition for light, moisture and soil nutrients. Depending on weed growth, the fodder bank should be thoroughly weeded every 2-4 weeks. This level of weed control should be maintained until the fodder bank species achieve a dominant canopy position and begin to suppress weed growth. This usually occurs six months after establishment.

The use of fertilizers to improve fodder bank establishment is not generally recommended. Fertilizers are expensive, and if available may be better utilized for food crop production. Fertilizer requirements of many fodder bank species are not well documented. When fertilizers are used, they must be accompanied with thorough weed control. Fertilization without adequate weed control results in decreased survival and growth of fodder bank species.

Written by James M. Roshetko, Program Director for Asia, NFTA

SPACING AND DESIGN

To maximize dry-season production, fodder banks should be dense, nearly pure stands. Recommended spacings vary from 5x5 cm to 1x1 m. Choice of spacing depends on management objectives. Total biomass yields per area increase at higher densities. Wider spacing are generally used when both fodder and small-diameter wood, for fuel or poles, are desired. Closer spacing maximizes fodder production, but may make access for harvest or grazing difficult. Spacing of 1x1 meter is common for many species.



Closer spacing encourages maximum fodder production. Wider spacing bank fodder and small-diameter wood.

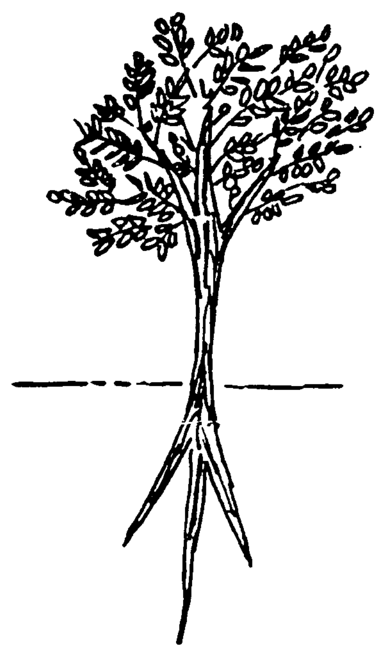
Fodder production and accessibility can be improved by using double-rows of fodder trees at wider spacing. Rows are established about 50 cm apart with 1-1.5 meters between double-rows. In-row spacing of trees varies from 5-50 cm. Ideally, rows are oriented along the contours in an east-west direction. This orientation provides optimum fodder bank sun exposure and erosion control. Of course this is not always possible. Row establishment should conform to site geography. When the slope is steep, it is best to establish rows along the contours. Control of soil erosion improves with closer in-rows spacing.

Once the fodder bank is well established, grass should be allowed to grow in the area between double-rows. Competition between bank trees and grass will not be as severe as during the establishment period. Tree roots will feed from deep in the soil, grass from near the surface. Their difference in height will also decrease competition for sunlight. This two-tiered system produces more fodder per area than either plant type alone. The grass grown in the interrow area should be an excellent fodder species. Competition between trees and grass should be monitored constantly so that fodder bank productivity does not decrease. The natural establishment of poor-quality fodder grasses should be closely controlled.

Researchers in Bali, Indonesia have designed a Three Strata Forage System (TSFS) which contains full-sized trees, trees maintained as hedges and grasses. Respectively, the components produce fodder for the late-dry season, middle-dry season and the wet season. Tree spacing is five meters, hedge species spacing 10 cm and grass planted the entire length and width. The TSFS is planted in five meters wide strips around crop land (Nitis et al. 1987).

MANAGEMENT

Age at first harvest. In most circumstances the first harvest should be delayed until the bank is 9-21 months old. Actual age at first harvest depends on environmental conditions and bank growth. Under arid or poor soil conditions growth will be slow and the first harvest should be later. When growth is fast, the first harvest may be sooner. The goal is to allow fodder bank species to establish deep roots and thick trunk diameters. The resultant healthy plants have ample carbohydrate reserves and respond well to harvesting. Biomass production/harvest and long-term production both increase when the first harvest is delayed. It is believed that the first harvest, whether from cutting or grazing, terminates the downward growth of taproots. This is an important consideration in arid and semi-arid environments.



To promote establishment of a healthy root-system the first harvest should be delayed until trees are 9-21 months old.

Grazing. Fodder banks can be directly grazed by livestock. This system saves labor and effort but can lead to plant damage and fodder waste from trampling. The key to direct grazing is subdivision of the fodder bank into paddocks. Livestock should be restricted to one paddock until the available fodder resource is fully utilized. Animals should then be moved to the next paddock.

If environmental and plant growth conditions are favorable, fodder banks may be grazed year-round. Grazing periods are generally 1-2 weeks, followed by recuperation periods of 3-6 week (or three-times the grazing period). Under arid conditions the recuperation period may need to be longer. To stimulate tree growth fodder banks should be cut to a uniform height after the grazing period. Cutting height is discussed in more detail below.

With most species complete defoliation during the grazing period is permissible, as long as cutting and grazing are excluded during recuperation. To assure adequate recuperation, paddocks should be fenced or protected in a similar manner.

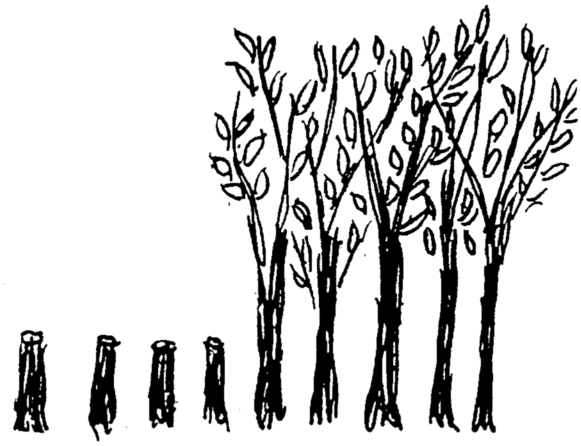
After long recuperation periods tree height may make fodder inaccessible to animals. This is often a problem when fodder banks are not grazed all year. Periodic cutting of sections of each paddock may be necessary to improve animal access. The cut fodder is left on the ground where livestock can access it. The area cut should correspond to what will be eaten before the next cutting.

Goats and sheep often eat the bark as well as leaves of fodder trees. This can lead to tree mortality and decreased long-term fodder bank productivity. Unless closely monitored, goats and sheep should not be allowed to graze fodder banks. Cattle generally do not cause this problem.

Cut-and-carry. Most fodder banks are managed through a cut-and-carry system in which the fodder is harvested and then 'carried' to the livestock. The animals may be a great distance from the fodder bank or just across a protective fence. Special harvesting equipment is available for fodder banks but all that is necessary is a sharp machete. A cut-and-carry system decreases fodder waste from animal damage and the necessity to monitor animals. However, labor inputs may be greater than with direct grazing systems.

Important management factors to consider for a cut-and-carry system are cutting height, cutting frequency, and dry season management. These factors are all influenced by precipitation, temperature, soils, species, plant spacing, as well as each other. Interactions are unique for each situation, resulting in effective management prescriptions that differ at each site. However, general recommendations are possible for each management factor. Farmers and managers should refine these recommendations to determine the best management prescription for their specific situation.

Cutting height. To obtain maximum fodder production research studies have recommend a great variety of cutting heights. Review of these results suggest a standard cutting height of 50-150 cm. Besides fodder production this height provides other advantage Trees retain adequate foliage to ensure rapid regrowth and plant longevity. Fodder is harvested with a minimum of bending or reaching, allowing for efficient movement by the harvester.



Cutting heights of 50-150 cm often maximize fodder production.

A notable exception to the standard recommendation is the management of *Sesbania grandiflora.* This species experiences a high degree of mortality when its main stem is cut. Side branches can be harvested, but it should not be completely defoliated or have its main stem pruned below 150 cm.

After 2-3 years of production it is recommended to cut *Leucaena* back to 25 cm. This lower height removes much of the dead wood and rejuvenates foliage production. This may be true for other species also. However, regular cutting below 50 cm may cause increased mortality and decreased long-term productivity.

Cutting frequency. As with cutting height research studies have recommended a great variety of cutting frequencies. The most common cutting frequencies are 6-18 weeks. Generally, longer cutting frequencies, 12-18 weeks, generate more total biomass but increase the proportion of small wood production. Shorter cutting frequencies, 6-12 weeks, favor fodder yields and fodder quality. Younger foliage tends to have a higher nutritive value and palatability. However, repeated cutting after short frequencies decrease longevity.

Standard cutting frequencies were developed for tropical conditions and tend to correlate with regrowth heights of 1-2.5 meters. Under arid, sub-humid or temperate conditions regrowth may take longer to reach this height, cutting frequencies may need to be extended.

Dry-season management. Dry-season fodder production is a main objective of fodder bank management. In areas with severe dry-seasons special management practices should be followed. Six to eight weeks before the beginning of the dry-season trees should be cut to the recommended height. The new foliage produced over the next few weeks will be retained well into the dry-season when it is most needed. Left uncut for 4-6 months, *Gliricidia sepium* will not retain its leaves into the dry-season. This may be true for other species as well.

When the dry-season is very long or the area of fodder bank very large, the pre-dry-season harvest should occur in phases. This will assure that fodder is available throughout the dry-season. During these pre-dry-season harvests the amount of fodder available may exceed normal needs. The excess may be used to increase animal rations, make silage for dry-season use, or mulch crops. Dry-season regrowth will be slow, and cutting frequencies may need to be extended.

Fertilization. Fodder banks are long-term crops that must be properly maintained to continue high productivity. Even under direct grazing, fodder banks remove large amounts of soil nutrients from the site. These nutrients must be replenished by application of manures or chemical fertilizers. As previously mentioned, little is known of the nutrient requirements of most fodder bank species. However, as with most crops, nitrogen, phosphorus and potassium are important nutrients. Application for these and other nutrients should be determined locally. Availability and costs of fertilizers may restrict their use. The nitrogen requirement may be self-provided if the species used are nitrogen-fixing.

Species. Many species make excellent fodder bank components. In general these species:

- establish readily
- grow fast
- out-compete weeds
- produce high-quality fodder
- remain productive under repeated harvest
- remain productive during dry seasons
- survive on poor sites

A list of recommended fodder bank species and their respective ecological zones appear in Table 1.

Table 1. Fodder bank species and their ecological zones.

Arid & Semi-arid Tropics	Humid Tropic	Highland tropics	Arid & Semi-arid Temperate
Albizia lebbeck	*Acacia angustissima*	*Calliandra calothyrsus*	*Chamaecytisus palmensis*
Cajanus cajan	*Albizia lebbeck*	*Calliandra tetragona*	
Sesbania sesban	*Cajanus cajan*	*Erythrina arborescens*	
	Calliandra calothyrsus	*Erythrina buranas*	
	Calliandra tetragona	*Erythrina edulis*	
	Desmodium spp.	*Sesbania sesban*	
	Erythrina berteroana	*Leuceana diversifolia*	
	Erythrina poeppigiana		
	Flemingia macrophylla		
	Gliricidia sepium		
	Leuceana leucocephala		
	Leuceana diversifolia		
	Sesbania grandiflora		
	Sesbania sesban		

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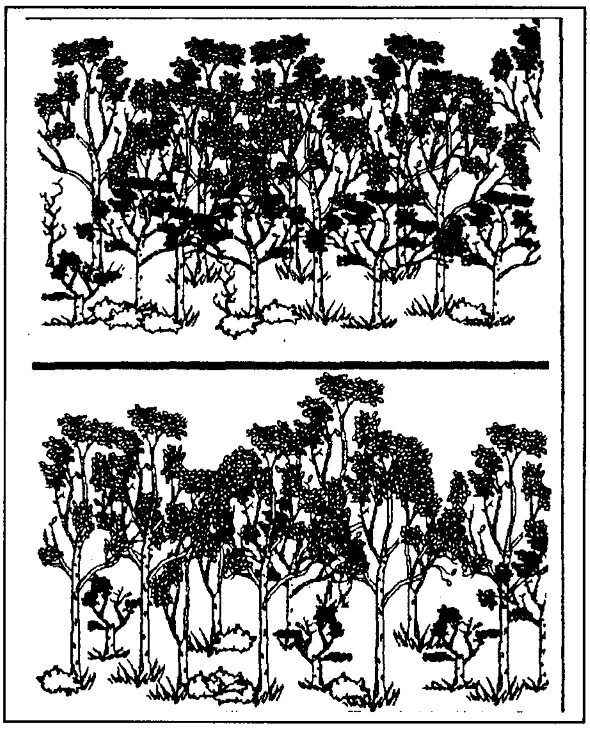
Agroforestry for the Pacific Technologies

A publication of the Agroforestry Information Service

Number 9 December 1994

Fuelwood Production in the South Pacific

Trees and forests are an important part of island resources. Trees can help the environment and provide the opportunity for future development activities. The importance of trees and forests is well-known to Pacific Islanders. Traditionally valued as a source of building materials for homes and canoes, food, firewood, fiber, medicine, and flowers, the significant role of trees is often taken for granted. Population growth, commercial and private development, and indiscriminate gathering of firewood and wood products are degrading the islands' native forest resources. In order to stop and reverse environmental problems due to the loss of native forest, a combination of traditional land management practices and innovative planning strategies is required. A basic element in achieving this goal is planting trees.



Fuelwood situation

In the South Pacific Islands the import of energy resources accounts for a substantial portion of the economy for many island nations and territories, with most commercial and domestic energy being provided by petroleum-fueled generators. Despite the increased reliance on these nonrenewable energy sources for modern societal needs, the continued use of wood fuel retains significant importance for traditional uses. This continuing importance suggests the need to promote both the public and private production of fuelwood to relieve pressure on native forest resources. Trees and shrubs contribute to energy supplies throughout the islands, while providing many other products and services as well.

The concept of incorporating trees in land use management is not new to the islands. Throughout the history of island settlement, the principal source of fuelwood has been attributed to the clearance of forest land for agricultural production. Traditional management schemes were also dependent upon trees as providers of nutrients, shade, and pest management. But, with escalating urbanization and population pressures, as well as interest for maximizing agronomic crop yields increases, the renewability of the forest resources in the South Pacific Islands is quickly being compromised. The role of trees becomes secondary.

Tropical storms

Throughout the South Pacific region the importance of natural disturbances in the form of tropical storms and hurricanes must be a prime consideration for the design and implementation of new resource management practices. These disturbances have always been a part of island life and regional development.

Most of the island nations and territories of the Pacific lie within the area of cyclogenesis and the subsequent path of storm tracks, being frequently affected by these annual

Written by Richard van-C. Adkins, P.O. Box 1433, Safford, AZ 85548-1433 USA. Information included in this Fact Sheet resulted from a Master's thesis submitted at Utah State University. The research is based on the author's work with theAmerican Samoa Community College Land Grant Program and the Institute of Pacific Islands Forestry, USDA Forest Service, Honolulu, Hawaii.

The species trials are located on the island of Tuuila, American Samoa.

disturbances. the season normally extends from December to April, with an average of 15 storms or cyclones of hurricane strength in any given year. Proper species selection that minimizes the risk of loss due to storm damage will promote opportunities for private production of fuelwood in small woodlots or as a component in an integrated land use system. Some tree species are better suited to perform these roles than others.

The greatest damage usually occurs at the forest edge, where the transition of vegetative type is most abrupt due to forest clearance for agriculture and urban development. Lessening the abruptness of this edge and maintenance of the vegetative structure across the landscape could result in decreased damage to crops and property located in the cleared areas. Due to the frequency of these storms, the importance of wind-firmness and the ability to recover following a storm are essential to management and design of land use strategies which incorporate tree crops. Although most species suffer some degree of damage, differences in resilience and recovery may suggest favorable usage.

Species Selection

While trees can provide many benefits, they can decrease the short-term productivity of an area. Proper selection and management of the right species is important, and can enhance crop yields while providing additional products --which will help compensate for any lose. Resulting micro-environmental changes may even allow production of other crops. Some criteria for selection include:

- multiple uses
- fast growth
- adaptability to the local environmental conditions
- compatibility with other plants
- tolerance to minor injuries
- availability of planting stock
- market potential

Good growth and survival, both during normal years and following a tropical storm, should be used to decide which trees to plant in your fields and around your home. All of the species presented below provide a variety of products, and are fast growing, wind-firm, compatible with traditional crops, and available throughout the Pacific region:

Acacia auriculiformis *
Adenanthera pavonina *
Albizia chinensis
Alphitonia zizyphoides
Calliandra calothyrsus *
Casuarina equiselifolia *
Eucalyptus camaldulensis
Eucalyptus urophylla
Gliricidia sepium *
Securinega flexuosa

* *Fact sheet or highlight on these species included in this volume*

There are many other common trees, as well as coconut, breadfruit, and other fruit trees that can be planted on farms. Planting and management of different combinations of trees can provide a number of products and help to limit damage in case of a tropical storm. Below are some suggestions concerning ways to plant these trees around crop fields and homes.

Line Plantings

Planting trees 1.0 m to 2.0 m apart in a line along field or property boundaries can protect crops from wind damage. This initially thick planting can be thinned by harvesting every other tree after 3 to 5 years, providing firewood and construction materials while maintaining the function of the windbreak. *Adenanthera pavonina, Albizia chinensis,* and *Acacia auriculiformis* all have similar shapes and growth characteristics, and can be used in line plantings. All three species resprout following harvest or wind damage, providing an excellent source of quality firewood. These trees can be planted together, either in a single line or by combining a number of lines. They can also be planted within crop fields in lines or as individuals. The small leaflets provide light shading and make good mulch, helping to control weeds and conserve soil moisture.

Albizia chinensis and *Acacia auriculiformis* are nitrogen fixers. When planting within crop fields, trees should be at least 0.5 m to 1.0 m tall. This will help prevent damage to the trees during crop planting and maintenance.

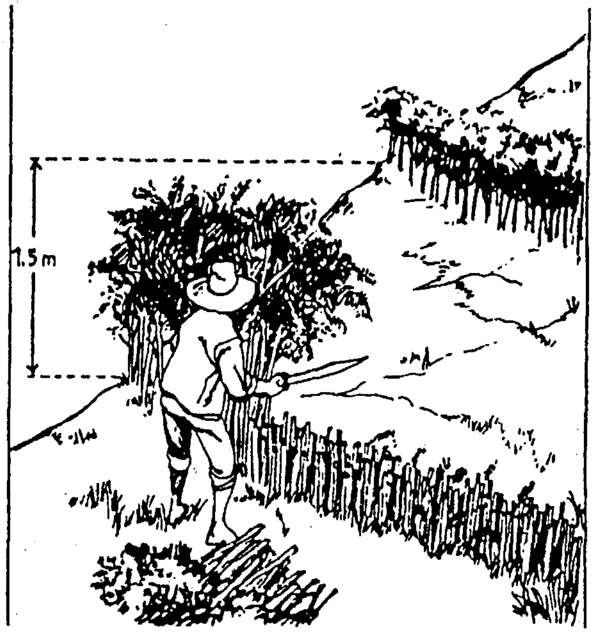
Eucalyptus spp. and *Securinega flexuosa* can also be planted in combination with *Adenanthera, Albizia,* and *Acacia.* These two trees have a tall, narrow shape and will grow well between the more branchy, rounded shape of these other trees. *Eucalyptus* and *Securinega* provide a good source of small poles and/or fuelwood in only 3 to 5 years. If land is available, small block plantings-can provide marketable pole products in a relatively short time. Otherwise, line plantings of these trees are good along roadsides and property boundaries.
Casuarina equisetifolia is very windfirm and can protect both crops and property from wind and salt spray damage.

While this tree grows well along the coast, it can also be planted inland. Planting a line at close spacing will provide a strong barrier to wind. Spacing between trees can vary from 0.5 m to 1.5 in for this purpose. Some trees can be harvested later for firewood or other wood products. Multiple-line plantings of *Casuarina* are best, with the trees being offset between lines, so as not to funnel the wind through any gaps or holes. *Casuarina* is best planted around field borders and property boundaries. *Securinega* and *Eucalyptus* can be planted with *Casuarina* on inland sites.

Although the optimum orientation of boundary/line planting which serves as a windbreak is perpendicular to the prevailing winds, tropical storms often are accompanied by shifting wind patterns. Making use of a grid design, a technique of planting lines of trees in a crisscross pattern forming several small squares within or around crop fields, can provide protection against shifting winds.

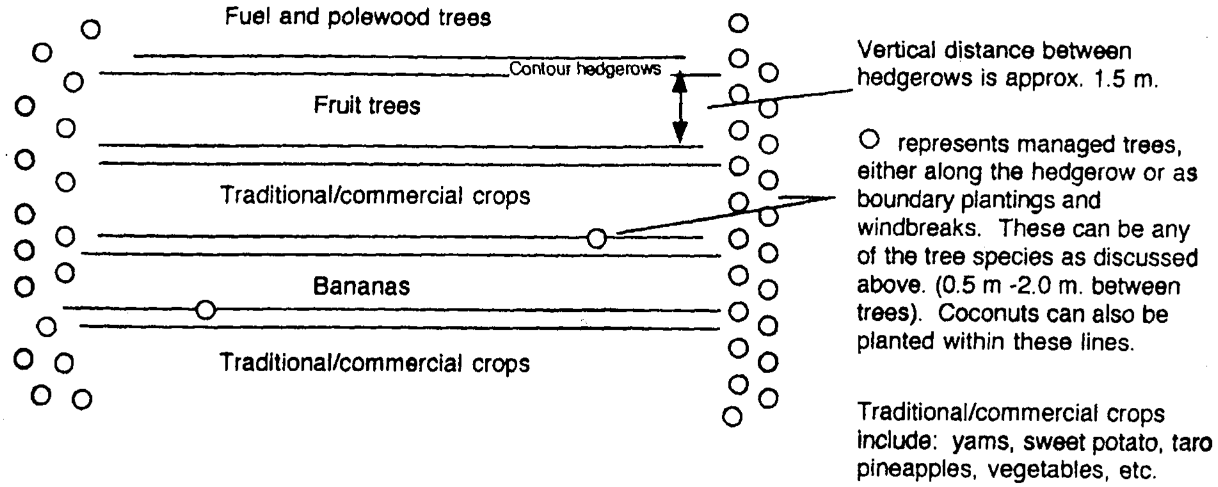
Alphitonia zizyphoides, like many other native forest trees, is an excellent source of firewood and onstruction timber. This large tree is best planted and managed on old field sites, surrounding crop fields, or near the home

Contour Hedgerows
Planting woody hedgerows along the contour of sloping land combines the advantages of soil conservation and multiple product yields. This integration of food and forest species serves to control soil erosion, help restore soil fertility and structure, and efficiently produce a variety of products. Contour lines are easily established with the aid of an A-frame. These lines can be from 1.5 m to 5.0 m apart depending upon the steepness of the slope. The area between these lines is planted with annual agricultural and perennial fruit crops.



Hibiscus manihot is a useful shrub for the early stages of contour hedgerow establishment. Cuttings of this shrub are easily planted, and grow quickly. This species can then be followed by the sowing of seeds, planting of cuttings, or seedlings grown in the nursery. This will help to maintain and strengthen the hedgerow.

Seeds of *Calliandra calothyrsus* and cuttings of *Gliricidia sepium* work well for this purpose. These two trees can be pruned every 3 to 4 months to maintain a short height. The vigorous resprouting ability of these trees makes for a thick hedgerow and provides a large quantity of mulch. When the hedgerow



Sample design of integrated management on a slope.

is 1.5 m to 2.0 m tall, it can be cut back to 0.5 m, with the cuttings being placed both behind the hedgerow to build up a terrace, or placed among the crops as mulch. Both species are nitrogen fixing.

One tree can be left uncut every 5.0 m along the hedgerow to provide for other product needs like fuelwood. Any of the other trees discussed here can also be planted at 5.0 m to 10.0 m spacing along the hedgerow. Multiple lines of trees and nitrogen-fixing shrubs and grasses will provide diversity and added stability to the hedgerow.

Calliandra, Gliricidia and *Leucaena* can also be planted and managed as trees around piggeries and along field borders. They provide a quick source of firewood and light construction wood for agricultural needs (planting sticks, banana props, fence posts, etc.). They also provide shade and bedding materials for the animals.

Utilization of trees in multiple- and single-line plantings, and in contour hedgerows promotes the use of multipurpose tree species that can benefit present management strategies and reduce the impact on the native forest resources.

Zonation of crops incorporating sloping agricultural land technology (SALT) would provide additional advantages. The incorporation of trees within a land holding as part of the overall management plan is necessary, not just in agricultural plots, but in the context of the entire production system.

While native species deserve foremost consideration, and should be emphasized, the use of exotics must also be acknowledged as a potential solution to the increasing problems of resource degradation. Consideration of seed and planting material availability and concerns of invasiveness must also figure in the evaluation and selection process.

The extensive use of fuelwood for both traditional and daily food preparation will remain important throughout the South Pacific despite the availability of alternative fuel and energy sources. Through a combination of culture, tradition, and technology, trees can be used to provide for these needs, helping to benefit farm production and protect island environments.

Agroforestry for the Pacific Technologies

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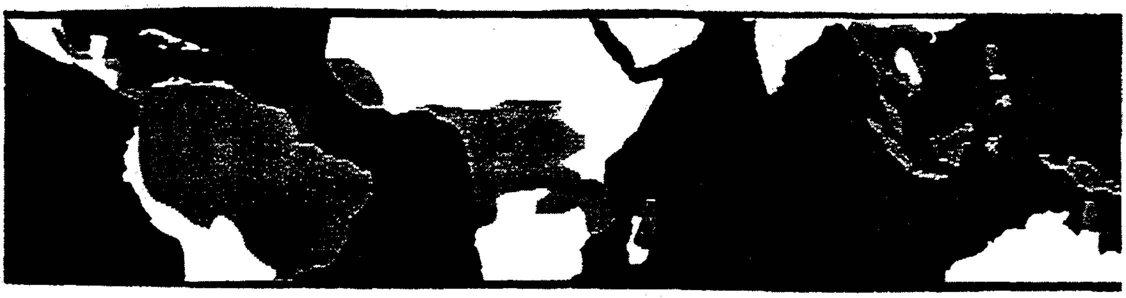
Number 10 **December 1994**

Selecting and Testing Nitrogen Fixing Trees for Acid Soils

Acid soils-the problem

How to practice low-input sustainable agriculture on marginal soils is a dilemma for small-scale farmers and government agencies responsible for providing technical assistance. This dilemma is greatest in tropical countries where population pressure is intense and much of the soil is acid and contains toxic levels of aluminum (Caudle, 1991). In the humid tropics, the relative importance of acid soils is greatest in Latin America (81%), but also significant in Africa (56%) and Asia (38%) (Sanchez, 1987).



Tropical regions in which soils are likely to be acid or low in bases such as calcium and magnesium. Source: Caudle, 1991.

By definition, any soil with a pH of less than 7 is acidic but the detrimental conditions for plant growth may not appear until soils have a pH of 5.0 or less. The main problems for plant growth on acid soils are infertility (low reserves of plant nutrients) and levels of exchangeable Al and manganese that are toxic to plants. Low nitrate levels and detrimental effects of high hydrogen ion concentration on plant growth may occur in some soils. The most common problem is aluminum toxicity, which generally inhibits root penetration below 15-20 cm. Manganese toxicity may be associated with higher pH levels than Al toxicity.

Soil acidity and aluminum toxicity constrain agricultural production in several ways. Farmers are limited to planting crop species or cultivars that tolerate such conditions. Many acid soils "fix" or hold phosphorus, making it unavailable for plant growth. Soil acidity can also be a barrier to root development, limiting a plants ability to reach moisture in the subsoil. In the humid tropics, soil acidity and associated problems often lead to land abandonment and the perpetuation of slash-and-burn agriculture (Tropsoils, 1991).

The use of species or cultivars tolerant of acid soils is the first step for low-input soil management (Sanchez and Salinas, 1981; Reddell, 1993).In addition, agroforestry is considered particularly applicable to marginal soils with severe physical, chemical or drought constraints (Sanchez, 1987).

On acid soils of the tropics, the fundamental challenge is to recycle the limited nutrients available in soil-plant systems (Sutherland and Sprent, 1993). Planting nitrogen fixing trees (NFTs) and crops in agroforestry system is one low-input technology that helps maintain levels of nitrogen, a key nutrient for plant growth. Nitrogen fixing trees are also grown for wood production, shade and support for crops, live fence posts, green manure, human food, as shelterbelts and windbreaks, browse or fodder for domestic animals, and as ornamentals.

Choosing the right species

In establishing an agroforestry system on an acid soil, the first step is to identify suitable tree species. Once the best available species are identified, further investigation is needed to determine their value for agroforestry.

In choosing nitrogen-fixing tree species, careful attention should be given to select species that are adapted to local environments and that provide farmers with products and services they need. This is best done through field visits, personal interviews with farmers, and careful research. The following steps are a guide to selecting NFTs for acid soils.

1. collect information on climate, characteristics, and soils of the planting site(s)
2. determine what products and services trees should provide
3. make preliminary species selections based on information in one and two above
4. research species to verify selections
5. determine if species are native or naturalized at the planting site(s)
6. if exotic species are selected, conduct field trials to determine adaptation.

Written by Mark H. Powell, Program Associate, NFTA/Winrock International

Collect information on the planting site(s)

The first research priority is to collect as much information as possible on the climate, characteristics and soils of the planting site(s). Minimum information on climate and characteristics should include:

- elevation
- average annual rainfall
- distribution of rainfall
- average annual temperature
- maximum and minimum temperatures
- incidence of frost
- number of months with less than 50 mm precipitation
- topography, including slope and aspect (N, S, E, W)

Minimum soil information should include texture, depth, drainage and pH. Include information on phosphorus, aluminum, calcium, potassium, magnesium and manganese, if available.

Testing kits and digital probes are widely available to determine pH. However, a pH test is only a general indication of soil acidity and does not indicate the level of aluminum or manganese in the soil. A good soil-testing laboratory, if available, can estimate the percent aluminum saturation-a good indicator of Al toxicity. A simple test can be run to determine manganese toxicity, if no information exists. Apply a solution of 5 percent hydrogen peroxide to a sample of soil. If the solution bubbles, the soil is likely to cause manganese toxicity in plants The symptoms of manganese toxicity are small, stunted plants with crinkled leaves with small brown spots. Liming to pH 5.8 or 6 will correct the problem for most plants (Caudle, 1991). However, liming tree crops may not be economical.

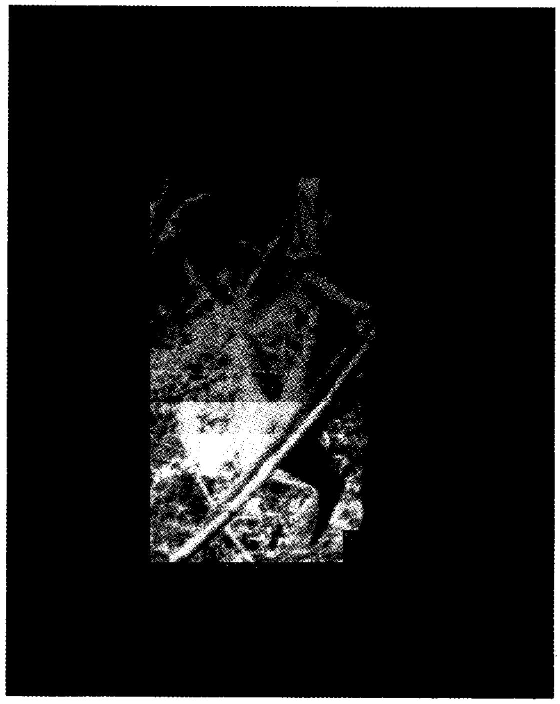
Determine products and services trees should provide

Careful research is necessary to determine which species will provide needed products and services in a given area. This is often best done through personal interviews with farmers and study of local tree-use markets. It is important that tree species are accepted within local cultures.

Some species can be hosts to pests and diseases. For example, *Erythrina* species in parts of the South Pacific are host to a fruit piercing moth (*Othreis fullonia* Clerck). The adults damage important commercial fruits such as oranges, guava, carambola, papaya, and banana, causing serious economic losses (Muniappan, 1993).

Select species

A preliminary selection of NFTs can be made with basic information on climate and soils in hand. A list of NFTs for acid soils (pH 5.0 or less) and given climatic ranges on the following page may be used as a guide to select species. Underlined species are reported to grow well in soils with greater than 60% aluminum saturation



Soil acidity and associated problems often lead to land abandonment and the perpetuation of slash-and-burn agriculture

Research species

Once species are selected, collect as much information on them as possible to verify that they are the best available choices. NFT *Highlights* by the Nitrogen Fixing Tree Association (NFTA) are handy references-highlights are available for species marked with asterisks in the list on the next page.

Are species native or naturalized?

After preliminary selection of NFTs, further research is needed to determine if selected species are native or naturalized in the area of interest. If species are present, their physical appearance would give an indication of how well they are adapted. If species are not present, then simple field trials should be conducted to determine how they will grow at the site.

Field trials to evaluate exotic species

In a Guide to Establishing Research and Demonstration Plantings with Nitrogen-Fixing Tree Species, Macklin et al. (1989) recommend a simple low-input design for species screening in situations where land, labor and technical expertise may be

Nitrogen-Fixing Tree and Shrub Species Tolerant of Acid Soils and Listed for Given Climatic Ranges

Mean Annual Rainfall > 1000 mm	
Mean Annual Temperature	
Greater than 20°C	Less than 20°C
Acacia angustissima	*Acacia koa**
*Acacia auriculiformis**	*Acacia mearnsii***
*Acacia koa**	*Acacia melanoxylon*
*Acacia mangium**	*Alnus acuminata***
*Albizia lebbeck***	*Enterolobium cyclocarpum***
*Albizia saman**	*Chamaecutisus palmensis**
*Calliandra calothrysus***	*Inga codonantha*
*Casuarina cunninghamiana***	*Mimosa scabrella***
Casuarina junghuhniana	*Robinia pseudoacacia***
Casuarina sumatrana	
Cedrelinga catenaeformis	
Cratylia argentea	
Dalbergia nigra	
Desmodium gyroides	
Desmodium intortum	
Desmodium nicaraguense	
Desmodium velutinum	
*Enterolobium cyclocarpum***	
Enterolobium contortisiliquum	
Erythrina abyssinica	
Erythrina berteroana	
Erythrina poeppigiana	
Erythrina fusca	
*Erythrina variegata**	
*Flemingia macrophylla***	
*Gliricidia sepium***†	
Inga acrocephala	
*Inga edulis***	
Inga marginata	
Inga punctata	
Inga spectabilis	
Mimosa caesalpinaefolia	
*Paraserianthes falcataria**	
*Pithecellobium dulce***	
*Pterocarpus indicus**	
Stryphnodendron adstringens	
Stryphnodendron excelsum	

Mean Annual Rainfall 500- 1000 mm	
Mean Annual Temperature	
Greater than 20°C	Less than 20°C
*Acacia holosericea**	*Albizia lebbeck-*
*Albizia lebbeck***	*Casuarina cunninghamiana***
*Casuarina cunninghamiana***	*Chamaecutisus palmensis**
*Enterolobium cyclocarpum***	*Enterolobium cyclocarpum***
*Gliricidia sepium***	*Phitecellobium dulce***
*Pithecellobium dulce***	*Robinia pseudoacacia***

Mean Annual Rainfall < 500 mm	
Mean Annual Temperature	
Greater than 20°C	Less than 20°C
*Acacia aneura**	*Acacia aneura**
*Acacia holosericea**	*Albizia lebbeck***
*Albizia lebbeck***	*Alnus glutinosa*
*Casuarina cunninghamiana***	*Phitecellobium dulce***
*Phitecellobium dulce***	

* NFT Highlights available in English from NFTA
** NFT Highlights also available in Spanish from NFTA
Select NFT Highlights also available in French. Indonesian and Chinese.

Underlined species reported to grow well in soils with greater than 60% aluminum saturation
† Retalheleu provenance from Guatemala reported superior (Fernandez, 1990)

a a a a a	b b b b b b	c c c c c c	d d d d d d	e e e e e e	f f f f f
a a a a a a	b b b b b b	c c c c c c	d d d d d d	e e e e e e	f f f f f
a a a a a a	b b b b b b	c c c c c c	d d d d d d	e e e e e e	f f f f f
a a a a a a	b b b b b b	c c c c c c	d d d d d d	e e e e e e	f f f f f
a a a a a a	b b b b b b	c c c c c c	d d d d d d	e e e e e e	f f f f f
a a a a a a	b b b b b b	c c c c c c	d d d d d d	e e e e e e	f f f f f
g g g g g g	h h h h h h	i i i i i	j j j j j j	k k k k k k	l l l l l l
g g g g g g	h h h h h h	i i i i i	j j j j j j	k k k k k k	l l l l l l
g g g g g g	h h h h h h	i i i i i	j j j j j j	k k k k k k	l l l l l l
g g g g g g	h h h h h h	i i i i i	j j j j j j	k k k k k k	l l l l l l
g g g g g g	h h h h h h	i i i i i	j j j j j j	k k k k k k	l l l l l l
g g g g g g	h h h h h h	i i i i i	j j j j j j	k k k k k k	l l l l l l

Example design for a screening trial with 12 species. Each letter represents a different species, each letter within a block represents an individual tree, bold letters are trees to be measured.

limited. These trials may be conducted by community organizations (farmer, church or women's groups), rural development workers (extension agents, staff of non-governmental organizations or Peace Corps Volunteers), or other types of grass-roots organizations and local government offices. Trials normally involve unreplicated plots of a relatively large number of potential species.

Soil and climatic conditions at the trial site should be similar to the entire planting area. If the planting area includes different environments, a trial should be in each environment. It is important to select a homogeneous site for the trial to eliminate differences in soil fertility, water availability, etc. between plots.

Tree spacing should be 1 m x 1 m or 2 x 2 m. The closer spacing is appropriate for trials that will be maintained for only a year or two. Each species should be planted with at least one border row of trees around the block that will not be measured-they are likely to be affected by trees in adjoining blocks, or have increased growth on field edges. It is recommended to have at least 16 inner am to measure (6 rows of 6 trees each). Larger blocks with a greater number of trees are recommended for long-term analysis (more than 2 years)

It is important to include indigenous and non-NFTs screening trials for comparison. In particular, species already prominent in local forestry efforts should be included. This will enable better evaluation of new species. Naturalized species should be included when possible as they may have undergone some adaptation and selection and could prove superior.

Data Collection

Measure tree survival, height and diameter at 6, 12, and 24 months after transplanting-the schedule will depend on local growing conditions. Calculate mean height, diameter and number of stems for each species after each measurement. Basal diameters are taken the first year or until diameter at breast height can be taken.

Caution!

Some NFT species will be new to an area, and nothing will be known about their performance. Many introduced tree species have the potential to become weedy in new environments by invading pasture and agricultural lands, and/or crowding out native vegetation. Any species, particularly thorny or non-fodder, that begins to exhibit weediness--prolific seed production or rapid, heavy, natural seedling establishment-should be watched carefully. Such species should be considered for eradication, especially if they have no clear potential for use

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Agroforestry for the Pacific Technologies

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Trees and Shrubs for Agroforestry on Atolls

Agroforestry is a traditional practice on many atolls. A wide variety of native and naturalized tree species have been and continue to be used by atoll inhabitants for multiple purposes i.e. construction, compost, fuelwood, human food, animal fodder, medicine and as ornamentals.

Harsh sun, salt spray and poor soils make atolls difficult places to grow trees. Under these conditions people know that to grow valuable trees such as breadfruit, they must first dig deep holes and compost in them to prepare planting soil.

On some atolls such as South Tarawa, Kiribati a rapidly expanding human population combined with coconut cultivation have contributed to the loss of native forests. This has resulted in a scarcity, of tree products for every-day use, in particular timber for construction and fuelwood. Tree trials conducted recently in Kiribati to identify fast-growing trees for agroforestry have revealed exotic species adapted to atoll environments.

Climate

Atoll climates are warm and humid, with little variation in temperature range from one island to another (Small 1972). In general, atolls to the North of the Equator receive more rainfall than atolls to the south of the equator. In Tarawa, Kiribati the temperature ranges between 25°C and 34°C-the average is 28°C-and the average humidity is 78%. Sunshine averages 257 hours per month (Barr 1993). Average yearly rainfall is a little over 2000 mm with the "wet" months from November to March. Droughts of several months and periods of a year or more with low rainfall occur (Webb 1994).

Soils

Atoll soils are derived from coral reefs and consist mainly of calcium and magnesium carbonates (Town 1982). Average soil particle size is extremely large compared to other igneous derived soils and therefore the soil is highly permeable with a low water holding capacity. The average pH is between 7.8 and 8.3 (Barr 1993).

In Kiribati, soils are shallow, well drained and deficient in nitrogen, potassium, and trace elements, especially iron, manganese, zinc and copper. The organic matter in the thin top-soil layer is almost totally responsible for nutrient recycling and exchange between plants and soil. Compost and organic material are added to planting holes/trenches to lower pH and make nutrients more available for plant growth. This is important not only for making primary elements available to plants, but also minor elements i.e. iron, copper, zinc and manganese (Barr 1993). The incorporation of organic matter also improves soil water holding capacity, of particular importance during periods of low rainfall (Webb 1994).

Iron deficiency is a common constraint to plant growth on atolls. Symptoms consistent with iron deficiency (Webb 1994) include:

- plant loses vigor and only newest leaves are pale while older leaves remain green and reasonably healthy looking;
- leaf veins remain green and tissue between the veins is yellow;
- many shoots are produced instead of a single upper shoot, causing a "witches broom" effect and;
- plant growth stops and the plant eventually dies.

Iron deficiencies can be corrected with foliar applications of iron sulfate (Webb 1994), or by adding iron chelate to the soil. With nitrogen-fixing legumes, iron deficiency may also manifest itself as a N deficiency, as

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rhizobial symbiosis is dependent on iron (Sarrantonio 1991).

Tree Trials

Trials to test exotic species with agroforestry potential were established in Kiribati in 1992 and 1994 in collaboration with the Nitrogen Fixing Tree Association's Agroforestry Information Service. Native, naturalized and exotic species were included in the trial. Nitrogen fixing tree (NFT) species included: *Acacia ampliceps, A. auriculiformis, A. aulacocarpa, A. crassicarpa, A. saligna, Albizia lebbeck, A. procera A. saman, Casuarina glauca, C. equisetifolia, Calliandra calothrysus, Gliricidia sepium, Leucaena leucocephala* (common type), *L. leucocephala* K636 (giant type), *Pithecellobium dulce* and *Sophora tomentosa.* Non-NFTs tested were *Delonix regia* and *Eucalyptus camaldulensis.*

Sophora tomentosa and *C. equisetifolia* grow well on most atoll soils with a minimum of extemal inputs. *Gliricidia sepium, L. leucocephala* (common type) and *D. regia* grow well only on improved soils, such as those found in home gardens. *Leucaena leucocephala* K636 (giant type) and *A. lebbeck* are growing well only under partial shade from coconut trees and in soil that received one fertilizer application at the time of planting. *Pithecellobium dulce* is surviving but is stunted and chlorotic. The other species tested did not survive.

Species to be included in future tree trials are *Sesbania sesban, Sesbania grandiflora, Erythrina fusca* and E. *variegata.*

Agroforestry Uses of Trees and Shrubs on Atolls

Table 1 lists agroforestry uses of some common trees and shrubs found on atolls throughout the Pacific.

Fuelwood. Pemphis *(Pemphis acidula)* and the coconut tree *(Cocos nucifera)* are the preferred fuelwood species in Kiribati. Pemphis provides small, thin sticks that burn hot, even when green. Coconut palm fronds are commonly burned, and in places were fuelwood is scarce, coconut husks are also burned.

Of exotic species, casuarina, or ironwood *(Casuarina equisetifolia)* is a popular fuelwood. The wood burns hot, branches are easy to cut, and it resprouts after repeated cuttings.

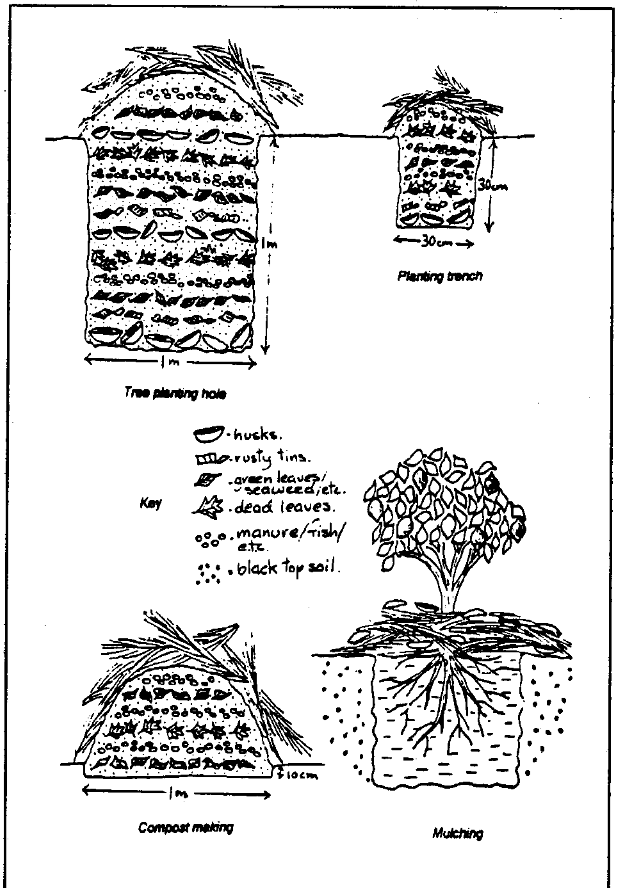
Albizia *(Albizia lebbeck)* Mexican lilac *(Gliricidia sepium)* and leucaena *(Leucaena leucocephala)* are good fuelwood species although they are not yet common on atolls.

Construction. The hard, durable wood of alexandrian laurel *(Calophyllum inophyllum)* is used in home construction and for canoes. The trunks and leaves of coconut trees and screwpine *(Pandanus tectorius)* are used for house supports and frames, and thatched roofs. Because of its hardness and durability, pemphis wood is used mainly for posts in house construction. It is also used to make tools, boat parts and eel traps. Straight branches of guettarda *(Guettarda speciosa)* are used as stakes in seaweed production as they are very resistant to sea water.

Compost. Dead leaves and flowers of guettarda and beach heliotrope *(Tournefortia argentea)* are preferred composting materials on many atolls. Green leaves of sophora *(Sophora tomentosa)* are commonly used as compost material where the species is naturalized. Leaves of casuarina, Mexican lilac and leucaena are occasionally used. Rotted coconut husks and trunks are added to compost to retain humidity. Rusty tin cans are added to provide iron.

Human Food. Night blindness is a serious problem on many atolls because of a lack of vitamin A in diets. The green leaves of hibiscus *(Hibiscus manihot),* Indian mulberry *(Morinda citrifolia),* hedge panax *(Polyscias guilfoylei),* tree spinach *(Pisonia grandis)* and drumstick tree *(Moringa oleifera)* are rich in vitamin A and can be boiled and eaten like leaf spinach.

Pig Fodder. Rotted breadfruit *(Artocarpus altilis)* coconut meat, and screwpine fruit are traditional pig fodders. Although not commonly used on atolls for this purpose, leaves of albizia, Mexican lilac and leucaena can be mixed in small amounts with traditional fodders as a protein-rich supplement.



Planting hole trench and composting methods.
From: Webb 1994, p. 64

Medicine. The leaves, fruits, roots, trunks, and branches of many of the species listed in Table 1 are used in local folk medicine. Recipes are often secret and known only to a few people.

Various parts of the coconut tree are commonly used to make medicinal remedies. Oil extracted from coconut meat is used in message, and is mixed in a drink to treat stomach aches. Juice extracted from husks and bark fibers is used to treat hepatitis.

Juice extracted from screwpine roots and mixed with juice extracted from leaves of other plants is used to treat diabetes. Juice extracted from Indian mulberry leaves is also used to treat diabetes, and children's coughs.

Ornamentals. Many of the species listed in Table 1 are valued as ornamentals for their shade, flowers, or shape. Hedge panax is a popular hedgerow shrub as it is shade tolerant and can be managed to grow to various heights. Alexandrian laurel is a popular shade tree planted around homes and Mexican lilac is planted primarily for its flowers.

Agroforestry Promotion

Because tree planting is such a labor-intensive effort on atolls, tree selection should focus on multi-purpose species that require a minimum of inputs to plant and maintain. Where native species are known and used locally, they often require less promotion than exotics. In Majuro, The Marshall Islands there is strong demand for native species, especially ones with medicinal properties (Fred Muller, personal communication).

Nitrogen-rich leaves from fast growing NFTs such as sophora, casuarina, Mexican lilac and leucaena should be promoted as compost material.

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Table 1. Agroforestry uses of trees and shrubs on atolls

Species	Common name	IN	SL	CP	FW	CW	PF	HF		AM	OR
Native & Naturalized								L	F		
Artocarpus altifis	breadfruit	x		x		x	x		x	x	x
Calophyllum inophyllum	Alexandrian laural	x	x			x			x	x	x
Cocos nucifera	coconut tree	x	x	x	x	x	x		x	x	
Cordia subcordata	sea trumpet	x	x	x		x				x	x
Ficus tinctoria	native fig	x		x					x	x	
Guettarda speciosa	guettarda	x	x	x		x	x				x
Hibiscus manihot	hibiscus spinach	x						x[1]			x
Hibiscus tiliaceus	native hibiscus	x		x		x				x	
Morinda citrifolia	Indian mulberry	x						x[1]		x	x
Pandanus tectorius	screwpine	x	x	x		x	x		x	x	
Pemphis acidula	pemphis		x		x	x				x	
Pisonia grandis	tree spinach	x					x	x[1]			
Polyscias guilfoylei	hedge panax	x						x[1]			x
Rhizophora mucronata	mangrove		x			x				x	
*Sophora tomentosa**	sophora	x	x	x						x	x
Terminalia catappa	beach almond	x				x			x	x	x
Tournefortia argentea	beach heliotrope		x	x	x	x				x	x
Exotics											
*Albizia lebbeck**	albizia	x	x		x	x	x			x	x
*Casuarina equisetifolia**	ironwood	x	x	x	x	x					x
Gliricidia sepium *	Mexican lilac	x		x	x	x	x			x	x
*Leucaena leucocephala** (K636 giant type)	leucaena	x		x	x	x	x				x
Moringa oleifera	drumstick tree	x		x	x	x	x	x[1]	x	x	x
Tamarindus indica	tamarind	x			x	x	x		x	x	x

Recommended planting site: **IN** Inland; **SL** Shorline

Agroforestry uses: **CP** Compost; **FW** Fuelwood; **CW** Construction Wood; **PF** Pig Fodder; **HF** Human Food (**L** Leaves, **F** Fruit); **MD** Medicine and; **OR** Ornamental

* Nitrogen fixing

[1] Source of vitamin A

References: (Thaman and Whistler 1994; Town 1977; Webb 1994; Whistler 1992)

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Seed Treatment and Inoculation

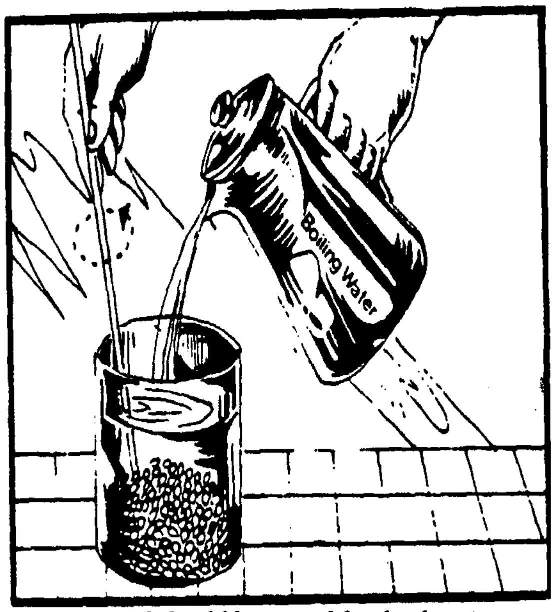
To germinate and grow, seeds must absorb water. The seeds of many tree species have waxy or thick "seed coats" that inhibit water absorption and thus delay germination. Seedcoats dissolve slowly in several ways. Exposure to sun, rain and wind dissolves the seedcoat over time. The heat from natural fire cracks the seedcoat. Insects and animals may nibble holes in the seedcoat without damaging the seed embryo. When seeds are consumed by animals, stomach acid weakens the seedcoat. Once passed through the animal, seeds germinate. Under natural conditions the seed crop of one year germinates unevenly over a long period. This uneven germination strategy assures that at least some of the seedlings will survive environmental hazards such as drought, fire, frost or insect or animal attack. Seedlings that germinate early may be well enough established to survive such hazards late in the season, while seedlings that germinate late will avoid early-season problems. Some seeds will remain dormant in the soil for years.

Seed Treatment

In nursery or plantation it is easiest to protect seedlings or trees when they are of uniform age and size. Uniform seedling size can be achieved by proper seed treatments before sowing. Seed treatments, which mimic nature, are designed to penetrate the protective seedcoat and allow water to be absorbed. Several seed treatment methods are common:

- Cool water - Seeds are soaked in cool, room temperature, water until they swell. The volume of water should be five times the volume of seeds. Soaking time may from 6-48 hours depending on species, provenance, age and quality of seed. This treatment is appropriate for seeds with a thin or soft seedcoat, recently harvested seed, seed of small-size, and large quantities of seed.

- Hot water - Pour boiling water over the seeds at a volume five times the volume of seeds. The seeds must be stirred gently during the 2-5 minute soak. **Hot water can kill the seed - it is important not to soak the seed for too long!** Pour off the hot

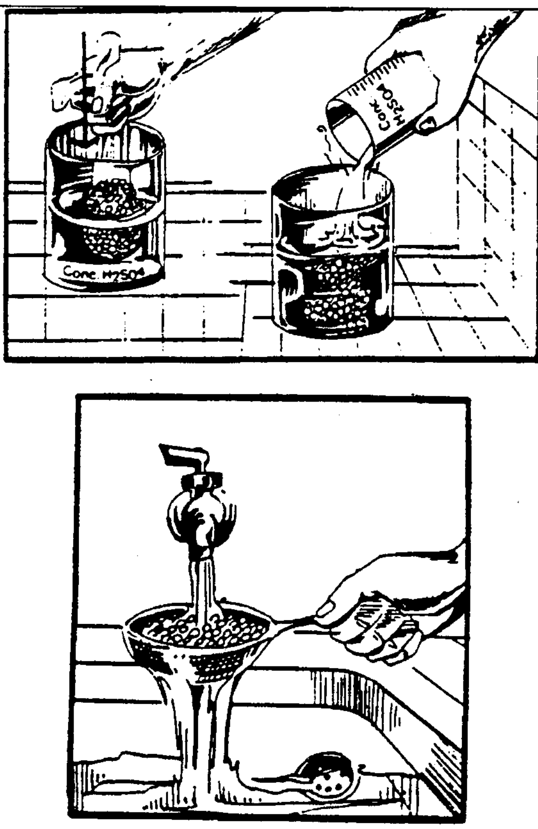


Seed should be stirred for the duration of the hot water treatment.

water, replace it with cool water and soak for 12 hours. This treatment is appropriate for seeds with hard or thick seedcoats, old seed, and large quantities of seed.

- Acid - Cover seeds with sulfuric acid for 10-60 minutes. Seed should be completely submerged but just below the surface of the acid. **Acid can kill the seed - do not soak the seed for too long!** Gauge the length of acid treatment by the appearance of the seed.The waxy gloss of the seedcoat should be replaced by a dull appearance. A pitted appearance indicates damage - remove the seeds before this occurs. Remove seed from acid, rinse with water for 10 minutes and soak in cool water for 12 hours. **Do not pour water into the acid or a violent reaction will occur!** The acid can be used several times. This treatment is appropriate for seeds with hard and thick seedcoats. **Acid treatment can be dangerous and expensive! In most circumstances it is not recommended!**

Written by James M. Roshetko, Program Associate, Winrock International



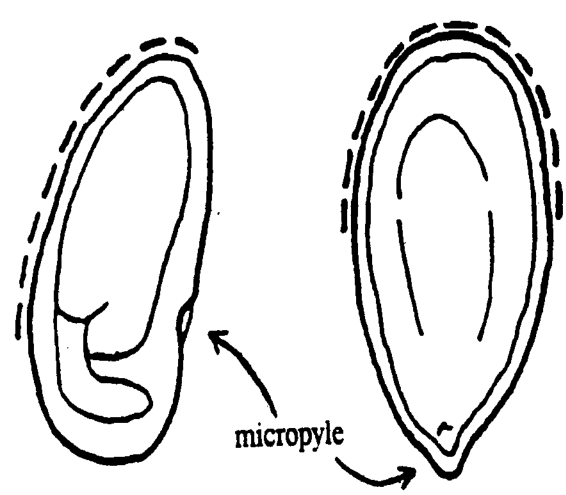
After soaking the seed in acid for 10-60 minutes rinse with water for 10 minutes.

- Nicking - Cut or scrape a small opening in the seedcoat. A knife , nail clipper, metal file, sand paper or sanding block can be used for this operation. To avoid damaging the seed embryo, cut or scrape the seedcoat only opposite the micropyle (the small ring where the seed was formerly attached to the fruit of its mother plant). Nicked seed is soaked in cool water for 12 hours. This treatment is appropriate for all types of seeds, with the exception of those that are very small or recalcitrant (having a soft seedcoat and short viability). However, being time consuming, this treatment is feasible only for small quantities of seed.

- No treatment - Some seeds germinate quickly without treatment Application of the above methods may be impractical, make seed difficult to handle or decrease viability. No treatment is needed for tiny seed, i.e. *Alnus* sp. and *Casuarina* sp.; seeds with thin or incomplete seedcoats: and recalcitrant seed, i.e. *Inga sp.*

The length of the initial soak in cool water, hot water or acid will vary according to species, provenance, age and quality of the seed. If large numbers of seedlings will be produced, or nursery operations will last for several years, it is recommended that several soaking times be tested in order to determine the most suitable time length for local conditions. As noted, with all methods the last process is to soak seed in cool water for 12 hours. This final process allows seed to absorb water, results in visible swelling and further hastens germination. To improve this process, and thus germination, this period may be increased up to 48 hours. A summary of appropriate seed treatments for select species is listed in Table 1. Once removed from this final soaking the swollen seeds should be sown immediately - do not store treated seed! At this point, follow standard nursery or and plantation procedures (Evans 1982, Jackson 1987, Liegel and Venator 1987). When sowing seeds directly in the field, operations must coincide with the beginning of the rains. Treated seed germinates quickly, and a short dry period will result in high mortality. It is best to wait for the first rain before direct sowing treated seed.

Nitrogen Fixation. Many tree species can transform or "fix" atmospheric nitrogen into a form the tree can use for growth: This allows the "nitrogen fixing tree" (NFT) to grow on degraded soils that are poor in nitrogen. NFTs are common components in farming systems, land reclamation schemes, pasture systems, fallow improvement, home gardens and ornamental plantings. These trees provide valuable timber, fuelwood, poles, fodder, green manure, honey, fruit, vegetables, shade and other products. For further details concerning NFT management systems and products see Macklin (1990).



Nicking the seedcoat opposite the micropyle (along the dotted line) avoids damage to the seed embryo.

Table 1. Appropriate seed treatments for select species (Revised from Macklin *et al. 1989*).

Species	Treatments	Seeds / kg
Acacia acuminata	C; D	60.000-80.000
Acacia aneura	A; C	75,000-95.000
Acacia angustissima	C; D	90.000-100.000
Acacia auriculiformis	A for 30 sec.; B for 15 min; C	30,000-90,000
Acacia crassicarpa	A for 30 sec.; C	40.000-60.000
Acacia holosericea	A for 1 min.; C	70,000-80,000
Acacia mangium	A for 30 sec.; C	80,000-100,000
Acacia mearnsii	A;C	48.000-85.000
Acacia melanoxylon	A; B for 15 min.; C	60,000-100,000
Acacia nilotica	A; C; D	7,000-11.000
Acacia polyacantha	D	10,000-25,000
Acacia salinga	A; C	14,000-25.000
Acacia senegal	C; D	10.000-30.000
Acacia tortilis	A; C; D	12,000-18.000
Albizia lebbeck	A; C; D	6,000-16.000
Albizia procera	A; C	20,000-24.000
Albizia saman (syn. Samanea saman)	A; C	6,000-8,000
Alnus sp.	E	200.000-2.300.000
Cajanus cajan	D; E	5,000-12,000
Calliandra calothyrsus	A; C; D	18,000-20,000
Casuarina sp.	E	150,000-1.500.000
Chamaecynsus palmensis	A for 4 min.	38,000-42.000
Dalbergia sp.	D	10,000-30.000
Desmodium sp.	E	500,000-600,000
Enterolobium cyclocarpum	C; D	800-2.000
Erythrina poeppigiana	D	3,000-5.000
Faidherbia albida (syn. Acacia albida)	A; B for 20 min.; C; D	20,000-40,000
Flemingia macrophylla	A; B for 15 min.; D	50.000-80,000
Gliricidia sepium	C; D,, E	7,000-12,000
Inga sp.	E - recalcitrant	50-150
Leucaena sp.	A; B for 5-15 min.; C	22.000-35.000
Mimosa scabrella	C; D	60,00-90,000
Paraserianthes falcataria (syn. Albizia falcataria)	A; B for 10 min.; C	40,000-50.000
Pithecellobium dulce	C; E	9,000-25.000
Prosopis sp.	A; C	20,000-50.000
Pterocarpus indicus	E	1,5000-2.000
Robinia pseudoacacia	A; B for 20-60 min.; C	35,000-50,000
Sesbania grandiflora	C; D	20,000-30,000
Sesbania sesban	A; C; D	85,000-100.000
Tipuana tipu	E	1,600-2,500

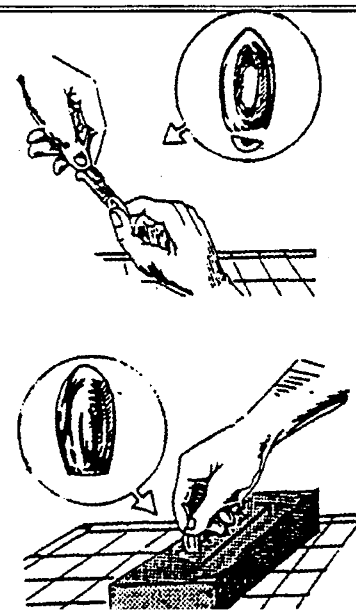
Key: A - Hot water; B – Acid; C - Nicking; D - Cold water; E - No treatment.

Nitrogen fixing trees fall into two categories, based on the symbiotic microorganisms which enable nitrogen fixation to occur. Trees in the families Leguminosae and Ulmaceae fix nitrogen with bacteria from the genus *Rhizobium*. Species from several families - including Betulaceae, Casuarinaceae, Elaeagnaceae, Rhamnaceae, Rosaceae - fix nitrogen with actinomycete bacteria from the genus *Frankia* (Postgate 1987, NFTA 1989). The most important NFT genera include the legumes *Acacia, Albizia, Calliandra, Chamaecytisus, Dalbergia, Erythrina, Flemingia, Gliricidia, Leucaena, Prosopis*

and *Sesbania,* as well as, the non-legumes *Alnus, Casuarina, Elaeagnus, Hippophae* and *Robinia.* The bacteria form nodules on the roots of the tree, and nitrogen fixation occurs inside these nodules. Healthy nodules that are fixing nitrogen are easy to identify. Cut them open and check their color. Pink or red nodules are fixing nitrogen, while green, black or brown nodules are not.

There are many strains of *Rhizobium* and *Frankia.* These bacteria and the NFTs exhibit an exclusive preference for one another. Some *Rhizobium* will form nodules with some legumes but not others. The same type of preference is shown between *Frankia* and the non-legumes. A successful match must be made if functioning nodules are to be formed.

In areas where a tree is native or naturalized, the soil will likely contain bacteria of appropriate bacteria strains. If a tree is not common in an area, or the site is degraded, there may not be enough of the correct bacteria in the soil to stimulate nodulation and fixation. It should be noted that *Frankia* survives in the soil without the presence of the host plant for longer periods than *Rhizobium.* In any case, it is best to treat seeds or seedlings with the appropriate strain of bacteria to stimulate maximum nitrogen fixation. This process is called inoculation.



Seed can be "nicked" by cutting or scraping through the seedcoat.

Inoculation

The material used to inoculate seeds or seedlings is produced by isolating bacteria from the root nodules on healthy trees, growing them in a laboratory and mixing them with peat. The peat-based inoculant contains 1000 times the number of bacteria normally found in the soil. The bacteria in inoculants are alive. They are sensitive to heat, drying out and direct sunlight. The inoculant should be tightly sealed and stored in a moist, cool, dark place when not in use. It should not be frozen, as freezing kills the bacteria. The inoculant should be applied to tree seed directly after seed treatment and immediately before sowing. Application of inoculant is most effective when seeds are first covered with a sticker solution. Place seeds in a plastic bag or bucket and cover them with the solution made of gum arabic, sugar or vegetable oil. Either dissolve the 40 g of gum arabic in 100 ml of hot water and allow to cool, or dissolve 1 part sugar in 9 parts water. Combine 2 ml of one of these mixtures, or 2 ml of vegetable oil, with 100 g of seeds and shake or stir until the seeds are well covered. Then add 5 mg of inoculant and shake or stir until the seeds again are well covered. Allow the inoculated seeds to dry for 10 minutes to eliminate any stickiness and sow immediately (Keyser 1990). Do not store inoculated seed - the bacteria will die.

Seedlings can also be inoculated in the nursery after germination. Mix inoculant in cool water and irrigate the seedlings with the suspension. Keep the mixture well shaken and irrigate until the inoculant is washed into the root zone. A 50 g bag of inoculant is sufficient to inoculate 10,000 seedlings (Keyser 1990). For effective inoculation of seeds or seedlings to occur the bacteria in the inoculant must be appropriate for the tree species involved. For information on inoculum availability contact :

Nitrogen Fixation in Tropical Agricultural
Legumes (NifTAL) Center
1000 Holomua Road
Paia, Hawaii 96779 USA
Phone: 1 (80-8) 579-9568
Fax: 1 (808) 579-8516

Lipha Tech (Nitrogen Inoculants)
3101 West Custer Avenue
Milwaukee, Wisconsin 53217 USA
Phone: 1 (414) 462-7600
Fax: 1 (414) 462-7186

AgroForester
Tropical Seeds
PO Box 428
Holualoa, Hawaii 96725 USA
Phone/Fax: 1 (808) 326-4670

It may not always be possible to obtain laboratory -produced inoculant. At such times, soil containing the appropriate bacteria can be gathered from under trees of the appropriate species. Choose healthy trees that are growing well and that have abundant and robust red or pink nodules. Some of this soil can be mixed with nursery potting mix or added to planting pits. Inoculation by this method ensures that the bacteria will be appropriate for the tree species and the local environment. However, this approach is generally not as effective as using a correct laboratory-produced inoculant.

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Agroforestry for the Pacific Technologies

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Community-based Tree Seed Production with *Desmodium rensonii* and *Flemingia macrophylla*

Community-based forestry and agroforestry programs around the world reforest denuded lands, protect valuable watersheds and produce indispensable tree products for local needs. These programs begin planting operations with a commodity of small size but great importance - seed! Adequate supplies of high-quality tree seed are necessary to grow high quality seedlings. Unfortunately, shortages of seeds are common and limit the success of many community-based tree planting programs.

Many of these community-based programs are operated by non-profit organizations or farmer groups on shoestring budgets. They are not able to purchase premium-priced seed from regional or international producers - where prices are as high as US $ 100/kg.

Rensonii and flemingia are used to control erosion on steep agricultural lands. (Photo: J.M. Roshetko).

Even if funds for seed purchase are available, other problems arise. Shipment through international and local mail may be time consuming and irregular. Seed viability often suffers and sometimes shipments never arrive. Information on the provenance (geographic origin) may be lacking, incomplete or inaccurate. When received, seed may be of inferior quality or inappropriate for local environmental conditions.

Local Seed Production

Organizations and individual farmers can overcome the 'seed problem' by 'growing' their own seed. Seed production serves organizations and individuals in several ways. Less time is spent searching for seed sources and less money is spent on seed purchases. The time and money saved can be allocated to other activities. Locally produced seed has a proven genetic quality for local environmental conditions. Organizations and farmers also realize a financial benefit when seed is sold. Seed sales increase income and decrease economic risk by diversifying farm production and targeting new markets.

The Mindanao Baptist Rural Life Center (MBRLC) in Bansalan, Davao del Sur, the Philippines has operated agroforestry and other rural development projects since 1971. To meet the seed needs of their extensive planting programs, MBRLC and their farmer collaborators produce seed of 12 to 15 tree and cover crop species. Stocks of seed in excess of their own needs are sold at reasonable prices to organizations and individuals throughout the Philippines and parts of Asia. Seed production focuses on multipurpose species with strong market demands. Two popular species are *Desmodium rensonii* and *Flemingia macrophylla.* Both species are nitrogen-fixing leguminous shrubs which produce large quantities of leafy biomass. They are commonly used to produce fodder, green manure or mulch, and for erosion control in hedgerow cropping systems on steep

Written by James M. Roshetko, Program Associate, Winrock International

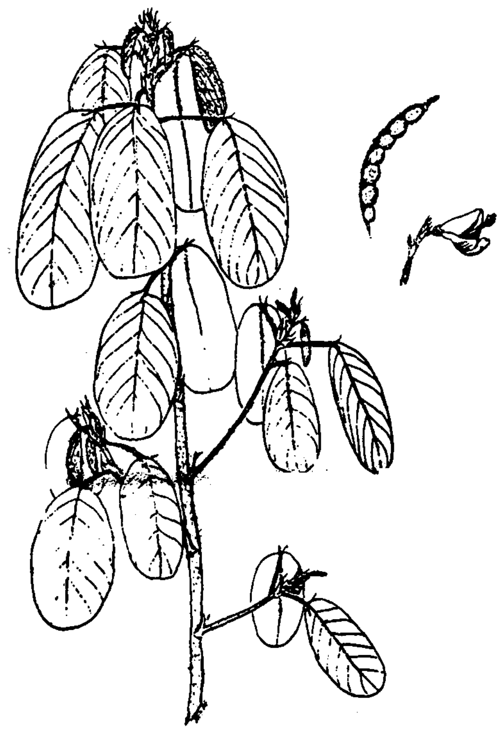
agricultural lands (Budelman 1989, Laquihon and Pagbilao 1994). Standard seed production methods employed by MBRLC with these two species are summarized below.

Desmodium rensonii

Rensonii seed is hard and small, about 500,000/kilogram. Seed color varies from brown and yellowish-brown through green. Large shiny-brown seeds demonstrate the best germination and growth.Seed germinates quickly, in 3-4 days, without treatment (MBRLC undated, Roshetko 1995). Rensonii is often established by direct sowing in double hedgerow systems. Spacing between double rows is 50 cm. Depending on percent slope and companion crops, distance between hedgerows varies from 24 meters; in-row spacing varies from 10 to 2.5 cm. A pinch of seed between the thumb and one finger is sufficient to establish one meter of hedgerow with an in-row spacing of 2.5 cm. Close spacing promotes leafy biomass production (for fodder or green manure) and soil erosion control, while still yielding good quantities of seed. It is necessary to coordinate pruning of hedgerows with the plant's biological seed production cycle, or preserve unpruned areas of the hedgerow especially for seed production.

Establishment of a seed orchard is recommended for maximum seed production. Trees are planted at a 2x2 m spacing by sowing 2-3 seed per position. After two weeks thin seedlings to one per position. Initial growth may be slow. As germinants and small seedlings, *Desmodium* species are particularly sensitive to weed competition (Roshetko *et al.* 1993). It is important to practice thorough weed control until trees are well established. Once established, rensonii will dominate most weed vegetation.

Seven months after establishment plants will produce seed, however quantity and quality of this first crop are low. Plants will be in full seed production by the second year. Seed yields will increase as the plants become larger. Seed is mature when pods turn brown. Green pods produce inferior seed. Pods should be harvested when 80% are brown. Harvest by hand stripping brown pods from branches. Use the least force necessary to remove mature pods. Green pods should remain on the branch to mature for subsequent harvest. Hand



Desmodium *sp.*
(Source: Hensleigh and Holaway, 1989).

harvesting allows four seed crops per year. Harvesting pods with a knife by removing foliage or branches reduces subsequent seed crops.

After harvest, sun dry pods for 2-3 days. To extract seed, pound pods with a mortar and pestle and separate debris by winnowing. Sun dry clean seeds for another 2-3 days or until moisture content is 10-12% (MBRL C undated). Clean seed can be stored for two years in air-tight containers. To guard against insect and fungal attack treat 3 kilograms of seed with 1 teaspoon of *Sevin* insecticide and 1 teaspoon of *Captan* fungicide (MBRLC undated). Seed should be stored in a cool dry place removed from direct light. On a fertile site, a well-maintained ten-meter double hedgerow can produce 3.5 kilograms of seed per year.

Flemingia macrophylla

The seed of flemingia is also hard and small, with 45,000-97,000 per kilogram (Budelman 1989). To improve germination, the shiny black seeds are treated before sowing. Soak seeds in boiled water for 2-3minutes, gently stirring the seed for the duration. Pour off the hot water, replace with cool water and soak for 12 hours. Merely soaking seeds in cool water for 12 hours will also improve germination (Roshetko 1995). Germination occurs in 7-14 days. Flemingia seedlings grow slow and are sensitive to competition. Weed control should be maintained for 3-6 months (Budelman 1989, Roshetko *et al.* 1993). As with rensonii, flemingia is usually established by direct sowing. Spacing and management for hedgerow systems or seed orchards are similar for the two species. With flemingia a larger volume of seed is needed to establish an equal length of hedgerow. A pinch of seed between the thumb and two fingers is needed to establish one meter of hedgerow with an inrow spacing of 2.5 cm

Flemingia macrophylla.
(Source: Hensleigh and Holaway, 1989).

Flemingia produces flowers and seed within 6-7 months. As with rensonii, seed yields are limited in the first year, but increase with age and size of the trees. The nutritious pods attract insect attack. It may be necessary to treat plants with insecticides (MBRLC undated). The small pods generally contain two seeds (Budelman 1989). At maturity, the pods turn brown and split, discharging their seeds. It is important to harvest pods before the discharge of seeds. As with rensonii, pods should be harvested by hand-stripping cutting branches will decrease subsequent seed crops. Branches are small, soft and damage easily. During harvesting operations, care must be maintained to avoid damaging the plants. Flemingia can produce two seed crops per year.

Harvested pods are sun dried for 2 days. Once dry, put pods in a sack and gently pound with a stick. This process will detach the seeds from the pods. Sun dry contents for two more days and winnow to separate seeds from debris. Seed storage methods are the same as with rensonii. A ten-meter double-hedgerow can produce 1 kilogram of seed per year.

General Guidelines for Seed Production

Local seed production programs for any species should observe some guidelines to assure the maintenance of high-quality genetic stock. First and foremost, the seed used to establish a seed production area must be of the highest genetic quality. The seed should be from an area with similar environmental characteristics to the establishment site. To ensure genetic diversity, the seed should have been collected from at least 25 healthy 'mother-trees' with a minimum distance of 100 meters between each tree. Mother trees, should display the same characteristics for which trees are being raised; i.e., straight boles or limbs, tall height, maximum biomass production, etc. Seed should not have been collected from isolated trees because they may have been self-pollinated or pollinated by only a few individuals. Seed obtained from harvesting operations that have complied with these precautions will produce trees with a broad and healthy genetic base.

When collecting seed from human-made seed production areas continue to follow the guidelines mentioned above. It is worth stressing the importance of collecting seed from a minimum of 25 healthy mother trees displaying the desired characteristics. Because seed production areas are of small size, it may not be possible for all mother trees to be 100 meters apart. In such cases, select mother trees that are equally spaced throughout the seed production area. With hedgerows, collect seed from across its length. Additionally, collect seed from all parts of a tree's crown -top, bottom and sides - each part may have been pollinated by different individuals. This precaution will help maintain a broad genetic base (Anonymous 1992). Be cautious of collecting seed from human-made stands of trees where origin of the mother trees is not known. Such stands may have been planted from seeds of only a few individuals and will have a narrow genetic base. Trees reproduced from a narrow genetic base often display depressed growth and survival - a situation not beneficial to the planter. Avoid this situation by maintaining a broad genetic base.

Once dried, seed should be separated from debris by winnowing. (Photo:J.M. Roshetko).

Acknowledgement:
Much of the information reported in this fact-sheet was collected during interviews with MBRLC staff members, including: Jeff Palmer, Carlos Juano, Generoso Laquihon Jr., and Calvin Fox.

For more information on community-based seed production of multipurpose trees and "Sloping Agricultural Land Technology (SALT) " contact:

Mindanao Baptist Rural Life Center
PO Box 80322
8000 Davao City
PHILIPPINES
Phone: 63 82 221-1185

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Seed Production Guidelines for Tropical Tree Legumes

Any discussion about tree seed production must consider the adage "garbage in equals garbage out". If you plant junk seeds you will inevitability harvest junk trees. Junk refers to inferior tree seeds derived mainly from inbreeding, collected from a narrow genetic base and uncontrolled hybridization. Junk also arises from indiscriminate seed collection from non-superior trees.

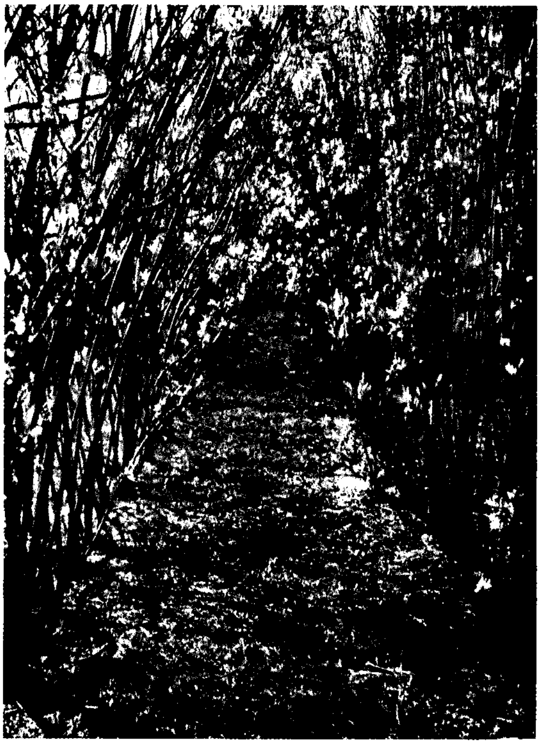
I. Meeting Short term seed needs

Genetically improved tree seed production is a long term objective. However, when quality tree seed is required for immediate planting, the following guidelines should be observed.

A. Collect seed from superior individual trees from large populations. Caution should be exercised since superior trees could be the result of environmental effects. Do not collect seed from all the trees in a population. The intensity of selection should be approximately 10% or less of the total population, but should consist of a minimum of 25 trees. Do not select heavy seeded trees since these trees put additional energy into producing seeds rather than wood or leaf. Generally, seed collected from superior individual trees from a large population will be adapted to local environmental conditions and tolerant of insects and diseases found locally.

B. Obtain tree seed from proven sources. This is the most common method of obtaining seed quickly. If local testing has identified a superior seed source or provenance that has proven well-adapted then this can be very successful. If the original testing and documentation were accurate and the integrity of the seed supplier is not in question, there should be no problems. Bulk collections of undocumented or vaguely defined seed sources should be avoided.

The Oxford Forestry Institute collected 30 *Gliricidia sepium* provenances that represent a wide range of variation and distributed the seed to over 100 collaborators in the tropics. Subsequent trials identified Retalhuleu (Guatemala) as a superior provenance of *G. sepium* appropriate for use at many sites. This example illustrates the benefit of using source identified tree seed when large quantities of specific tree species are required.



Gliricidia *seed orchard. (Photo: Mulawarman)*

II. Three Aspects of Seed Production

Genetic diversity should be promoted since a large range in genetic variation is necessary to achieve improvement of tree quality. Without sufficient genetic variability it is difficult to make gains for traits of interest. Any attempt to improve trees from a narrow base will be unsuccessful.

Inbreeding depression results from a high proportion of self-pollination in the breeding population. This must be avoided at all costs since inbreeding confers a lack of fitness or a lack of adaptation.

Written by Nicklos S. Dudley, Tree Crop Specialist, Crop Science Department, Hawaiian Sugar Planters Association, 99-193 Aiea Heights Drive, Aiea, Hawaii 96701 USA

Hybridization is a cross between two varieties or species. Vigor and fitness are associated with hybridization between superior individuals. What must be avoided is "uncontrolled" hybridization (i.e. contamination from inferior individuals) that dilutes the genetic quality of superior parent trees. For agricultural crops, hybridization is generally between different varieties of the same species. However, in forestry hybridization most often occurs at the species level as interspecific hybridization.

III. Meeting long-term seed needs - Seed orchards

Relatively few organizations are willing or able to make the long term commitment necessary to establish orchards for tree seed production. If the decision is made to establish a seed orchard, a long term plan is very important. Several years of planning are required before the first tree is planted. A number of issues must be considered before establishment. Some relevant issues include: Are there sufficient financial resources and have land tenure issues been resolved? What type of orchard is appropriate for the tree species of interest? Are there locations where tree species will flower early and heavily? Does your organization have the expertise to manage the seed orchard successfully?

A seed orchard is an area where seeds of particularly valuable genotypes are produced to obtain seed as quickly and economically as possible. This is a specialized plantation of selected progenies which are isolated to avoid contamination, and managed to produce frequent, abundant, and easily harvested seed crops. Orchards can be for genetic improvement and production of large quantities of seed for operational planting. Generally, the benefits of orchards are the production of seed with improved disease and insect resistance, growth, wood qualities, adaptability, and tree form.

Types of Seed Orchards

Seedling seed orchards are plantations with known family identity that are managed for maximum seed production. They consist of a population of open (naturally) pollinated families of selected trees. Often, they are "first-generation" orchards that are the result of species and provenance trials. Typically, they result from rouging, a process of removing the trees with less desirable genetic potential. Most multiple-purpose tree seed orchards are of this type.

Harvesting seed in a Leucanea *orchand*
(Photo: James M. Roshetko)

Vegetative orchards are established from vegetative material such as clones, cuttings, grafts, or other asexual methods such as micropropagation. These are the most common operational orchard for large scale seed production. They are categorized as being "advanced-generation" orchards where selected parents trees of known pedigrees are utilized. Vegetative orchards are most often associated with industrial forest species such as eucalyptus and pines.

Both types of orchards serve specific needs. The tree species of interest and breeding method will determine which type of orchard is most suitable for seed production requirements.

Site Selection Criteria

An ideal site will have good soil structure, drainage, and fertility, with protection from high winds. Seed orchards also require level or gently sloping terrain with easy access and good security. They should be located near the nursery or farm offices so that equipment and personnel are readily available. This will aid in overall orchard efficiency by reducing travel time to the site. Generally, abandoned agricultural lands make good sites.

It is important that site environment characteristics encourage early and heavy flower production. Site requirements differ depending on the tree species of interest.

The distance between the orchard and contaminating foreign pollen is called the pollen dilution zone. The appropriate isolation distance for dilution zones are not well documented for most tropical tree legumes and depends on the mode of pollen transport. A wise approach is to keep as great a distance as possible from the orchard and sources of contamination. Many tree legumes are pollinated by insects. In such cases, a dilution zone of at least 100 in should reduce contamination to an acceptable level.

Seed orchard size depends on seed production objectives. Generally, if average rate of seed production per tree is known, then calculating the number of trees needed to reach the production objective is straight forward. An orchard where insects are controlled and soil fertility is well managed will yield seed of higher quality and quantity then an unmanaged orchard.

Orchard Establishment and Management

Ripping with a subsoiling implement to eliminate soil compaction should be considered on abandoned agricultural land. Soil pH should always be tested and nutrient levels amended as required to promote growth and flowering. Generally, the elements of importance are nitrogen for growth and phosphorus for flowering. However, a deficiency of any marco or micro-nutrient can effect seed production.

Tree spacing in seed orchads is wide (Photo : James M. Roshetko)

Orchards should be established with planting material of high quality. Containerized seedlings have worked well in most tropical conditions. Weed control is very important and can be achieved through chemical, mechanical or manual means. Planting seedlings of high quality and reducing weed competition are the first steps to developing a successful seed orchard. Tree spacing in a seed orchard is wider than timber plantations or agroforestry plantings. The general rule is "Wider is better". Actual spacing will be determined by the canopy shape and size of each specific species. For *Leucaena* and *Gliricidia* a final spacing of 4 x 4 meters is recommended. Often seedlings are planted at closer spacings, 4 x 2 or 2 x 2 meters. After a few years inferior trees are removed to achieve the desired spacing.

Irrigation will improve establishment success, and help maintain growth and vigor of the seed orchard. On arid sites it may be possible to induce flowering by timing of irrigation. There is some indication that flower induction is promoted by moisture stress in some tree species.

Ground covers should be considered between rows to suppress weeds and conserve moisture. The orchard floor will be protected from wind and water erosion, while nutrients and soil moisture will be retained for longer periods.

The size of the canopy of the tree will influence flowering and seed production. Generally, the larger the canopy the greater the seed production. Pruning and coppicing can be used to modify tree form to increase sunlight penetration and canopy size. Both modifications enhance flowering, seed production and ease of seed harvest. Each tree species responds to priming differently, so prune with care until the tree responses as desired. Pruning and coppicing must be timed to disrupt seed production as little as possible. Most tropical tree legumes will benefit from management to increase seed production. A word of caution, poor timing or lack of care in applying these practices will negatively effect seed production and may take a season or more for the tress to recover and produce the next seed crop.

A major factor of determining whether a seed orchard is economically viable will depend upon success of controlling orchard pests. There are two categories of consequential orchard pests, those that attack the flowers and seeds and those that

Coppicing produces wide canopies (Photo : James M. Roshetko)

attack the tree. Monitoring and control measures are important strategies for improving seed yields.

Seed Orchard Records

Record keeping will provide a reference of orchard performance and give insight into productivity and corrective actions that should be taken if problems develop. Records of importance include age at first flowering, months of flower production, and level of flowering. Complete weather records and historical data will aid in seed orchard management and help in planning future orchards. Recording fertilizer rates and formulation, as well as dates of application, is also important. Irrigation quantity, frequency, and dates will help to establish relationships between flowering and seed production. Insect and disease management records of material used, dates and rates applied, method of application and results are very important. Silvicultural treatments such as pruning and thinning should be recorded. Site maps should be updated when trees are removed. Records of adverse environmental conditions such as droughts, high winds, floods and heavy rains, and hurricanes should be noted, and the effect these events had on flowering and seed production.

IV. Techniques of Seed Harvesting and Handling

When the seed of most tree legumes is mature and ready to harvest, pods will become dry and turn color. This indicates that the seed embryo is mature and can be harvested without loss of germination ability. Harvest windows are fairly narrow, about 2 to 4 weeks in duration. It is important to stay on top of harvesting. Late harvesting can result in yield loss due to pod shatter and pest predation, so correct harvest timing is essential.

Dry seed pods can be collected by hand picking, knocking onto tarps with pruning poles, by machinery, or from felled trees during harvest operations. Extraction of seed can be accomplished by beating the pods with a flail, walking over them, or rubbing them through a screen. For larger operations, commercial threshers are more practical.

Cleaning infested or bad seed using flotation will work with seed having hard seedcoats, i.e. *Leucaena. Fill* a container to about 25% with seed and pour in clean water until the container is 75% full. Good seeds will sink. The poor seeds, trash, and insects will float to the top where they are removed. Stir the water and continue to skim off the trash. Slowly pour off the water by tilting the container at a slight angle. The water treatment may need to be repeated several times to remove the bulk of poor seeds. After the water has been poured off, the seeds are removed from the container and spread out on a drying rack until dry then stored. Air sorting is another method that can be used to blow off chaff and empty seeds.

Proper storage is necessary to maintain seed viability. Most seeds with hard seedcoats store for 1-2 years with little loss of viability. The factors that will effect seed viability most are moisture content of the seed, humidity, and temperature. For long term storage a moisture content of 4 to 6 percent is ideal. Storage temperature should be 4.5-10° C (40-50° F) with relative humidity no higher than 70 but preferably below 50. Seed stored for extended periods should be sealed in air-tight moisture-resistant containers. This will protect seed against insects, diseases and mold.

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Agroforestry for the Pacific Technologies
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Understory Cropping with *Pogostemon cablin* : Raw Material for Rural Enterprise

Harvesting non-timber products such as fruits, oils, latex, gums, and fibers offer a way to use forests productively, while protecting them as reserves of bio diversity, wildlife habitat, and watersheds. Many plants produce oils which are important commercial products. Edible oils are usually processed from the seed of a wide variety of crops and forest species. Essential oils are extracted from many plant leaves, flowers, fruits, bark, wood, and roots. They are used in perfumes and cosmetics, medicinal products, pesticides and pest repellants, wood finishing and preservation, and various other industries. Many important essential oils are derived from tropical plant species such as nilam *(Pogostemon cablin),* lemon grass *(Cymbopogon citratus),* vetiver grass *(Vetivaria zizanioides),* sandalwood *(Santalum* spp.), cinnamon *(Cinnamomum* spp.), clove *(Syzygium aromaticum),* ylang-ylang *(Cananga odorata),* and cajuput *(Melaleuca leucadendron).*

Understory cropping: Pogostemon cablin *(nilam) planted under a four-year-old teak stand in West Java. (Photo: C Stoney)*

The Java Social Forestry Project

The Java Social Forestry Project, funded through Ford Foundation grants to Winrock International and several other collaborating organizations, helped to sustain forest resources in an area of high population pressure and land scarcity. The project introduced improved agroforestry technologies which increase the employment and income earning opportunities of landless community members. Forest farmer groups cultivated annual and perennial crops in the open rows of timber plantations on land owned by the state forestry corporation. As their livelihood become moresecure, the forest farmers' motivation to protect the timber plantations also increased. As a result, tree survival and growth rose dramatically on sites that in previous years had been plagued by forest fire, illegal clearing, and timber theft.

Farmers planted rice, corn and other annual crops between the rows of seedlings in newly reforested timber plantations. While the trees were young, harvests from these crops greatly increased family incomes. However, once the forest canopy began to close, shade from the trees prevented further intercropping. Winrock worked with Indonesian forestry and agricultural research agencies to develop improved agroforestry systems that would allow farmer groups long-term access to the forest land in exchange for their continued cooperation in protecting the plantations and halting the recurring cycle of encroachment by surrounding communities. Shade tolerant understory crops were introduced through a participatory research and demonstration process.

Shade Tolerant Crops in the Understory

At one project site near Tasikmalaya in West Java, shade from a four-year-old teak stand prevented farmers from continuing to grow rice between the tree rows. Winrock, working in cooperation with local NGOs and Indonesian researchers, helped farmers to plant and manage trial plots to test shade tolerant crops that could thrive in the understory. One species, cardamom (*Elettaria cardamomum*), required more inputs than the farmers were interested in investing,

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A member of the farmer group with bales of dried nilam leaves ready for processing. (Photo: C Stoney)

and also did not produce a harvestable fruit until the second year of growth. Another of the species tested was a small, mint family shrub, *Pogostemon cablin,* which the farmers call nilam. The leaves of this shrub are harvested, dried, and processed by steam distillation to extract patchouli oil. The trial plots were productive enough to encourage other members of the farmer group to begin planting nilam under the canopy of the teak plantation, as well as under coconut palms on lands outside the forest.

The farmers initially sold the dried leaves to a factory in a nearby city, however, they were not satisfied with the prices paid for the product. Steam distillation is a fairly low-tech operation, and the leader of the farmer group at Tasikmalaya had some previous experience with it. A large boiler is filled with the dried plant material and water, which is boiled to produce steam. The steam containing the vaporized oils passes from the boiler through pipes, which are placed underwater in a small pond to cool. As the steam cools, the oil condenses and separates from the vapor. The oil can then be collected, purified, packaged and marketed.

Feasibility Studies: the First Step to Developing Rural Enterprises

In 1992 Winrock and its collaborating partner organizations assisted the farmer group to conduct a study of the feasibility of producing and marketing the patchouli oil themselves. After visiting a similar operation in a neighboring district, community members gathered information on local costs, and prices needed in the analysis of the enterprise. They had to determine the equipment and construction needs, the availability of fuel to heat the boiler, the availability of a year-round water source, the availability of nilam leaves to keep the process in operation, and local market conditions. Based on the analysis, a loan was obtained to cover part of the costs from the State Forestry Corporation, the agency that manages forest lands in Java. The State Forestry Corporation also agreed to make more forest lands available for intercropping with nilam to ensure that a sufficient supply of raw material would keep the operation profitable.

The steam distillation operation at Tasikmalaya used locally available materials including bamboo pipes and a second-hand boiler, which had previously been used for processing sugar cane. Since fuelwood is scarce in the area, dried coconut leaves are burned to heat the boiler. A small pond was excavated at the site to cool the pipes connected to the boiler. The total investment for the steam distillation operation was about US $5500, including equipment, construction, and start-up costs. The farmer-owned operation was able to repay the loan within 2 years. Interest in planting nilam has spread within the community and to neighboring communities.

Farmer group members posing by the distillation shed and cooling pond (Photo: C Stoney)

The scale of production is an important element in evaluating the feasibility of this type of microenterprise. According to a report in *Indonesia Business Weekly* (June 19, 1995), one of the main obstacles to increasing patchouli oil exports is the supply of raw materials. Because nilam leaves are produced by small holders cultivating in their home gardens, the supply of leaves for distillation is often limited and unreliable. Projects need to ensure that small holders have access to land to grow nilam on a large enough scale. If the scale becomes large enough to support a local distillery, the village can retain more of the income by processing the leaves themselves, rather than sending the leaves (and the profits) to a centralized processing site.

In 1994 the steam distillery added a second product line, cardamon oil, which is processed from cardamon seed husks. The cardamon oil is sold to a local company specializing in traditional medicines, which uses it in the preparation of a skin ointment, for export to Korea. Previously the husks had been a waste product with no commercial value. The cardamon husks are processed during the dry season when the nilam plants produce few new leaves. Because nilam is reproduced from cuttings, members of the original farmer group are also supplementing their income during the planting season by selling cuttings from their mature plants to other farmers who want to cultivate nilam.

Non-Timber Forest Enterprises Help Protect Forest Resources

By diversifying the use of timber plantations, the project increased the flow of benefits from the forest to local communities. The project was also able to forestall uncontrolled encroachment into protected forests and onto fragile sites, including steep slopes and watersheds, by providing people with legal access to forest land. The nilam shrub is a good crop to ensure protection of soils and water on forest lands and critical watersheds. It is a perennial crop, so it does not need to be replanted each year. After 3-4 years, frequent harvesting of the leaves will weaken the plant to the point that it needs to be replaced. During the interim, however, the soil is subject to much less disturbance than with annual cropping systems.

On sites with sufficiently high rainfall, nilam may be more productive in full sunlight. The species is shade tolerant, however, and can be grown under forest plantations; tree crops (oil palm, coconut, rubber); fruit tree orchards; home gardens; and other multistrata agroforestry systems. Intercropping nilam with an overstory component increases the overall productivity of a unit of land, as well as diversifying the cropping system. Farmers can get 2-3 harvests per year, beginning six months after planting. The flow of income from the understory crop may provide the incentive farmers need to allocate farm lands to an agroforestry system. Nilam is easy to propagate. As an understory crop on fairly fertile forest soils in West Java, nilam was productive with minimal fertilizer inputs. For optimal productivity, management and fertilization guidelines are given in Table 1.

Table 1: Cultivation of *Pogostemon cablin*.

Ecological conditions for growth	
Elevation:	0-1200 in (optimal: 10-400m)
Rainfall:	2000-3000 mm/year
Temperature:	24-28° C
Light Intensity:	Shade to Full Sunlight
Establishment	
Parent Stock:	It is important to use the best available genetic material, as this will affect the quantity and quality of oil produced. In Indonesia the Aceh variety is the most highly valued.
Cuttings:	20-30 cm long with at least 3 buds from 1-year-old parent stock.
Nursery Beds:	Space seedlings 10xl0 cm in a sand/soil mixture (2: 1). Insert cuttings in the bed at a 45° angle.
Out Planting:	Directly from cuttings or using 4-weeks old nursery stock at the beginning of rainy season.
Spacing:	60-100 cm between rows and 30-70 cm apart within rows (usually 30-70 cm x 30-50 cm).
Fertilizer Application	
Manure:	20-40 tons/ha.
Urea:	250-500 kg (applied one month after planting and after harvesting).
TSP:	75-150 kg/ha, at time of planting
KCl:	150-300 kg/ha (applied 3 times, same as urea),
Mulch:	Research findings indicate that mulching combined with fertilizer gives the best results, especially during the dry season.
Management and Harvest	
Weeding:	Needed after planting and after each harvest until plants produce enough foliage to shade out weeds.
Pruning:	After harvest to stimulate new growth.
Layering:	After harvesting, branches can be layered to vegetatively produce new plants.
Harvest:	**The first harvest can take place 6-8 months after planting, and thereafter at 3 to 4 month intervals. Harvest leaves during cool temperatures, in the early morning or late afternoon, to ensure a high oil yield.**
Drying:	Harvested leaves are dried in full sunlight for 5 hours, then in a sheltered space for 3-4 days.

Some of the plants from which essential oils are distilled have become important cash crops in Indonesia. Total exports of various Indonesian essential oils grew from 12,667 tons valued at US $64 million in 1993 to *16,669* tons valued at US $77.41 million in 1994. Patchouli oil, which is used as a binder ingredient in perfume and cosmetic manufacture, is one of the most important commercially produced essential oils in Indonesia, and constituted the largest percentage among the Indonesian essential oil exports. In *1993,* Indonesia exported 1,165,560 liters of patchouli oil worth US $19 million. In 1994, exports grow by 36.32% and 20.77% in volume and value terms, respectively, to reach 1,588,868 liters worth US $22.7 million. The export price for Indonesian patchouli oil ranges from $12 to $15 per liter, but could increase if quality standards and a more stable supply can be guaranteed. The main purchasers of Indonesian patchouli oil are the US (28.3%), Switzerland (14.0%) and France (12.9%).

Further Reading on Non-timber Forest Products:

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Peters, Charles M. 1994. *Sustainable harvest of nontimber plant resources in tropical moist forest: an ecological primer.* The Biodiversity Support Program, 1250 24th Street, NW, Washington, DC 20037, USA. 47 pp.

For more information on the Java Social Forestry Project, contact the following two organizations:

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Agroforestry for the Pacific
Species Highlights

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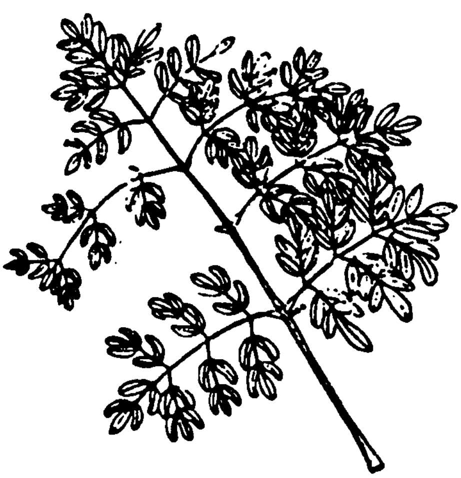
Number 1 **April 1993**

Moringa oleifera : A Perfect Tree for Home gardens

Moringa oleifera, commonly called the "drumstick tree", is well-known for its multi-purpose attributes, wide adaptability, and ease of establishment. Its leaves, pods and flowers are packed with nutrients important to both humans and animals.

Botany. Drumstick is a small, fast-growing, drought deciduous tree or shrub that reaches 12 m in height at maturity. It has a wide-open, typically umbrella shaped crown and usually, a single stem. Its wood is soft and its bark is light. It tends to be deeply rooted. (F/FRED, 1992)



Source: F/FRED 1992

Its leaves are imparipinnate-rachis 3 to 6 cm long with 2 to 6 pairs of pinnules. Each pinnule has 3 to 5 obovate leaflets that are 1 to 2 cm long (von Maydell, 1986). The terminal leaflet is often slightly larger.

Its leaflets are quite pale when young, but become richer in color with maturity. Cream-colored flowers emerge in sweet-smelling particles during periods of drought-or stress-when the tree loses its leaves. The pods are triangular in cross-section-30 to 50 cm long-and legume-like in appearance. The oily seeds are black and winged.

Ecology. Drumstick readily colonizes stream-banks and savanna areas where the soil are well-drained and the water table remains fairly high year-round. It is usually cultivated in home gardens and courtyards, where it is most useful. It produces lots of palatable green foliage. Leaf production is increased with frequent additions of kitchen and waste water.

Moringa oleifera is adapted to a wide range of soil types but it does best in a well-drained loam to clay-loam. It does not withstand prolonged waterlogging. It is observed to prefer a neutral to slightly acidic soil reaction, but it has recently been introduced with success to Pacific atolls where soil pH is commonly greater than 8.5. It does best where temperature ranges from 26 to 40°C and annual rainfall totals at least 500 mm. It grows well from sea level to 1000 m in elevation.

Moringa is quite drought tolerant, but it yields much less foliage where it is continuously under water stress. Where annual rainfall is below 300 mm the tree requires a relatively high water table to be productive.

Distribution. *Moringa oleifera* has its origin in Arabia and India. Today the tree is a common to landscapes all over the tropics of the Old World-from South Asia to West Africa (von Maydell, 1986). It is most visible in parts of East and South Africa. It is now also finding its way into gardens on many Pacific islands-from Kiribati to the Northern Marianas.

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Uses. *Moringa oleifera* is one of the most useful trees for semi-arid and drought-prone areas. It is quite often found next to kitchens and in courtyard gardens where its succulent leaves are harvested daily for soups, sauces, or salads. These palatable leaves are high in protein, vitamin A and vitamin C. Where diets lack in these essential nutrients-like on Pacific atolls-the Drumstick tree makes a major contribution to human health.

Moringa is not a nitrogen fixing tree, but its fruit, flowers and leaves all contain 5 to 10% protein-on average. All of these parts are eaten widely as vegetables, providing excellent food for both humans and animals. The pods are often cooked and eaten like green beans. The root tastes similar to horse radish and is a popular food in East Africa. *Moringa* flowers also produce a good honey.

The wood is light, but provides a fairly good fuel for cooking. It has a density of 0.5 to 0.7 and yields approximately 4,600 kcal/kg (F/FRED, 1992). The bark contains a gum that is used as a seasoning-and a treatment for some stomach ailments. Various parts of the *Moringa* plant are also used in medicines as diuretics and treatments for bladder ailments.

The seed is often used purify dirty or cloudy drinking water. It is pounded into small fragments, wrapped in some sort of cloth, and then placed into water jars or containers. This pounded seed acts as a flocculent, taking impurities out of the water solution. In the Nile Valley, the name of the tree is "Shagara al Rauwaq" which means "tree for purifying" (von Maydell, 1986).

Planted as a hedge in courtyards, *Moringa oleifera* provides wind protection, shade and support for climbing garden plants. One can easily understand the popularity of this versatile and adaptable tree in many locations as a household/garden component.

Moringa seed contains about 35% oil. Sweet and nonsticking, this oil is often extracted for cooking and in rare cases-even lubrication purposes. It does not turn rancid, is excellent in salads, can be used for soap making, and burns without smoke (von Maydell, 1986).

In India, economic analysis has illustrated that cultivation of *Moringa oleifera*-or 'Sahjan'-can be very profitable for farmers with access to urban markets (Sherkar, 1993). The leaves, pods, flowers, and wood are all in high demand, and even a few scattered trees can yield enough marketable produce to make frequent trips to town worthwhile.

Silviculture. *Moringa oleifera is* easily established by cutting or by seed. Seed can be sown either directly or in containers. No seed-treatment is required. The rapidly germinating seedlings can reach 5 m in one year if sheltered from drying winds and provided with enough water. Plants raised from 1 m cuttings bear pods from the second year of growth onwards- with maximum production at 4 to 5 years. In a favorable environment an individual tree can yield 50 to 70 kg of pods in one year (Sherkar, 1993).

The drumstick is an ideal tree for agroforestry uses as the branches can be easily trimmed to regulate shade effects. Its open crown allows plenty of sunlight to reach under-story crops-often garden vegetables that benefit from some shading.

Frequent pruning, lopping, coppicing or pollarding will increase and maintain leaf production. Drumstick will sprout back repeatedly and vigorously when lopped or pollarded. It is best to keep trees at a height that facilitates leaf-harvesting. The leaves are attractive to all livestock however, so harvesting practices should keep the sprouting area out of reach of local browsers.

Limitations. Though quite tolerant to drought, the tree is deciduous, and it loses most of its leaves in periods of extended water-stress.

The wood of *Moringa* is relatively soft. Because of this, it is not used in heavy construction. The tree is also susceptible to breakage in high winds.

The pods of some varieties taste quite bitter and may be poisonous if eaten in large quantities.

Moringa is relatively short-lived reaching only 20 years on average (von Maydell, 1986). Because it is so easy to establish, however, this limitation does not discourage cultivation of this very useful and adaptable tree.

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Agroforestry for the Pacific
Species Highlights

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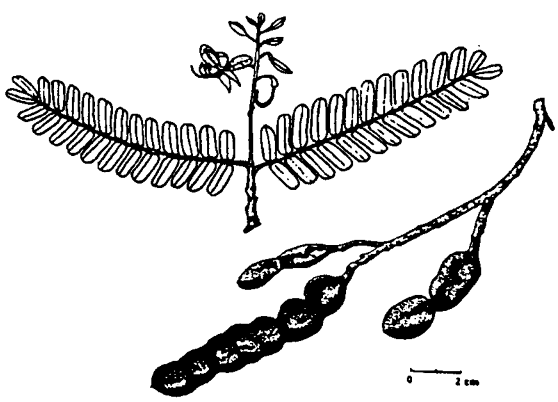
Number 2 **July 1993**

Tamarindus indica : A Widely Adapted, Multipurpose Fruit Tree

Tamarindus indica is best known for its delicious fruit. The brown, sticky, sour-sweet pulp is used widely as a flavor in a variety of dishes and drinks.

The usefulness of the tamarind tree does not end with its fruit. Sometimes compared to the coconut as another "tree of life", it is widely adaptable and easily managed. It produces many valued food, medicine, wood and construction products. Drought resistant and strong, it performs well as a windbreak, preventing soil erosion and protecting people, crops and animals in harsh environments. *Tamarindus* also provides a handsome element in thousands of park, garden and roadside landscapes.



F/FRED 1992

Botany

Tamarindus is a monotypic genus within the Caesalpiniaceae subfamily of legumes. It is large tree averaging 20 to 25 meters in height and 1 m in diameter. It has a wide, spreading crown and a short, stout trunk. The bark is strongly fissured and scaly grey on the stem and smooth on the branches. Leaves are alternate and paripinnate-each with 9 to 12 pairs of small leaflets. Small yellow flowers streaked with pink are contained in groups of 5 to 10 in drooping racemes 3 to 5 cm long. The pods are typically leguminous in appearance, oblong, straight or slightly curved, turning from green to dark brown as they ripen.

Tamarindus is slow growing but long lived. Individual trees commonly remain productive for 150 years or longer.

Ecology

A truly pantropical tree, *Tamarindus indica* performs well in both semi-arid and humid monsoonal climates. Individual trees produce up to 50 kg of fruit in West Africa where rainfall often totals less than 500 mm a year. Tamarind also thrives in humid areas of Southeast Asia that receive more than 1500 mm of rainfall annually. It is found from sea level to 1500 m elevation.

Six to eight month droughts are common in most areas where the tree is cultivated (F/FRED 19,02). Regardless of total annual rainfall, tamarind produces more fruit when subjected to a fairly long, annual dry period (Allen and Allen 1981; von Maydell 1986). Tamarind is not tolerant of persistent cold or brief frost. The tree prefers slightly acid (pH 5-5) deep alluvial, well-drained soils of loamy texture (von Maydell 1986). However, it also tolerates, a wide range of physical site characteristics. In Fiji, tamarind is successfully cultivated in soils of pH 4.5 to pH 8.7 (IIRR 1990). In India, it grows in soils with of pH 8.5 (Relwani 1993).

Tamarind cannot withstand stagnant inundation though it is often found on plains and stream banks where frequent flash flooding occurs. Because of its very deep, extensive root system, it can withstand violent typhoons and cyclones. It also tolerates the stiff, salty air of coastal areas (von Maydell 1986; von Carlowitz 1992).

Distribution

Tamarindus indica originated in tropical East Africa-probably Madagascar. Seafaring Arabian traders are thought to have spread seeds to Southeast Asia. Marco Polo mentions *Tamarindus* in the year 1298 (von Maydell, 1986). It is mentioned in Bhuddist sources from 650 AD and in Indian Brahmasamhita scriptures written between 1200 and 200 BC. Today tamarind is cultivated in India, Africa, Southeast Asia, Australia and the southern U.S. It is commonly known in India as "imli", and in the Pacific as "tamirini".

Uses

Fruit. Tamarind fruit is marketed worldwide in sauces, syrups and processed foods (F/FRED 1992). The soft, succulent pulp is used as a confectionery and an ingredient in curries, chutnies, preserves, pickles, sherbets and beverages. Nutrient composition is as follows: water 20.6%; protein 3.1%; fat 0.4%; carbohydrates (mostly sugars) 70.8%; fiber 3.0%; and ash 2.1% (Purseglove1968). The tender pods can also be eaten as a vegetable cooked or pickled. Reports of attainable fruit yields for individual trees vary widely

Prepared by K.R. Dalla Rosa, Program Director for the Pacific, NFTA

depending upon degree of domestication. F/FRED (1992) reports an average yield at 10 to 50 kg per tree. ICRAF (1992) informants in semi-arid and humid India report yields of 800 and 500 kg respectively for domesticated trees. Once the seeds are extracted and the pods removed, tamarind pulp can be stored for several months in a compressed form. This is important in India where tamarind pulp yield averages 250,000 t annually, 3,000 t of which are exported (von Maydell 1986).

Ripe tamarind fruit has a widely recognized and proven medicinal value. The American pharmaceutical industry processes 100 t of tamarind pulp annually. The fruit is said to reduce fever and cure intestinal ailments. Its effectiveness against scurvy is well documented. It is a common ingredient in cardiac and blood sugar reducing medicines (von Maydell 1986). The pulp is also used as an astringent on skin infections.

Seeds. Young seeds contain an amber, sweet-tasting oil (10 to 15% by weight) (Allen and Allen 1981). This high-quality oil has been used in varnishes and paints, for finishing Indian cloth, and as an illuminant. In India and Southeast Asia, tamarind seeds are also crushed and boiled to produce a paste that is used as a roofing material. This material is highly resistant to sea water and salt spray corrosion (PCRDF 1993).

The human nutritional value tamarind seed is quite low. It is used widely as animal feed, however, because ruminants are able to digest its complex starch.

Wood. Tamarind wood burns well as fuel and makes a high-grade charcoal for cooking. The wood ash and bark contain high tannin concentrations.

The wood is hard and dense (900 kg/m^3) and takes a fine polish (Allen and Allen 1981). Unfortunately, it is very difficult to work and the tree's typically short bole limits its worth as sawn timber. It is, however, used extensively by local artisans and furniture makers.

Silviculture

The large brown seeds (2,000 to 2,500/kg) are viable only if removed from fresh, ripe pods. Seeds taken from dry fruit do not germinate well (von Maydell 1986). Germination normally occurs 7 to 10 days after sowing. The recommended seed treatments are scarification or an overnight soak in warm water. Seed can be sown in either seed beds or containers. Containers are recommended if seedlings will remain in the nursery for longer than four months. Thereafter, deep tap root development will make eventual lifting out and transplanting more difficult. Germinated seedlings should be shaded until they reach a height of about 30 cm. Clean seed can be stored for 3 to 4 years in a sealed moisture-free container (Relwani 1993).

Vegetative propagation produces trees with superior fruiting characteristics in the African Sahel (von Maydell 1986). Trees started from branch cuttings often produce more and better-quality fruit than those propagated by seed. They also remain smaller-a trait that facilitates fruit harvesting. Superior clones can also be grafted onto seed-propagated root stock.

Transplanting of bare-root seedlings requires extreme care as tamarind is especially susceptible to injury and denudation. Roots must be kept moist.

Orchards are usually planted at 12 x 12 in or 15 x 15 in (Relwani 1993). An effective windbreak can be created by planting one or two parallel lines of tamarind trees at 12 x 12 in. Small seedlings are susceptible to browsing damage and weed competition so some initial protection and spot weeding may be necessary. Young trees might also be tied to stakes to encourage a straighter stem form. In more arid climates, irrigation during the first dry season speeds growth substantially. Apart from these suggested treatments, once planted, tamarind trees require little management

Tamarind starts bearing fruit at about 10 years, depending upon the environment. The fruit must be allowed to mature on the tree because fruit harvested prematurely has a highly acidic and fibrous pulp (von Maydell 1986). Mature fruit pods are cinnamon or dark brown and brittle.

Limitation

The primary limitations of *Tamarindus* are its slow growth and poor stem form. Unfortunately, although a legume, the species has not been observed to nodulate or fix atmospheric nitrogen

Further Reading

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Appendix 1 – Chronological List of Highlights and Factsheets

Nitrogen Fixing Tree Association (NFTA) Highlights

Number	Date	Title
NFTA 85-02	May 1985	*Acacia mearnsii* – Multipurpose Highland Legume Tree
NFTA 85-03	December 1985	*Casuarina* – Difficult Sites are Home to Casuarina
NFTA 86-03	May 1986	Actinorhizal Trees Useful in Cool to Cold Regions
NFTA 87-05	October 1987	*Prosopis pallida* – Pioneer Species for Dry, Saline Shores
NFTA 88-01	March 1988	*Mimosa scabrella* – The Tree that Fueled the Railroads of Brazil
NFTA 88-03	August 1988	*Albizia lebbeck* – A Promising Fodder Tree for Semi-Arid Regions
NFTA 88-04	August 1988	*Acacia holosericea* – A Successful Newcomer for the Dry Tropics
NFTA 88-05	November 1988	Leucaena Psyllids – A Review of the Problem and its Solution
NFTA 88-06	November 1988	*Cajanus cajan* – It's More than Just a Pulse Crop
NFTA 89-01	May 1989	NFT Gums – Ancient and Modern Commercial Products
NFTA 89-02	May 1989	Acacias for the Hot Dry Subtropics
NFTA 89-03	September 1989	Why Nitrogen Fixing Trees?
NFTA 89-04	September 1989	*Flemingia macrophylla* – A Valuable Species in Soil Conservation
NFTA 89-05	September 1989	*Paraserianthes falcataria* – Southeast Asia's Growth Champion
NFTA 89-06	December 1989	*Casuarina cunninghamiana* – The River She-Oak
NFTA 89-07	December 1989	*Dalbergia sissoo* – The Versatile Rosewood
NFTA 90-01	May 1990	*Leucaena* – An Important Multipurpose Tree
NFTA 90-02	May 1990	*Casuarina equisetifolia* – An Old-Timer with a New Future
NFTA 90-03	July 1990	*Acacia aneura* – A Desert Fodder Tree
NFTA 90-04	July 1990	*Casuarina junghuhniana* – A Highly Adaptable Tropical Casuarina
NFTA 90-05	November 1990	*Enterolobium cyclocarpum* – The Ear Pod Tree for Pasture, Fodder and Wood
NFTA 90-06	November 1990	*Alnus nepalensis* – A Multipurpose Tree for the Tropical Highlands
NFTA 90-07	December 1990	*Prosopis glandulosa* – A Multipurpose Tree for Arid Lands
NFTA 91-01	April 1991	*Acacia tortilis* – Fodder Tree for Desert Sands
NFTA 91-02	April 1991	*Acacia senegal* – Gum Tree with Promise for Agroforestry
NFTA 91-03	July 1991	*Robinia pseudoacacia* – Temperate Legume Tree with Worldwide Potential
NFTA 91-04	July 1991	*Prosopis cineraria* – A Multipurpose Tree for Arid Areas
NFTA 91-05	July 1991	*Casuarina glauca* – A Hardy Tree with Many Attributes
NFTA 91-06	November 1991	*Prosopis alba* and *Prosopis chilensis* – Subtropical Semiarid Fuel and Fodder Trees
NFTA 92-01	March 1992	*Pithecellobium dulce* – Sweet and Thorny
NFTA 92-02	March 1992	*Pterocarpus indicus* – The Majestic N-Fixing Tree
NFTA 92-03	June 1992	*Acacia saligna* – For Dryland Fodder and Soil Stabilization
NFTA 92-04	June 1992	*Acacia nilotica* – Pioneer for Dry Lands
NFTA 92-05	October 1992	*Leucaena diversifolia* – Fast Growing Highland NFT Species
NFTA 92-06	October 1992	*Erythrina sandwicensis* – Unique Hawaiian NFT
NFTA 92-07	December 1992	*Elaeagnus* – A Widely Distributed Temperate Nitrogen Fixer
NFTA 92-08	December 1992	*Olneya tesota* – A Potential Food Crop for Hot Arid Zones
NFTA 93-01	March 1993	Juliflorea acacias – New Food Source for the Sahel
NFTA 93-02	June 1993	*Hippophae rhamnoides* – An NFT Valued for Centuries
NFTA 93-03	June 1993	*Chamaecytisus palmensis* – Hardy, Productive Fodder Shrub
NFTA 93-04	September 1993	*Inga edulis* – A Tree for Acid Soils in the Humid Tropics
NFTA 93-05	September 1993	*Dalbergia melanoxylon* – Valuable Wood from a Neglected Tree
NFTA 94-01	January 1994	*Erythrina edulis* – Multipurpose Tree for the Tropical Highlands
NFTA 94-02	January 1994	*Erythrina variegata* – More than a Pretty Tree
NFTA 94-03	April 1994	*Alnus acuminata* – Valuable Timber Tree for Tropical Highlands
NFTA 94-04	April 1994	*Dalbergia latifolia* – The High-Valued Indian Rosewood
NFTA 94-05	June 1994	*Sesbania grandiflora* – NFT for Beauty, Food, Fodder and Soil Improvement

NFTA 94-06	June 1994	*Sesbania sesban* – Widely Distributed Multipurpose NFT
NFTA 94-07	September 1994	*Acacia seyal* – Multipurpose Tree of the Sahara Desert
NFTA 94-08	September 1994	*Acacia koa* – Hawaii's Most Valuable Native Tree
NFTA 95-01	January 1995	*Albizia odoratissima* – Tea Shade Tree
NFTA 95-02	January 1995	*Albizia saman* – Pasture Improvement, Shade, Timber and More
NFTA 95-03	June 1995	*Myroxylon* – Balsam and Much More
NFTA 95-04	June 1995	*Ougeinia dalbergioides* – A Multipurpose Tree for Sub-Tropical and Tropical Mountain Regions
NFTA 95-05	September 1995	*Pentaclethra macrophylla* – A Multipurpose Tree from Africa with Potential for Agroforestry in the Tropics
NFTA 95-06	September 1995	*Faidherbia albida* – Inverted Phenology Supports Dryzone Agroforestry

Note: Early NFTA Highlights that were later replaced by updated editions are not listed here.

Forest, Farm, and Community Tree Network (FACT Net) Factsheets

Number	Date	Title
FACT 96-01	January 1996	*Adenanthera pavonina* – An Underutilized Tree of the Humid Tropics
FACT 96-02	January 1996	*Andira inermis* – More than a Beautiful Ornamental Tree
FACT 96-03	June 1996	*Acacia mangium* – An Important Multipurpose Tree for the Tropic Lowlands
FACT 96-04	June 1996	*Acacia leucophloea* – Shade and Fodder for Livestock in Arid Environments
FACT 96-05	September 1996	*Acacia auriculiformis* – A Multipurpose Tropical Wattle
FACT 96-06	September 1996	*Erythrina poeppigiana* – Shade Tree Gains New Perspectives
FACT 97-01	January 1997	*Albizia procera* – White Siris for Reforestation and Agroforestry
FACT 97-02	January 1997	*Guazuma ulmifolia* – Widely Adapted Tree for Fodder and More
FACT 97-03	June 1997	*Pongamia pinnata* – A Nitrogen Fixing Tree for Oilseed
FACT 97-04	June 1997	*Gleditsia triacanthos* – Honeylocust, Widely Adapted Temperate Zone Fodder Tree
FACT 97-05	September 1997	*Azadirachta indica* – Neem, a Versatile Tree for the Tropics and Subtropics
FACT 97-06	September 1997	*Leucaena leucocephala* – A Versatile Nitrogen Fixing Tree
FACT 98-01	January 1998	*Azadirachta indica* – Use of Neem as a Biological Pest Control Agent
FACT 98-02	January 1998	Improving Markets for Farm Forestry Products
FACT 98-03	June 1998	*Ziziphus mauritiana* – A Valuable Tree for Arid and Semi-Arid Lands
FACT 98-04	June 1998	*Gliricidia sepium* – The Quintessential Agroforestry Species
FACT 98-05	September 1998	*Grevillea robusta* – A Versatile and Popular Tree for Farm Forestry
FACT 98-06	September 1998	*Hymenaea courbaril* – The Flour Tree
FACT 99-01	January 1999	*Acacia angustissima* – A Promising Species for Agroforestry?
FACT 99-02	January 1999	*Calliandra calothyrsus* – An Indonesian Discovery for Humid Tropical Regions
FACT 99-03	June 1999	*Pterocarpus erinaceus* – An Important Legume Tree in African Savannas
FACT 99-04	June 1999	*Senna siamea* – A Widely Used Legume Tree
FACT 99-05	September 1999	*Gmelina arborea* – A Popular Plantation Species in the Tropics
FACT 99-06	September 1999	*Prosopis tamarugo* – Uniquely Adapted to the Atacama Desert of Northern Chile

Agroforestry Information Service (AIS) for the Pacific Technology Factsheets

Number	Date	Title
AIS 01	December 1992	Why Agroforestry?
AIS 02	December 1992	Hedgerow Intercropping with Upland Root Crops
AIS 03	April 1993	Managing Organic Matter: Composting and Mulching
AIS 04	April 1993	Nitrogen Fixing Trees as Atoll Soil Builders
AIS 05	April 1993	Windbreaks for Pacific Islands
AIS 06	July 1993	Intercropping Coconuts with Nitrogen Fixing Trees
AIS 07	July 1993	Cattle under Coconuts: A Practical Pacific Tradition
AIS 08	April 1994	Fodder Bank Establishment and Management
AIS 09	December 1994	Fuelwood Production in the South Pacific
AIS 10	December 1994	Selecting and Testing Nitrogen Fixing Trees for Acid Soils
AIS 11	July 1995	Trees and Shrubs for Agroforestry on Atolls
AIS 12	July 1995	Seed Treatment and Inoculation
AIS 13	September 1995	Community-based Tree Seed Production with *Desmodium rensonii* and *Flemingia macrophylla*
AIS 14	September 1995	Seed Production for Tropical Tree Legumes
AIS 15	September 1995	Understory Cropping with *Pogostemon cablin*: Raw Material for Rural Enterprise

Agroforestry Information Service (AIS) for the Pacific Species Factsheets

Number	Date	Title
AIS 01	April 1993	*Moringa oleifera*: A Perfect Tree for Home Gardens
AIS 02	July 1993	*Tamarindus indica*: A Widely Adapted, Multipurpose Fruit Tree

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