Leucaena: Promising Forage and Tree Crop for the Tropics (1977)

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LEUCAENA

Promising Forage and Tree Crop for the Tropics

Board on Science and Technology for International Development
Commission on International Relations
National Research Council.

Report of a study conducted jointly by
the Philippine Council for Agriculture and Resources Research
and the United States National Academy of Sciences

Avec Résumé en Français
Con Resumen en Español

NATIONAL ACADEMY OF SCIENCES
Washington, D.C. 1977

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NOTICE: The project that is the subject of this report was approved by the Philippine Council for Agriculture and Resources Research and by the Governing Board of the National Research Council, acting in behalf of the National Academy of Sciences. Such approval reflects the Board's judgment that the project is of international importance and appropriate with respect to both the purposes and resources of the National Research Council.

The members of the committee selected to undertake this project and prepare this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. Responsibility for the detailed aspects of this report rests with that committee.

This report has been reviewed and approved by independent groups of qualified individuals in the Philippines as well as in the United States, where procedures established and monitored by the Report Review Committee of the National Academy of Sciences were followed. Distribution of the report is approved, by the President of the Academy, upon satisfactory completion of the review process.

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Preface

This report examines *Leucaena leucocephala*, a versatile legume whose full potential, thus far, is untapped. A "new" crop plant for tropical and subtropical countries, its possibilities are particularly important to marginal lands and low-income farmers. Leucaena was used 2,000 years ago by Mayans and Zapotecs of Central America, but only in the past two decades has a suggestion of its promise become apparent.

During that brief period several significant factors emerged: researchers in Hawaii and tropical Australia have found that cattle feeding on leucaena may show weight gains comparable to those of cattle feeding on the best pastures anywhere; private firms in the Philippines have developed a sizable trade in processed animal feeds containing leucaena; researchers in the Philippines demonstrated leucaena's potential for reforesting eroded hillslopes, for use as firewood, for fueling industrial boilers, and for producing paper pulp; while in Mexico (leucaena's native habitat) researchers have located over 100 varieties for future testing.

Since this information had not come to public attention, the U.S. National Academy of Sciences (NAS) and the Philippine Council for Agriculture and Resources Research (PCARR) jointly convened a meeting for a systematic review of the data in the hope that it might benefit nations throughout the tropics. The joint panel met at Los Baños, the Philippines, 2-4 September 1976. It assembled, from both sides of the Pacific, researchers specializing in a variety of areas including agronomy, plant breeding, tropical pastures, animal nutrition, forestry, and wood products research. (For a list of the study participants see Appendix B.)

This panel report is meant to introduce leucaena to agencies and institutions engaged in development assistance and agriculture in tropical countries and to research institutions with relevant interests. It is not a comprehensive technical review, but a document intended for the attention of decision makers and administrators as well as for research workers. By reaching this audience we hope to stimulate increased funds and facilities for leucaena development and exploitation.

In this report the plant is considered in light of its potential as a crop without specific regard for any particular country where it might flourish. Attempts to assess leucaena's merits or limitations for specific regions, countries, or localities would have unnecessarily complicated the panel's discussions. Accordingly, the report provides a general overview that leaves to the reader the task of weighing the technical prescriptions while bearing in mind his country's economics, needs, resources, and capabilities. The reader should also appreciate that, though treated separately in this report, many of leucaena's uses are interrelated and the plant can be used for several purposes simultaneously (e.g., for reforestation and for firewood production). Further, it is clear that many tests, trials, and development studies are needed to learn the extent of the plant's value. Chapter 8 outlines a program for research and action that will help determine leucaena's potential to alleviate major feed, wood, and fuel shortages, as well as deforestation problems in the tropics.

Those who would like to study leucaena in more depth may refer to the articles and general reviews cited in Appendix A; more specific advice may be obtained from scientists actively engaged in leucaena research (see Appendix C). Finally, a few institutions have offered to provide small quantities of leucaena seed and/or inoculum to bona fide researchers (see Appendix D).

A more detailed leucaena report is being published by PCARR. It, too, was drafted at the Los Baños meeting and contains the papers presented by individual panel members as well as the statements developed by working groups on the following topics:

- varietal introduction, hybridization, selection, and seed production technology
- farming systems
- management and utilization for forage and soil amelioration
- management and utilization for wood products.

Copies may be obtained without charge from Dr. Joseph Madamba, Director-General, Philippine Council for Agriculture and Resources Research, College, Laguna, the Philippines.

The panel is indebted to Dr. Madamba and his staff for hosting the meeting at Los Baños. The foreign visitors were much impressed with the organizational precision and attention to detail that characterized the meeting.

The Advisory Committee on Technology Innovation of the NAS Board on Science and Technology for International Development (see page 111), is assessing scientific and technological advances that might prove especially applicable to problems of developing countries.* This report is one of a series that considers promising crop plant species that heretofore have been little known, neglected, or overlooked. Other titles include:

- *Underexploited Tropical Plants with Promising Economic Value* (1975)
- *Products from Jojoba: A Promising New Crop for Arid Lands* (1975)
- *The Winged Bean: A High-Protein Crop for the Tropics* (1975)
- *Making Aquatic Weeds Useful: Some Perspectives for Developing Countries* (1976)
- *Guayule: An Alternative Source of Natural Rubber* (1977)
- *Underexploited Tropical Legumes with Promising Economic Value* (In preparation)

For information on obtaining copies see page 113.

This report was prepared for publication by Noel Vietmeyer and Beverly Cottom and edited by F. R. Ruskin.

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Contents

Chapter 1

Introduction and Summary

Of all tropical legumes, leucaena probably offers the widest assortment of uses. Through its many varieties, leucaena can produce nutritious forage, firewood, timber, and rich organic fertilizer. Its diverse uses include revegetating tropical hillslopes and providing windbreaks, firebreaks, shade, and ornamentation. Although individual leucaena trees have yielded extraordinary amounts of wood–indeed, among the highest annual totals ever recorded–and although the plant is responsible for some of the highest weight gains measured in cattle feeding on forage, it remains a neglected crop, its full potential largely unrealized.

Inasmuch as the varieties with exceptional size, vigor, and other desirable qualities have been discovered or developed only during the past 2 decades, experience is still limited and literature sparse. Moreover, leucaena's reputation has suffered in some areas due to an aggressive variety (spread throughout the tropics during the last two-and-a-half centuries) that has become a weed. Further, leucaena's development has been retarded because its foliage contains an uncommon amino acid, mimosine, that is toxic to nonruminants at levels of about 10 percent in the diet. Leucaena is not fatal to ruminants such as cattle, since stomach microorganisms convert mimosine to dihydroxypyridine (DHP), which causes problems only if cattle consume leucaena in excessive amounts for months on end (see Chapter 3).

Leucaena* is the common name for *Leucaena leucocephala*. Some strains are many-branched shrubs that average 5 m (15 ft) at maturity; others are single-trunked trees that grow as high as 20 m (65 ft). Originating in Central America (Figure 1), some of the varieties were spread widely throughout the region thousands of years ago by the Maya and Zapotec civilizations. Indeed, the name Oaxaca, (Mexico's fifth largest state and a prominent modern city) is derived from a pre-Columbian word "uaxin" meaning "the place where leucaena grows" (Figure 2).

*Variously pronounced loo-*see*-na, loo-*kee*-na, loo-*kay*-na, loo-*kuy*-na. In this report, "leucaena" refers only to *L. leucocephala* and not to other species of the genus *Leucaena*. Literature published before 1960 uses the botanic name *Leucaena glauca* for the plant.

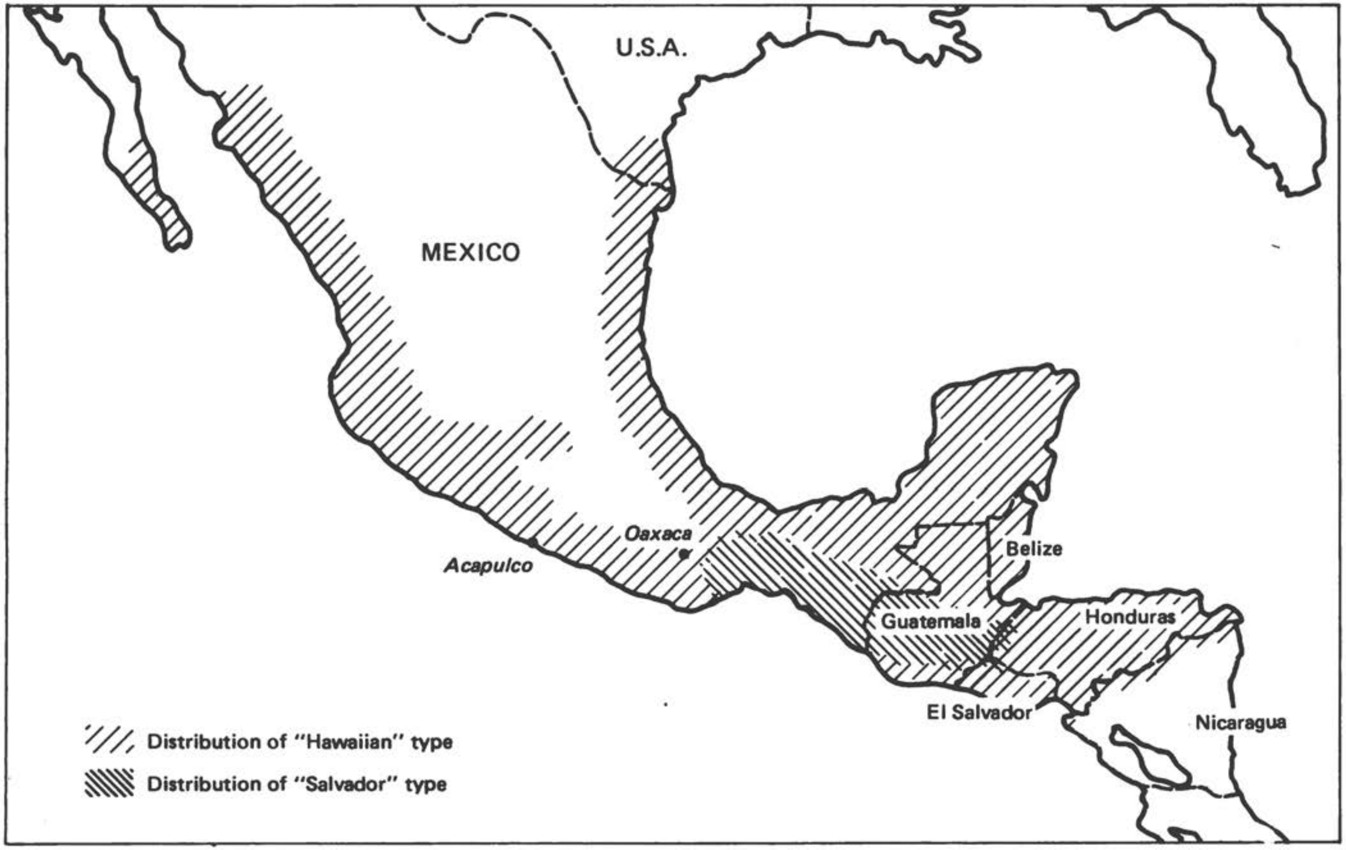


FIGURE 1 Leucaena originated in the midlands of southern Mexico, Guatemala, El Salvador, and Honduras. It was spread throughout lowland regions on both the Pacific and Caribbean coasts of Central America by pre-Columbian Indians. The major strain of leucaena surviving in these areas is a rapidly flowering, highly seedy shrub known as the Hawaiian type. In the southwestern portion of this region the native leucaena is often a tall tree, reaching 20 m in height, called the Salvador type. Today, specimens of the Salvador type, which has large-sized pods, can be found scattered throughout western Mexico, where leucaena pods are a traditional food.

FIGURE 2 West-central Mexico, circa 1550. A Nahuatl (Aztec) pictograph representing "uaxin," meaning "the place where leucaena grows." A depiction of leucaena pods is clearly visible. This is the earliest historical reference to leucaena. The Spanish mistranscribed the wood uaxin as "oaxaca." Today, Oaxaca is the name of a state and a city in Mexico. (G. Sánchez Rodríguez, photographed from Codice Mendoza, Biblioteca Nacional de Mexico)

In 1565, after their conquest of Mexico, the Spanish conquistadores organized trade with the Philippines: each spring a galleon left Acapulco on Mexico's west coast and crossed the Pacific. Sometime during the 250 years that this continued, leucaena reached the Philippines, probably carried as forage.

The "Acapulco" variety is a rugged, persistent, vigorously growing type that flowers abundantly. It became firmly established in the Philippines, Guam, and other Spanish west-Pacific island possessions. Local people soon learned that it made good firewood; later, plantation owners found that coffee, cocoa, cinchona, pepper, vanilla, and other shade-loving crops established themselves well beneath an overstory of this leucaena variety. Accordingly, leucaena was introduced to plantations in the Netherlands East Indies (now Indonesia), Papua New Guinea, Malaya (Malaysia), and other countries of Southeast Asia. During the nineteenth century it was taken to Hawaii, Fiji, northern Australia, India, East and West Africa, and islands of the Caribbean. It is now truly pantropical.

The variety that became so widely disseminated descended from the Acapulco type (now known as the "Hawaiian" type); the wealth of other leucaena germ plasm scattered throughout Central America remained uncollected and virtually unrecorded until recently.

Leucaena is a species of the family Leguminosae and, like most other legumes, can form a mutually beneficial partnership with soil bacteria of the genus *Rhizobium*. These bacteria penetrate young rootlets and multiply to form nodular swellings on the root surface. The *Rhizobium* in the nodules is capable of absorbing large amounts of nitrogen gas from air in the soil, transforming it into nitrogen-containing organic and inorganic compounds. This process, which converts otherwise unusable nitrogen gas into compounds used by the legume to form proteins, is known as "nitrogen fixation." Leucaena usually has large and prolific nodules and requires little or no fertilizer-nitrogen, because the *Rhizobium* alone provides nitrogenous compounds in amounts adequate for normal growth. This permits leucaena to thrive in some soils where nitrogen levels are inadequate to sustain the growth of most other crops.

The nodules occur on rootlets in the aerated surface soil layers, but leucaena develops a taproot that penetrates deep soil layers and exploits water and minerals below the root zone of many agricultural crop plants. This, too, helps it to grow where other plants fail. Parts of Yucatan and Oaxaca have such extended dry seasons that the number of years in which crops fail outnumber those in which they succeed, yet this is leucaena's native habitat; it survives by tapping deep soil moisture.

A summary of leucaena's main uses follows.

Forage

In the lowland tropics large quantities of protein can be produced efficiently and economically from leucaena grown on well-drained, fertile soils and harvested regularly as hay or forage (Chapter 3).

Suited mainly to cattle, water buffalo, and goats, leucaena forage is highly palatable, digestible, and nutritious. Both beef and dairy cattle thrive on it and can live on leucaena alone until mimosine-related toxicity occurs. This can be delayed or eliminated entirely by supplementing the diet with other forages.

The plant's drought-tolerance and hardiness make it a promising candidate for increasing meat and milk supplies throughout the dry tropics.

New, low-mimosine varieties now in advanced development hold great promise as trouble-free tropical feedstuffs for the future.

Wood

The newly discovered arboreal leucaena varieties grow rapidly, yielding wood of useful size for lumber and timber. Although few details are known about its quality, initial tests are encouraging. Leucaena wood has the potential to become a major source for pulp and paper, roundwood (e.g., poles and posts), and construction materials (Chapter 4).

Fuel

Leucaena wood makes excellent firewood and charcoal. It has long been used for these purposes in the Philippines, and the new varieties are so productive that they are already being planted to provide fuel for electric generators, factories, and agricultural-processing facilities. The wood has uncommonly high density and calorific value for a fast-growing tree, and because the stumps readily regrow (coppice), the plant "defies the woodcutter." As such, it could become a renewable fuel resource in areas suited to its agronomic requirements (Chapter 5).

Soil Improvement

Leucaena helps to enrich soil and aid neighboring plants because its foliage rivals manure in nitrogen content, and natural leaf-drop returns this to the soil beneath the shrubs (Chapter 6). Recent experiments in Hawaii have shown that if the foliage is harvested and placed around nearby crop plants they can respond with yield increases approaching those effected by commercial fertilizer.*

In addition, leucaena's aggressive root system breaks up impervious subsoil layers, improving moisture penetration and decreasing surface runoff. Nutrients from deep strata are gradually deposited on the surface through decay of the leaves and other plant parts; soil organisms increase, topsoil humus rebuilds.

As a renewable source of green manure for rural areas in the tropics, leucaena deserves increased testing.

Reforestation

Leucaena's ability to thrive on steep slopes, in marginal soils, and in areas with extended dry seasons makes it a prime candidate for restoring forest cover to watersheds, slopes, and grasslands that have been denuded through reforestation or fire. For example, leucaena can be established on degraded

*Guevarra. 1976. See Selected Readings.

soils dominated by coarse grasses, a common feature of many tropical areas that have been deforested or depleted by agriculture (Chapter 6).

Other Uses

In Central America and Indonesia the young pods and seeds are an important food, even though mimosine may cause hair loss in humans. If eaten in moderation the pods and seeds have little effect. Other products include beadlike decorations made from the seeds, and dyes extracted from the pods, leaves, and bark. An overstory of leucaena is still used to shade plantation crops such as coffee, cacao, and cinchona, shielding them from excessive sunlight. Leucaena has also been used in windbreaks, as a shade-providing ornamental, and for roadside beautification. Furthermore, the plant can be important in shifting-cultivation (slash-and-burn), for, by improving soil fertility, leucaena can reduce the fallow time needed between plantings (Chapter 7).

Limitations

In addition to the mimosine toxicity already mentioned, leucaena has a number of limitations and special requirements.

The plant will grow vigorously only in lowland areas; in Hawaii its growth rate is retarded at elevations over 500 m (1,500 ft) though the altitude at which noticeable retardation occurs is much higher in countries close to the equator (see Chapter 2).

Although the plant can survive and even grow aggressively in many marginal soils and environments (see Chapter 2), its exceptional yields occur only in fertile, well-drained soils where rainfall or irrigation is adequate. This is particularly true when the plant is intensively harvested for forage or green manure. Soil fertility is of less concern when leucaena is used for reforestation or halting soil erosion.

Like all legumes and grasses, leucaena requires a reasonable mineral balance in the soil, so that attention to nutrient inputs (particularly phosphorus, sulfur, calcium, molybdenum, and zinc) is very important. Even under favorable conditions, continual browsing or cutting and removing the wood or foliage will deplete a leucaena plant of some vital nutrients; fertilization is then required.

There are a number of types of poor soils where leucaena cannot survive easily. For example, it adapts badly to acid soils; lime pelleting and the addition of a special *Rhizobium* strain as well as fertilizer containing molybdenum, phosphorus, sulfur, and calcium are needed to get it well-established.

The plant's main potential, therefore, is for areas with nonacid soils. Leucaena also grows poorly in high-alumina soils and requires careful fertilization with phosphate and calcium if it is to survive and grow. Nevertheless, with fertilization good yields are possible in aluminous soils.

Leucaena seedlings grow slowly at first and this complicates plantation establishment: aggressive weeds or adverse climatic conditions can lead to total failure of the planting.

The prolific nature of the Hawaiian-type leucaenas creates problems in locations where the plant is not harvested regularly. This has occurred, for example, on Guam. Leucaena charcoal was once a popular cooking fuel, but with electrification of the island the plant now grows unchecked, produces dense, weedy tangles, and has become a nuisance. In some parts of Tanzania Hawaiian-type leucaena is considered a noxious weed. Although reports from Zanzibar claim that it is useful for stabilizing eroding slopes where other species have failed, the low bushy growth is regarded as an ideal breeding site for the tsetse fly. These problems are not expected to occur with the aboreal Salvador types.

Chapter 2

The Plant

Leucaena is a genus of Central American shrubs and trees with about 10 species.* Its taxonomy is confused. Although all the species may have value throughout the tropics, only *Leucaena leucocephala* (Lam.) de Wit has been exploited extensively. *Leucaena leucocephala* has been recorded in the literature under several (incorrect) botanic names.† Its most universal common name is "leucaena," but many countries use different, local names.‡

Genetics

Much of the confusion over naming *Leucaena leucocephala* results from the fact that its many varieties differ enormously in size and form. Over 100 varieties are known,§ but they can be classified broadly into these three types:

- Hawaiian type: short, bushy varieties to 5 m (15 ft) in height (Figure 3) that flower when very young (4–6 months old). This type flowers year-round rather than seasonally (i.e., it is not photoperiodic and seasonal changes in day length are not needed to initiate flowering). Compared with the two types mentioned below, its yield of wood and foliage is low; its continuous flowering produces many seeds and it becomes an aggressive weed. This is the common type native to coastal Mexico that is now widely spread

*Botanical literature of the past 2 centuries contains claims for 51 species, but the only valid species appear to be *L. leucocephala, L. pulverulenta, L. diversifolia, L. lanceolata, L. collinsii, L. esculenta, L. macrophylla, L. retusa, L. shannoni*, and *L. trichodes*. The remainder are suspected to be synonyms. (More detail is given in Brewbaker, Plucknett, and Gonzales. 1972. See Selected Readings.)

†Notably *L. glauca* (Willd.) Benth.; *L. latisiliqua* (L.) W. T. Gillis; and *L. salvadorensis* Standley.

‡Including ipil-ipil, giant ipil-ipil, lepile, and bayani (Philippines); lamtoro (Indonesia); guaje, yaje, and uaxin (Latin America); koa haole (Hawaii); hediondilla (Puerto Rico); tangatan (Guam); as well as horse tamarind, white popinac, and leadtree (in various former British colonies).

§Brewbaker, Plucknett, and Gonzales. 1972. Hutton and Gray. 1959. See Selected Readings.

throughout the tropics. Its value lies particularly in its ability to revegetate tropical hillslopes, to provide firewood and charcoal, and to shade plantation crops (see Chapters 5, 6, and 7).

- Salvador type: tall, treelike plants to 20 m (65 ft) in height (Figure 3), having large leaves, pods, and seeds, and thick, branchless trunks (Figure 4; see also Figures 28–30). Originating from inland forests of Central America, varieties of this type have been studied only in the last decade. They are also known as arboreal or Guatemala types. They often produce more than twice the biomass of the Hawaiian type. Some extremely-high-yielding Salvador-type cultivars now being planted as sources of timber, wood products, and industrial fuel (see Chapters 4, 5, and 6) are known as "Hawaiian Giants" or by the designators K8, K28, or K67 (see Figure 3 and Appendix D).
- Peru type: tall plants to 15 m (45 ft), like the Salvador type, but with extensive branching even low down on the trunk (see related hybrid, Figure 24). They produce little trunk, but extremely high quantities of foliage grow on their branches. Although these are highly productive forage varieties (see Chapter 3), they have only recently been discovered, and their use outside Australia, Hawaii, and Mexico still awaits testing.

FIGURE 3 Waimanalo, Hawaii. Common Hawaiian type (right) is dwarfed by Salvador type (Hawaiian Giant strain) leucaena (left). As can be seen here, both varieties make excellent windbreaks. The Hawaiian Giant strains, selected for their vigorous arboreal growth, are among the fastest growing trees known. The trees in this picture (left) reached heights of 4 m (13.5 ft) in 6 months, 9 m (30 ft) in 2 years, and 17 m (55 ft) in 6 years. (J. L. Brewbaker)

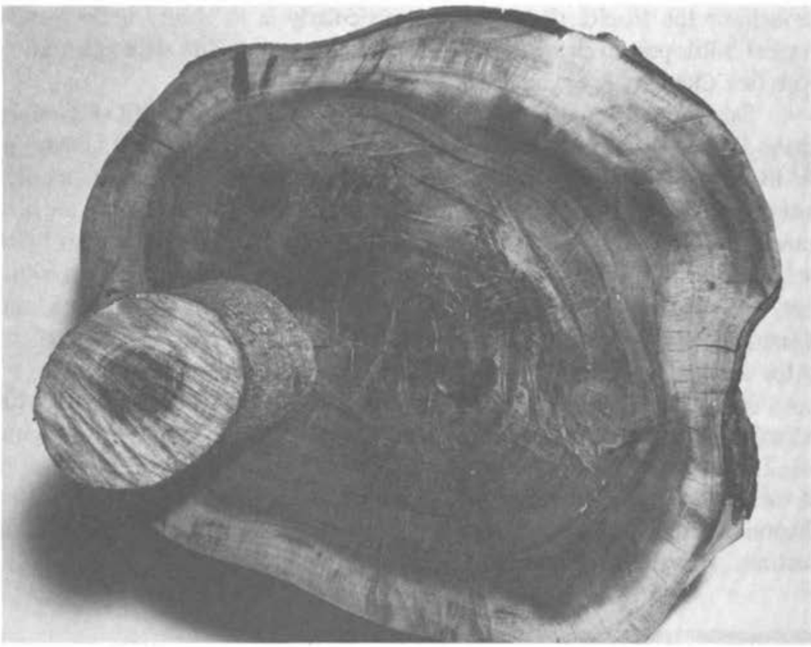


FIGURE 4 Hawaiian-type leucaena, now widespread throughout the tropics, falls far short of the size of newly developed Salvador-type varieties. The smaller cross section shown here is the stem of an average-size Hawaiian type and the larger (diameter 28 cm, 11 in.) is that from a 6-year-old Salvador type. (N. D. Vietmeyer, specimens of M. D. Benge)

Such genetic diversity offers the plant breeder much promise for enhancing desirable characteristics. Already it has been observed that the arboreal habit appears dominant over the highly branched one. Thus, it is possible to breed and select varieties for high yields of timber on the one hand, and for high yields of browse (within easy reach of cattle) on the other. Leucaena crosses readily with some other species in the genus, and its hybrids with *Leucaena pulverulenta* were used as shade trees in Indonesia as early as 1900. These are largely sterile and seedless, but they also have far less mimosine than leucaena itself, and thus they hold much promise as future forage crops (see Figures 24 and 48).

Foliage and Roots

Leucaena is an evergreen; however, in high winds, frosts, or prolonged drought, its compound leaves (Figure 5) shed their dozens of tiny leaflets (Figure 6). Both leaves and leaflets fold up in response to moisture stress (e.g., during the hottest part of the day), cool temperatures, or darkness.

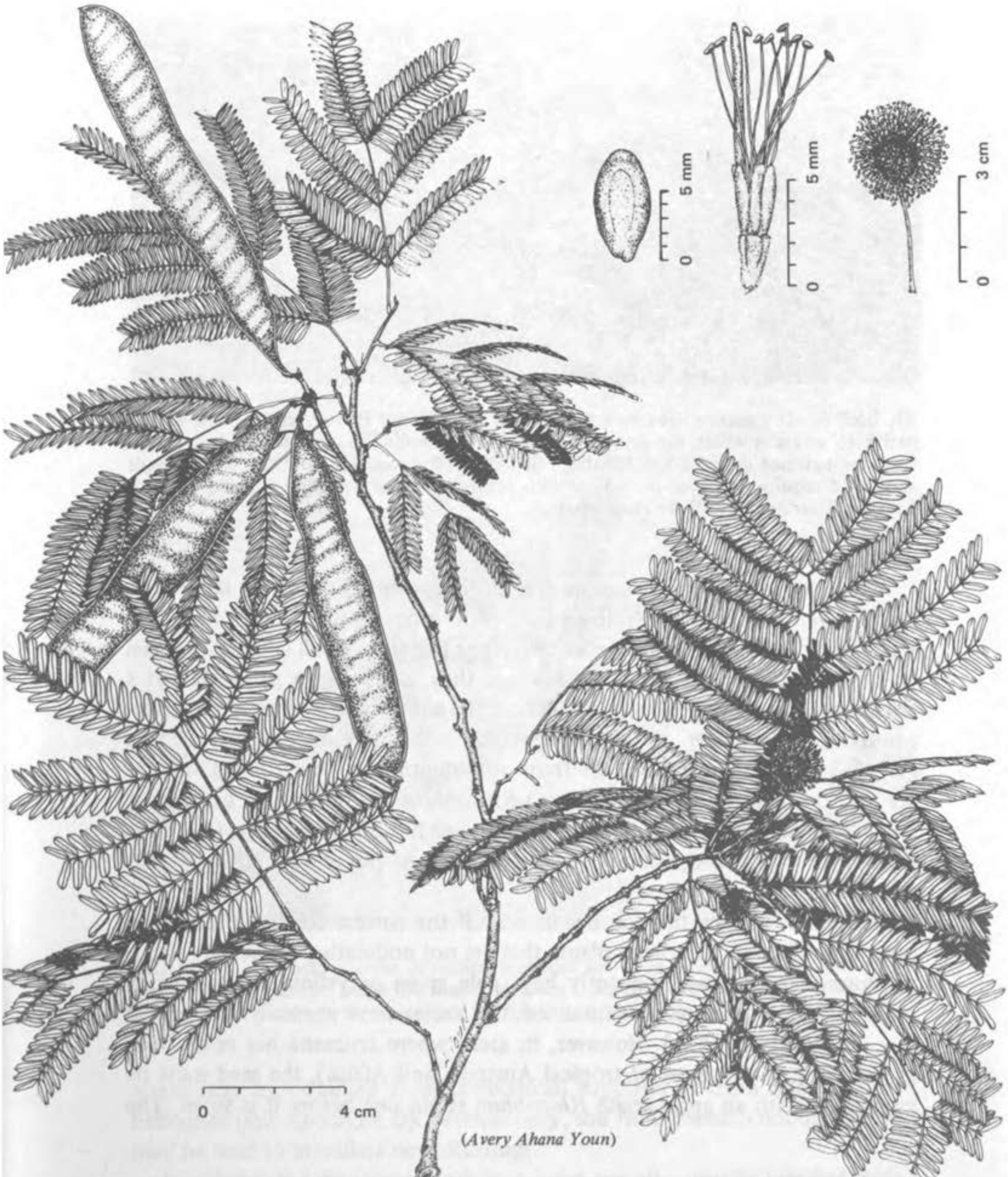


FIGURE 5 Leucaena [*Leucaena leucocephala* (Lam.) de Wit.] Drawing supplied by D. L. Plucknett.

FIGURE 6 Dry season, Guerrero State, Mexico (left) and Hawaii (right). Leucaena is native to a region where the dry season extends 6 months. Its ultimate mechanism for surviving extreme drought is defoliation. Shedding all leaves, the plant enters a dormant state that requires little or no water. With returning water it springs back to life. (G. Sánchez Rodríguez and D. L. Plucknett)

While still very small, leucaena seedlings develop a substantial taproot to reach water before the vulnerable young plant is caught by drought. Seedlings will usually have a taproot almost as long as the plant is tall (Figure 7). Even on adult plants, lateral roots are few and they usually grow downward at a sharp angle. But small laterals occur near the soil surface and carry the nitrogen-fixing *Rhizobium* nodules (Figure 8), which are usually 2.5-15 mm (0.1-0.5 in.) in diameter and are frequently multilobed. Functioning nodules are bright pink inside. The leucaena-*Rhizobium* partnership is capable of annually fixing more than 500 kg nitrogen per ha (500 lb per acre).* This is equivalent to 2,500 kg ammonium sulphate per ha per annum (2,500 lb per acre per annum).

However, nitrogen fixation occurs only if the correct *Rhizobium* strain is present in the soil. Leucaena plants that are not nodulating are usually stunted, unproductive, and frequently have pale green or yellow foliage low in protein. Where leucaena is naturalized, the bacteria are normally widespread (e.g., in Southeast Asia). However, in areas where leucaena has never been grown before (e.g., most of tropical Australia and Africa), the seed must be inoculated with an appropriate *Rhizobium* strain just before it is sown. The

*Such yields have been measured both at the University of Hawaii and at the Commonwealth Scientific and Industrial Research Organisation, Queensland, Australia.

Rhizobium strains are also available for special soil conditions; for example, CB81 from Australia for use in acid soils, and NGR-8 or NGR-35 from Papua New Guinea for use in alkaline soils.

FIGURE 7 To help survive droughts, leucaena seedlings develop a deep root system early. This mechanism helps the tender seedling avoid desiccation by giving it maximum access to soil moisture. Note nodules. (G. Sánchez Rodríguez)

strain may be obtained from commercial suppliers or from research microbiologists (see Appendix D). Alternatively, soil from beneath nodulating trees may be used to inoculate new plantings.

In nature, the fine roots and root hairs are also usually infected with a beneficial mycorrhiza fungus whose vast network of hyphae helps the plant obtain phosphorus and other nutrients. This is of considerable importance in enabling leucaena to grow in soils low in minerals such as phosphorus.

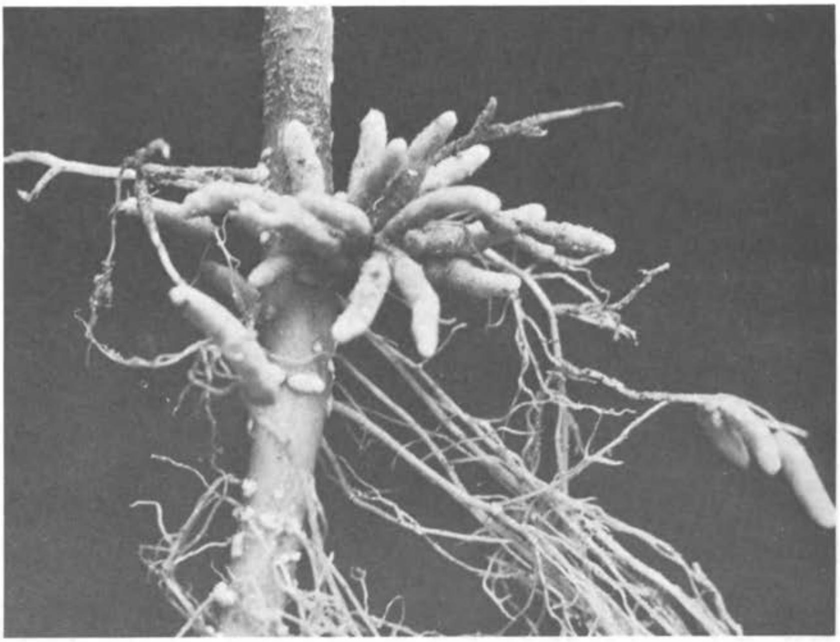


FIGURE 8 Although leucaena develops a vigorous taproot, small lateral roots near the soil surface develop abundant nodules housing *Rhizobium* bacteria that fix atmospheric nitrogen and provide the plant with usable nitrogenous compounds. As the plant grows, the nodules enlarge and often branch. (M. J. Trinick)

Reproduction and Growth

Leucaena's tiny flowers form in white, fluffy balls (see Figure 5). They are usually self-pollinated, and the flower heads produce drooping clusters of thin, flat, almost straight pods (Figure 9). Translucent when young, the green pods redden and harden with age, eventually splitting along both edges and ejecting the 15–30 seeds they contain. The shiny-brown, flattened seeds have an impervious, waxy seedcoat and must be treated to ensure quick and uniform germination.*

Seed viability is high and the seeds can be successfully planted by hand or by machine. As already mentioned, Hawaiian-type leucaena produces seeds at an early age (seedlings less than a year old are often laden with pods), then continues to bear abundantly year-round. That is why this type spreads rapidly and forms dense stands that choke out other plants. On the other hand,

*A method that gives 80-percent germination within 8 days involves treating the seeds with hot (80°C, 176°F) water for 2–3 minutes. Further increases can be obtained by then soaking the seed for 2–3 days. The seed may then be sun-dried and stored prior to sowing. (Information supplied by R. J. Jones.)

FIGURE 9 Leucaena pods (N. D. Vietmeyer)

Salvador and Peru types mature more slowly and flower less frequently. Consequently, they are less fecund and less likely to become troublesome weeds.

Although they eventually grow rapidly, leucaena seedlings are slow starters (this is not uncommon among legumes).* Early in life, the seedlings can be smothered by fast-growing weeds. Thus, slow growth complicates establishment and often causes total failure of the planting. To get leucaena established efficiently, the site must be carefully prepared and weeds controlled (for an innovative approach see Figure 10); sometimes a little phosphate fertilizer must be added to boost the seedlings through the first few months.

Once rapid growth begins, the leucaena plants form a canopy of foliage that shades out weeds. The result is a pure leucaena stand with a forest floor free of weeds and even free of leucaena seedlings (see Figure 42). If both Salvador and Hawaiian types grow together, the taller Salvador type exerts a similar "birth control" by shading the shorter Hawaiian type until eventually it dies out. Characteristically, on the periphery of dense stands the plants lean outward (see Figure 30) and, as the seeds drop, germinate, and grow, the

*In Malawi, it has been noted that seedlings grow slowly in newly broken land, but much faster where crops had been grown previously; also, that mulching the seedbed greatly increases seedling growth where rainfall is erratic. (Information supplied by R. Savory and D. Thomas.)

FIGURE 10 Researchers in Malawi have found that leucaena pastures can be easily established by sowing the seed beneath growing corn plants. This avoids the time and expense of preparing a seedbed. In addition, the seedlings establish quickly because they are shaded and protected from desiccation, and they require no weeding or maintenance. Although the first-year forage yield is lower than normal, the corn yield is unaffected and contributes to the profitability of the crop. (R. Savory)

stands expand. Because the seeds are not scattered widely and plants cluster together densely, leucaena has been termed a "gregarious" plant.

Leucaena can be reproduced by cuttings or grafts, but with difficulty. The plant readily coppices (also known as ratooning, or pollarding); i.e., the stumps of mowed, or logged, plants will regenerate new shoots instead of dying. Stumps from plants of almost any age, and of any variety, quickly resprout (Figure 11; see also Figure 19). Sprout growth is even more vigorous than seedling growth because sprouts expend no energy growing roots and they are served by a root system designed for "feeding" a much larger above-ground plant. Sprouts of Hawaiian-type varieties have been known to grow 4 m (12 ft) tall with a diameter at breast height of 5 cm (2 in.) in just one year. Sprouts of Salvador-type varieties have reached 6 m (18 ft) in 12 months.* Leucaena's coppicing ability allows repeated harvest of firewood, timber, or forage. Hedges that have been trimmed at least twice a year for more than 40 years are cultivated in Hawaii. If, after a time, the plants begin to lose vigor, replacement from seedlings is sufficient to maintain the stand's vitality. In cases where leucaena's growth gets out of hand, the plant can be killed with standard herbicides, or girdling.

*Information supplied by J. L. Brewbaker.

FIGURE 11 Coppice regrowth of Hawaiian Giants. After these varieties are cut for timber or firewood, the stumps sprout and quickly regrow new trunks. The resprouted stumps in the background are only 2½ years old. (J. L. Brewbaker)

Environmental Tolerance

Successful growth in a wide range of environments is a hallmark of leucaena. True, it is restricted to the tropics and subtropics, and within that huge region to elevations below about 500 m (1,500 ft),* but it withstands large differences in rainfall, sunlight, salinity, and land terrain, as well as periodic inundation, fire, windstorm, slight frost, and drought.†

*The plant continues growing at high elevation, but without its lowland vigor. The altitude where growth retardation becomes noticeable may vary with latitude (perhaps due to temperature differences) because it is lower in Hawaii than in more equatorial nations such as Indonesia and the Philippines. At 1,000 m altitude in Malawi, yields as high as 8 tonnes per ha have been achieved. (Information supplied by R. Savory.) There are some indications in the Philippines that retarded growth may be due to increased acidity in upland soils. Treatments with lime or urine have enhanced growth rates remarkably. (Information supplied by Bro. A. Goldberger.)
†Oakes. 1968. See Selected Readings.

Leucaena grows best where annual rainfall is 600-1,700 mm (25-65 in.). However, it is the dominant vegetation covering Honolulu's Diamond Head where annual rainfall amounts to only 250 mm (10 in.).

The plant grows well even where there are long, severe, dry seasons. In its native Mexican habitats in Yucatan and Guerrero, leucaena survives where no rain falls for 8½ months a year. In this area, it is often the only forage that remains green and productive year-round (Figure 12).

Although leucaena tolerates partial shade, it grows best in full sun. It becomes defoliated with even occasional light frosts, but with returning warm temperatures the plant bursts with greenery once again.

By reaching deeper for nutrients and water than most crop plants, leucaena's root system allows it to tolerate a wide array of soil conditions. Leucaena is found in soils varying in texture from rock to heavy clay to coral (Figures 13a and 13b). It is commonly found growing from almost vertical cliffs (Figure 13c).

Unaided, leucaena grows well only in neutral or alkaline (especially limestone) soils. It grows poorly in acidic soils, and much of the tropics has acidic latosolic soils high in alumina and often deficient in molybdenum and zinc.

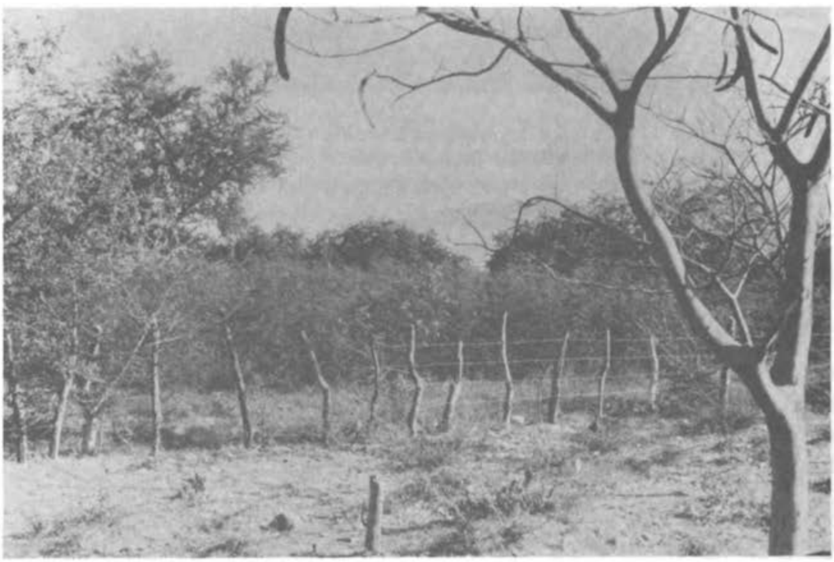


FIGURE 12 Ciudad Altamirano, Guerrero, Mexico. In semiarid regions such as west-central Mexico, leucaena is often the only greenery to be seen during dry seasons. The plant's deep taproot reaches underground water unavailable to other plants. Leucaena's ability to provide forage when pasture grasses have succumbed to drought is an important feature. (G. Sánchez Rodríguez)

To make leucaena grow well in such soils is a challenge. That it can be done is shown by legume trials on an acid (pH 4.2) latosol at Belém in Brazil's Amazon region. Leucaena was easily the most productive legume in the trial, but to get it established required lime pelleting and the use of molybdenum and fertilizer containing phosphorus, sulfur, and calcium.* (See also Figure 13d.)

Furthermore, the exceptional yields on the island of Kauai reported in Brewbaker, Plucknett, and Gonzalez, 1972 (see Selected Readings), were achieved on a highly aluminous soil, but they were made possible only by the addition of rock phosphate and calcium (Figure 13e).

The actual levels of mineral nutrients–including those for phosphorus, sulfur, calcium, potassium, molybdenum, zinc, and copper–that leucaena requires for best growth are as yet little known.

The plant has considerable salt tolerance and grows in exposed coastal areas–often right down to the high water mark (Figure 13f).

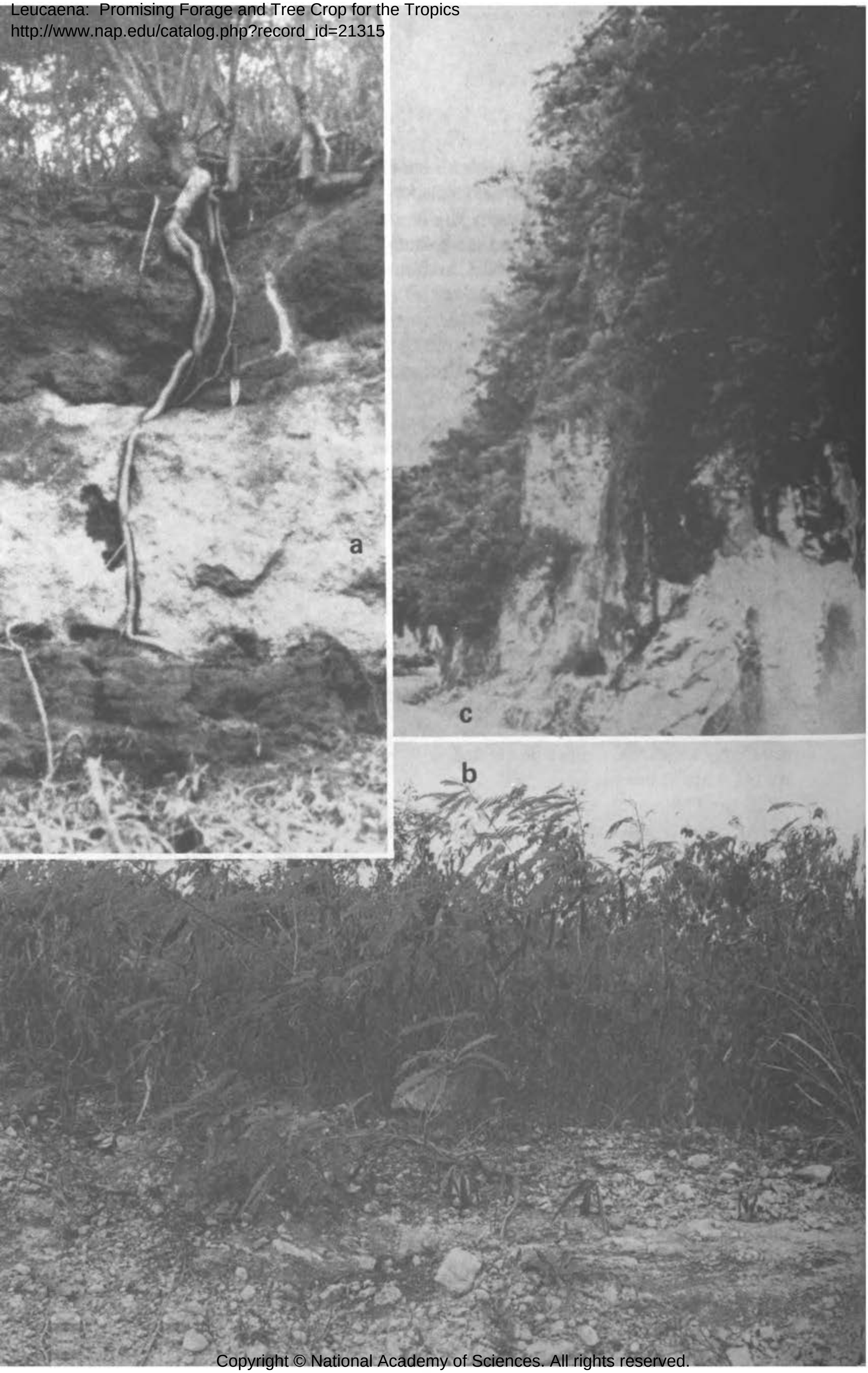
Pests and Diseases

Leucaena shows high resistance to pests and diseases, but experience is based largely on the Hawaiian type. A common pest is the seed weevil, which attacks the young pods and eats the developing seeds. Twig borers are seen on leucaena, but rarely cause serious damage. In Malawi, termites attack young seedlings, which then must be treated with insecticide, or planted in extra numbers at the outset.

In the Philippines, a fungus has been found recently that attacks seeds and young pods of the Salvador type. Whether this portends a serious problem remains to be seen. Other fungal diseases such as damping-off can occur in wet soils.

Seedlings of all varieties are relished by goats, feral animals, rats, deer, wallabies, and other wildlife. Sometimes much perseverance (or fencing) is needed to get a plantation through the seedling stage.

*Information supplied by E. M. Hutton.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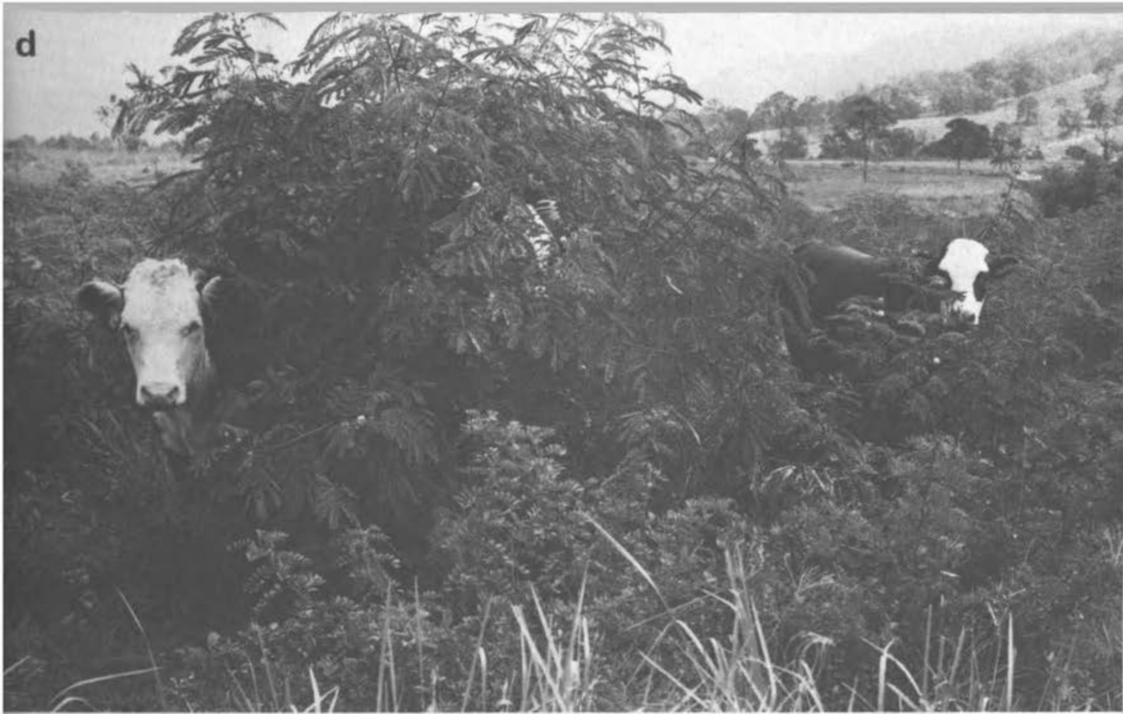

FIGURE 13 Leucaena's ability to grow in difficult soils is remarkable. Although the plant is poorly adapted to acid and aluminous soils, fertilization can be used to develop highly productive stands, as shown at top and at middle of this page. Facing page: upper left; rock wall, Oahu, Hawaii. (M. Takahashi) Alongside: limestone cliff, Cebu Island, Philippines. (R. L. Pendleton) Bottom: dry, rapid-draining, coral soil, lacking organic matter, phosphorus and micronutrients. St. Croix, U.S. Virgin Islands. (O. Skov) Top of this page: acid soil. Samford, Queensland, Australia. (T. H. Stobbs) Middle: highly aluminous soil. Kauai, Hawaii. (R. S. de la Peña) Bottom: heavy salt spray leucaena growing right to the high tide mark). Mindanao, Philippines. (R. Savory)

Chapter 3

Animal Feed

Because there is an acute shortage of animal feed throughout the tropics, the need for high-protein forage and digestible nutrients is a chronic concern. Nowhere is the shortage worse than in the seasonally dry tropics—vast scattered areas where recurring dry seasons preclude shallow-rooted perennial forage grasses and pasture legumes. Leucaena pastures are some of the most productive in the tropics. Although their scraggly bushes have a misleading appearance, they promise to become especially useful forage sources for the dry tropics.

Young or mature, green, dry, or ensiled, the foliage is relished by livestock as well as wildlife—particularly when green feeds are scarce. Succulent young leucaena foliage is mainly used to feed cattle, water buffalo, and goats, which are less affected by mimosine than other animals. It can be harvested and carried fresh to the animals, dried into a leaf meal, or fermented to silage. Alternatively, cattle can be allowed to browse the standing bushes.

To feed on topmost foliage, cattle will bend branches over with their bodies or hoofs. Luckily, leucaena is not thorny, and its strong pliable stems are not easily broken.

For grazing purposes, short and multibranched Peru-type varieties are best, for they yield more leafy foliage within reach of cattle. In Australia, an 18-year project resulted recently in the registration of a new forage variety named Cunningham. This dark-green, vigorous, leafy type was derived from crossing Salvador- and Peru-type varieties. It produces up to 50 percent more edible dry matter than other forage varieties in Australia. Cunningham produces large numbers of branches, buds, shoots, and leaves within reach of grazing cattle.* A new, low-branching, Hawaiian-type forage, K341, that produces outstanding yields, has recently been developed at the University of Hawaii.†

*More information is given in Hutton and Beattie. 1976. See Selected Readings.
†More information is given in Guevarra. 1976. See Selected Readings.

Management

Leucaena can be cropped for forage several ways. It can be grown as a range plant in scattered untended stands, in intensively cultivated pastures, in small plots, or along fencelines and roadsides. As noted above, the plants can be browsed by free-ranging cattle, or hand harvested and hauled to the cattleshed. They can also be mechanically harvested using machinery developed for bulk handling other forage (Figures 14–20). The herbage, which can be fed

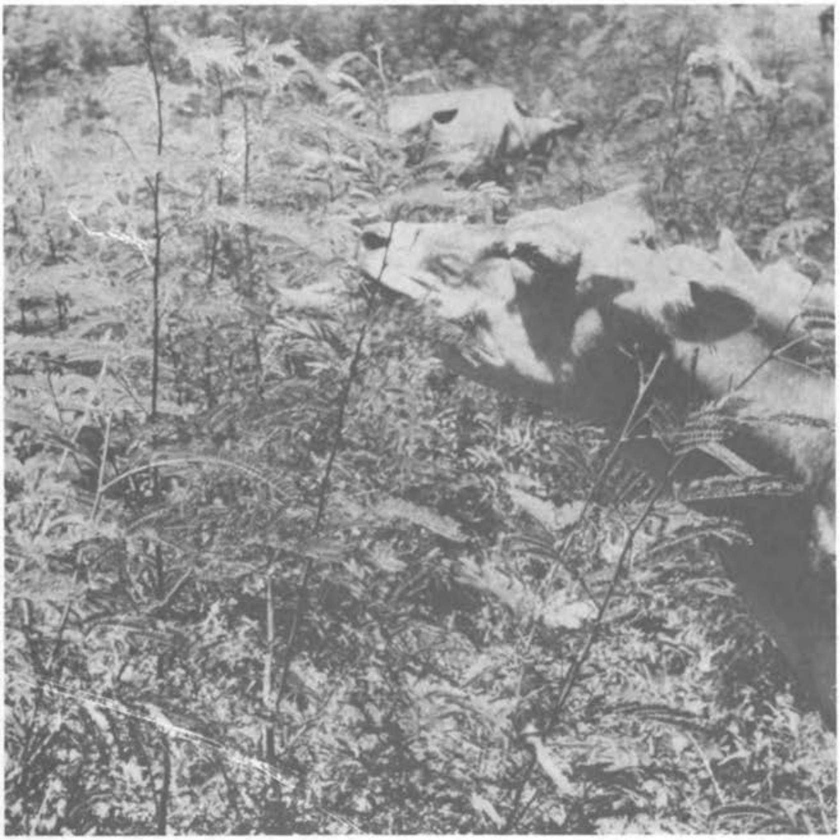

FIGURE 14 Guerrero State, Mexico. In contrast to most conventional pastures, leucaena pastures are "three-dimensional." The tall-growing leucaena provides cattle with grazing from ground level to eye level. An interplanting of grasses adds an edible ground cover as well. Leucaena's feathery leaves allow sunlight to pass, so that grass can also survive and thrive. Leucaena grows rapidly, and once established is seldom smothered by even the most vigorous grasses. The combination makes extremely productive pastures that capitalize on the potential of each type of growth. (G. Sánchez Rodríguez)

FIGURE 15 Herbivorous animals find leucaena foliage extremely palatable. Often they strip stems of all leaves before moving to other feeds. Leucaena's strong, pliable branches are seldom damaged and the leaves quickly regenerate. (G. Sánchez Rodríguez)

fresh, or sun-dried, can even be fed as the dehydrated product from a commercial alfalfa (lucerne) dryer (Figure 20).* With this adaptability leucaena can meet the needs of small-scale farmers both in rural areas and on the periphery of cities, as well as the needs of feedlot operations and of ranching on tropical rangelands.

Cattle should not be fed solely on leucaena for extended periods because of mimosine toxicity (see below). However, feeding it for up to approximately 3 months does not usually cause problems. It is advantageous to

*In Malawi it has been found that the dried leaf can be compressed into feed pellets without milling and without addition of water, molasses, or other binder. (Information supplied by J. A. Breen.)

FIGURE 16 Not only is leucaena useful in pastures where cattle can graze for themselves, but with its long leafy branches it is well-suited to cut-and-carry forage production in developing countries. Here, in Guerrero State, Mexico, a farmer cuts leucaena to carry home to a dairy cow. (G. Sánchez Rodríguez)

incorporate grass into the diet by rotating the animals between leucaena and grass pastures. Alternatively, leucaena can be grown interspersed among fast-growing pasture grasses.* Its leaves allow sunlight to filter through to the grass, and the combination makes a highly productive two-level pasture. Established leucaena is compatible with the most vigorous grasses, e.g., pangola, *Brachiaria decumbens*, and guinea grass (*Panicum maximum*), and under heavy grazing the combination remains well-balanced so that neither leucaena nor the grass dominates. In northern Australia leucaena/pangola grass pastures have retained balanced proportions for 4 years (Figure 21). Conventional pasture legumes (siratro, *Glycine wightii*, centro, etc.) are less aggressive than such grasses and prove difficult to maintain in balance, which greatly complicates pasture management.

Once they reach a height of 1 m (3 ft), the plants can be browsed, but both overgrazing–which cuts forage yield–and undergrazing–where plants grow too tall for cattle to reach–must be guarded against. If it grows too tall, leucaena can be chopped back (mechanically or by hand).

*In odd cases, even supplementing a leucaena diet with grass fails to overcome mimosine toxicity. For an example see Blunt. 1976.

FIGURE 17 Ngabu, Malawi. The Malawi system for dehydrating leucaena. Branches are cut by hand when they reach a height of about 1.5 m (5 ft). Often they are laid on their own stubble, which stands about 30 cm (1 ft) high . . . .

. . . After 1 or 2 days in the hot sun, the tiny leaflets dry out and are easily beaten off into a portable canvas container, which is moved along the rows as the work proceeds. Pods and twigs are then removed and the leaflets are pelleted for poultry and cattle feed. Japan and Singapore both import leucaena pellets. (R. Savory)

FIGURE 18 Waimanalo, Hawaii. The mechanized production of forage from leucaena. Although the plant grows naturally as a bush, young leucaena can be mowed close to the ground as if it were pasture forage like alfalfa or clover . . . .

FIGURE 19 . . . After mowing, the rootstocks rapidly regrow stems and leaves. Each year three or four harvests can be obtained this way; in Australia some fields are still in production after 17 years of periodic grazing. [Reprinted from Kinch and Ripperton. 1962. (See Selected Readings)]

FIGURE 20 Waimanalo, Hawaii. Freshly mowed leucaena leaves and stems are dehydrated in machinery designed for alfalfa. Sophisticated processes for bulk handling of temperate-zone forages can be adapted to the large-scale production of leucaena feedstuffs in the tropics. (See also Figure 18.) [Reprinted from Kinch and Ripperton. 1962. (See Selected Readings)]

Yield

The plant is a prolific producer of leaves, flowers, pods, buds, and twigs (all of which are eaten by cattle), and with careful management leucaena fields can maintain heavy yields and survive heavy grazing (Figure 22).

Forage yields are influenced by the variety as well as by climatic and environmental conditions. Generally, however, the annual yield of dry matter is between 2 and 20 tonnes per ha (1-10 tons per acre). A small proportion of this is usually inedible, woody stems. From the best forage varieties on

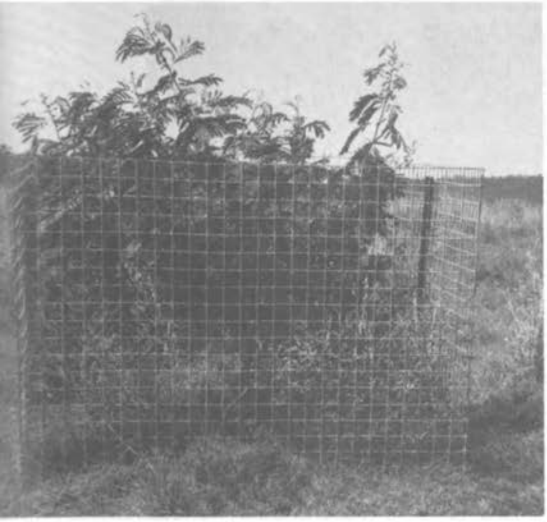
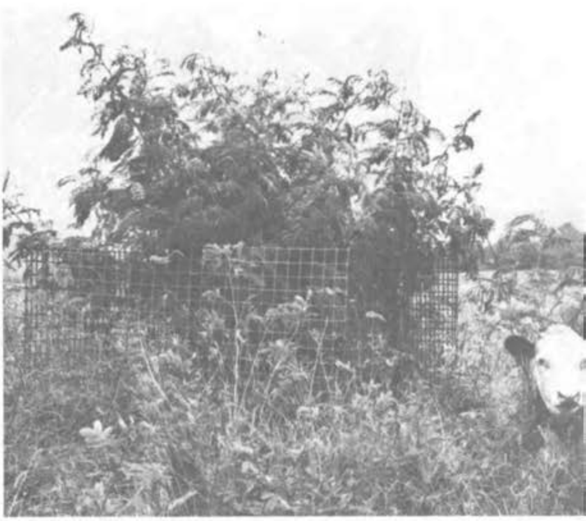

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FIGURE 21 Samford, Australia. Leucaena is a very palatable forage, as demonstrated by the picture at left, where leucaena outside the cage has been browsed so heavily it is almost invisible. But leucaena is also very persistent. The picture at right shows its remarkable recovery. This leucaena/grass pasture was rotationally grazed (4 weeks on and 4 weeks off) between the times that the pictures were taken. The relative amounts of grass and leucaena remain balanced, but if grazing is stopped the leucaena rapidly dominates, as can be seen within the cage. (R. J. Jones)

good sites, annual yields of edible dry matter (leaves and fine stems) are 12–20 tonnes per ha (6–10 tons per acre). This is equivalent to the annual production of 800–4,300 kg of protein per ha (800–4,300 lb per acre).

In the dry tropics, yields are reduced because the plants are stressed during the dry season. Nonetheless, good forage varieties will annually yield about 8 tonnes of edible dry matter per ha (4 tons per acre). Irrigation can increase this to the higher levels, however.*

These yields compare favorably with those of the finest forage legumes. For example, under favorable conditions alfalfa produces 8–9 tonnes of dry

*These yields are based on results reported by Takahashi and Ripperton 1949, Kinch and Ripperton 1962, Brewbaker, Plucknett, and Gonzalez 1972, Guevarra 1976 (all Hawaii); Oakes and Skov 1967 (U.S. Virgin Islands); Hill 1971 (Papua New Guinea); Hutton and Bonner 1960 (Australia); and Partridge and Ranacou 1973 (Australia). See Selected Readings. Yield figures quoted in the literature are difficult to compare because of differing amounts of stem in the samples.

FIGURE 22 A heavily grazed leucaena pasture cut out of tropical rainforest in Papua New Guinea. The scraggly appearance of the bushes belies their productivity and usefulness as browse. (Department of Primary Industries, Port Moresby)

matter per ha (4–4.5 tons per acre), and under dry-land conditions it averages 2–3 tonnes per ha (1–1.5 tons per acre).*

Nutritive Value

The whole leaf contains both nutrients and roughage and makes a more-or-less complete ruminant feed, pretty much comparable to alfalfa forage (Table 1). Leucaena leaflets, which can be readily separated from the leaf stems, make a high-protein feed for they contain 27–34 percent protein.† Because the protein content is so high, leaflets are being sun-dried in Malawi,

*These alfalfa yields are given in: Hanson, C. H. 1972. *Alfalfa Science and Technology*. Monograph Number 15, American Society of Agronomy, Madison, Wisconsin, USA; and Leach, G. L. 1977. The ecology of lucerne pastures. In *Proceedings of the Plant Relations in Pastures Symposium 1976*. Ed. J. R. Wilson, CSIRO, Melbourne, Australia.

†In standard tests, mimosine registers as protein, so leucaena's protein content is usually slightly overestimated. (Depending on the leucaena variety, mimosine comprises 2–5 percent of the protein figure usually quoted).

Thailand, and the Philippines for local use and export to Japan and Singapore (Figure 23).

Leucaena's protein is of high nutritional quality. Amino acids are present in well-balanced proportions, much like in alfalfa (Table 2). Leucaena can also be a rich source of carotene and vitamins. Provitamin A content, among the highest ever recorded in plant specimens, yellows the fat of leucaena-fed cattle, which consumers in some countries consider undesirable. In chickens, however, the yellowing is much desired (see below). Depending on the soil minerals available to the root system, leucaena foliage can be an exceptional

	Leucaena Leaf	Alfalfa Leaf
Total Ash (percent)	11.0	16.6
Total N (percent)	4.2	4.3
Crude Protein (percent)	25.9	26.9
Modified-acid-detergent fiber (percent)	20.4	21.7
Calcium (percent)	2.36	3.15
Phosphorus (percent)	0.23	0.36
Beta carotene (mg/kg)	536.0	253.0
Gross energy (KJ/g)	20.1	18.5
Tannin (mg/g)	10.15	0.13

TABLE 1 Comparative compositions (dry weight basis) of alfalfa and Malawi-grown leucaena forage (Information supplied by J. P. F. d'Mello and D. Thomas, University of Edinburgh).

	Leucaena	Copra	Alfalfa
Arginine	294	822	357
Cystine	88	76	77
Histidine	125	128	139
Isoleucine	563	244	290
Leucine	469	419	494
Lysine	313	220	368
Methionine	100	120	96
Methionine + Cystine	188	196	173
Phenylalanine	294	283	307
Threonine	231	212	290
Tyrosine	263	167	232
Valine	338	339	356

TABLE 2 Essential and other important amino acids in the protein of leucaena, copra, and alfalfa (mg amino acid per g of N). In leucaena protein the amino acids, essential for good nutrition in livestock and poultry, show a pattern comparable with that in other animal feed sources available in developing nations. Leucaena protein is better than copra in a number of the amino acids and is equivalent to alfalfa in most of them. It is particularly rich in isoleucine. (Information supplied by M. P. Hegarty)

FIGURE 23 Cebu City, Philippines. A shipload of leucaena meal at the General Milling Company's dock. In 1974, this company alone was buying 1,000 tons of leucaena meal each month. Several Philippine feed mills, having found that it substitutes for imported alfalfa, have become large buyers of leucaena leaf meal for use in animal feeds. Thousands of families in Central and Eastern Visayas and in Northern Luzon Provinces now harvest and sun-dry leucaena foliage, pound the dried leaflets, and bag the resulting meal for shipment to the feedmills. The meal, used in poultry rations, is also exported to Japan. (R. Savory)

source of calcium, phosphorus, and other dietary mineral nutrients. However, samples measured in northern Australia have been consistently deficient in sodium (0.01-0.03 percent of the dry matter.)*

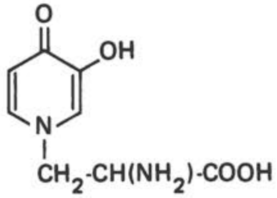
Mimosine

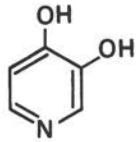
When diets contain less than 30 percent leucaena (dry weight), cattle thrive for prolonged periods. But when leucaena makes up more than half the diet, and feeding is continued for more than 6 months, the result may be general ill-health with loss of tail and rump hairs, excessive salivation (drooling), and poor growth. The cause has recently been traced to the underproduction of thyroxine by the animal's thyroid gland, which results in goiter.† Swollen thyroids (goiters) are common among cattle feeding on leucaena. The cause is

*Information supplied by R. Jones.
†Jones, Blunt, and Holmes. 1976. See Selected Readings.

3,4-dihydroxypyridine (DHP) 2* created in the animals' rumens by bacteria that produce it by chemically transforming the amino acid mimosine 1.† Mimosine comprises 3–5 percent (dry weight basis) of the protein of the now-available leucaena types. In single-stomached animals (horses, pigs, rabbits, etc.), mimosine causes hair to fall out. In cattle, the rumen microorganisms transform it to DHP so quickly that even when animals are fed on a diet rich in leucaena their blood, meat, and milk is quite free of mimosine.

Fear of mimosine's effects have for years been a barrier to leucaena's wider use as forage. Today, with better understanding of its pharmacology, much of this fear is being dispelled.





1 Mimosine **2** 3,4-dihydroxypyridine

Under field conditions, cattle with goiter don't die; the effects are reversible and can be seen early enough that the animals can be removed from the leucaena pasture to recover. Leucaena contains little or no cyanide, selenium, or bloat-causing agents that *do* kill cattle feeding on pastures such as white clover or alfalfa.‡ Mimosine has no known effect on the meat or milk of ruminants that can be detrimental to humans.

Nonetheless, mimosine is a concern, and searches are being made for low-mimosine varieties. Most leucaena strains have about equal mimosine levels, but some from Colombia and other species such as *Leucaena pulverulenta* (from northern Mexico and southern United States) have much less. Pioneering researchers in Hawaii and Australia have crossed leucaena (i.e., *L. leucocephala*) with *L. pulverulenta* to obtain hybrids with less than half leucaena's mimosine content (Figure 24). The research in Australia has reached an advanced stage, and low-mimosine leucaena lines should be available for grazing trials in 2 years. Goat-feeding trials have shown that, compared with strains

*This may actually exist in a tautomeric keto form, 3-hydroxy-4-1(H)-pyridinone.

†Hegarty, Court, Christie, and Lee. 1976. See Selected Readings.

‡Contrary to some speculations in the literature, leucaena has no effect on conception or reproduction in cattle. In Australia, leucaena-fed animals have been mated and continuously fed a heavy leucaena diet during pregnancy. The calves they produced suffered from enlarged thyroids, but 100-percent calving occurred. Indeed, of 14 legumes tested in one study, leucaena had the least estrogen (a female hormone, present in some forages, that interferes with reproduction).

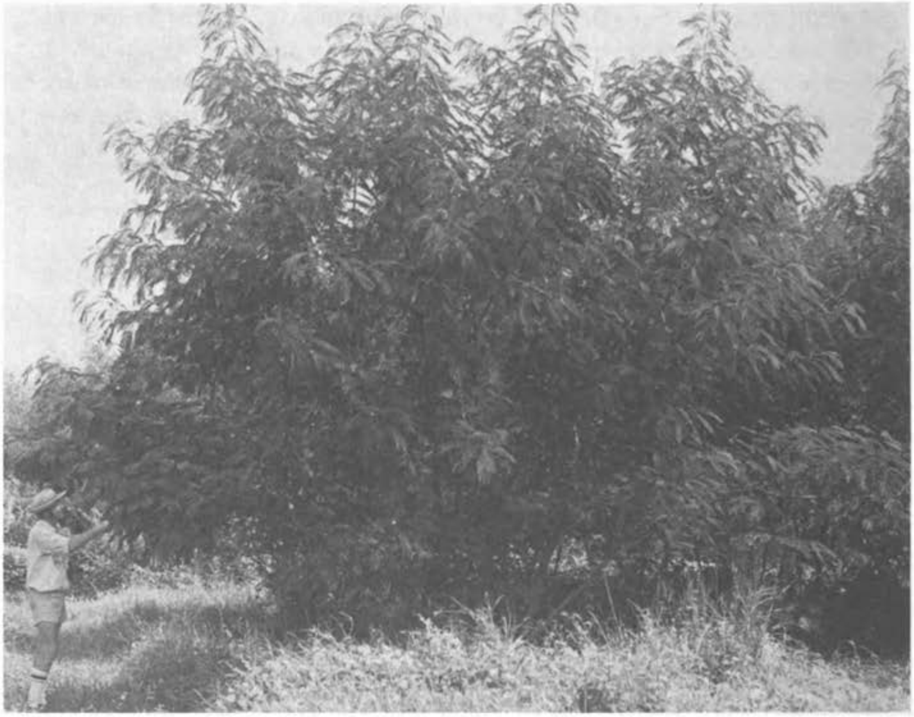


FIGURE 24 Low-mimosine leucaena. This hybrid, bred by back-crossing leucaena (cultivar Cunningham) with *Leucaena pulverulenta* (a closely related, but distinctly different species), is a vigorous, well-branches forage plant whose leaves contain only half the mimosine of leucaena. Bred at the Commonwealth Scientific and Industrial Research Organisation, Townsville, Queensland, Australia. For a treelike hybrid from a similar cross see Figure 48. (W. M. Beattie)

available today, the new hybrids markedly reduce adverse effects caused by mimosine.*

When fresh moist leucaena leaves are heated, their mimosine content decreases, causing their feed value to increase. The reduction is greatest at temperatures above 70°C (158°F). Adding ferrous sulfate to rations containing unheated leucaena leaf meal also reduces mimosine toxicity.†

Cattle Performance

With their vigorous growth and high nutritive value, leucaena pastures can support heavy stocking. They have demonstrated some of the highest carrying

*Information supplied by E. M. Hutton and R. J. Jones.
†Matsumoto et al. 1951. See Selected Readings.

capacities of any tropical pastures. Interplanted with guinea grass, leucaena pastures often carry up to 2.5 cattle per ha (1 per acre). In favorable locations, leucaena/grass pastures (1:1 ratio) can support 6 or more steers per ha (2.5 per acre). The high carrying capacity continues into dry seasons longer than shallow-rooted forages, and with the rainy season's return, leucaena recovers rapidly so that animals can be restocked early.

Requiring little more care than grasses, leucaena pastures continue producing year after year, especially when soils are good. On the island of Hawaii, some stands planted before World War II are still prolific.

Leucaena's palatability is high. When cattle are first put into a leucaena/grass pasture they seem to prefer the grass, but after a few days their preference for leucaena becomes apparent.

The *in vivo* digestibility of leucaena forage is similar to that of other legumes (50–70 percent). (Mimosine reduces the activity of cellulolytic bacteria, and *in vitro* digestibility is often underestimated by 2-7 percent. But in a week the rumen bacteria of cattle adapt and overcome any reduction in digestibility.)

Very high live-weight gains have been recorded in southeast Queensland. Young steers grazing a leucaena/Nandi-setaria pasture near Brisbane gained up to 1 kg (2.2 lb) per day during the main summer season (Figure 25).* It has also been found that steers fed chopped sugar cane supplemented with leucaena can gain 0.6 kg (1.3 lb) per day.†

Given the pastures' heavy stocking rates and the animals' high weight gains, the amount of meat that can be produced on leucaena pasture in a high rainfall, or irrigated area, is impressive. Annual live-weight gains of 900 kg per ha (800 lb per acre) have been recorded in northern Australia. This is about double what is normally expected from good, tropical, grass or legume pastures.*

Dairy cattle also produce well on leucaena; in northern Australia, the annual production can be 5,000-6,000 liters (11,000-13,000 lb) of milk per ha.‡ For 12 years the Machelona hospital on the island of Kauai in Hawaii stocked dairy cows on leucaena/guinea grass pasture (1:1 ratio) at 6 animals per ha, and each year obtained over 9,700 liters (21,400 lb) of milk and 400 kg (800 lb) of live-weight gain per ha.§

Fresh milk from leucaena-fed cows has an attractive yellow color (from the leucaena carotene), but may have an objectionable odor. The odor dis-

*Information supplied by R. J. Jones.

†Siebert, Hunter, and Jones. 1976. See Selected Readings.

‡Information supplied by T. H. Stobbs.

§Plucknett. 1970. See Selected Readings. (Each animal consumed 12–14 kg of leucaena and were fed about 5.5 kg of concentrates and 2 kg of molasses daily.)

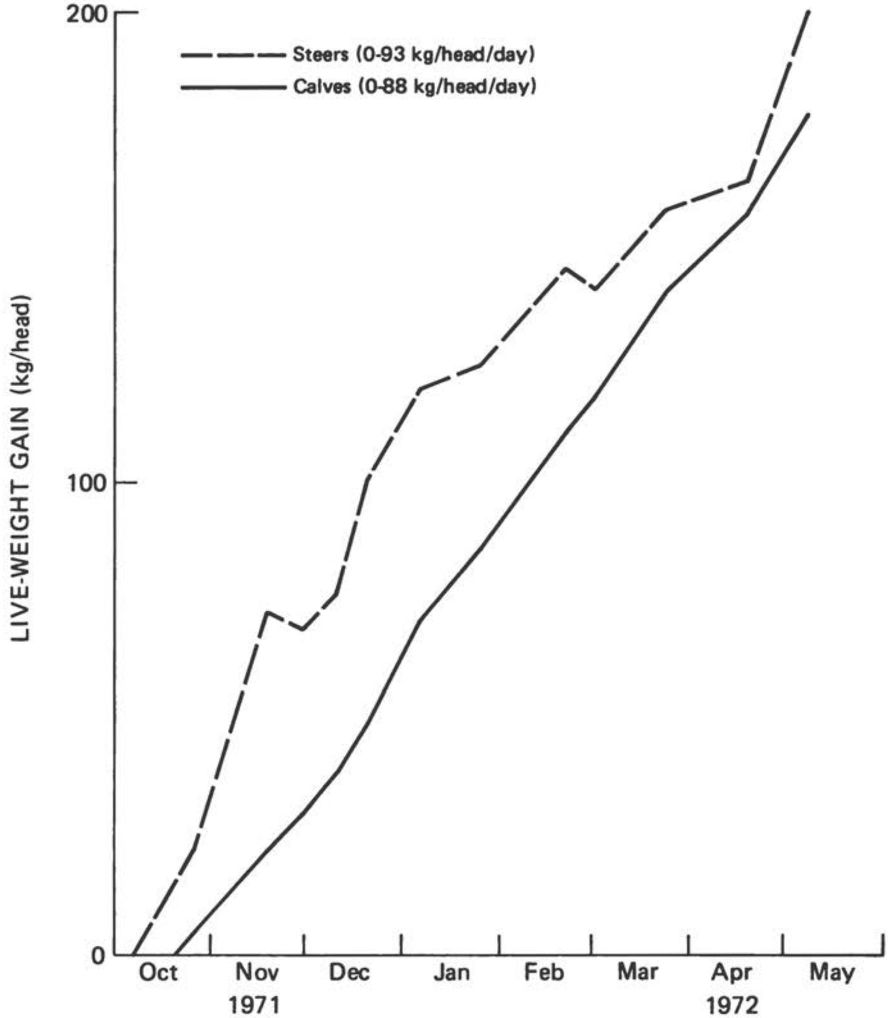


FIGURE 25 Exceptional live-weight gains of steers and calves on leucaena/Nandi-setaria-grass pasture, Samford, Queensland, Australia. The steers grazed this pasture continuously for 215 days, the calves for 203 days. Although this trial took place in a tropical area, the weight gains compare favorably with those that can be obtained anywhere in the world. Leucaena was the dominant forage, but no hair loss or other adverse effects were found. Daily weight gains of 1 kg (2.2 lb) per head were achieved over prolonged periods, but the average was lowered by an autumn period (March–April) when, due to cooler weather, the pasture could not maintain its optimum productivity. A mineral supplement was used to complement the diet and may have contributed to the unexpected lack of mimosine toxicity. (Information supplied by R. J. Jones)

appears, however, on boiling or pasteurizing, and can be avoided entirely by eliminating leucaena from the animals' diets for 2 hours before milking.

Other Animals

This chapter has emphasized leucaena's use for feeding cattle because, though other animals will eat the plant (Figure 26), they are less able to tolerate mimosine in their diets. The rumen bacteria of sheep, for example, don't convert mimosine to DHP as efficiently as those of cattle; some passes the rumen and enters the bloodstream. Ten days after ingesting a substantial amount of leucaena, mimosine's depilatory effects are dramatically evident (Figure 27). Nonetheless, if sheep are slowly introduced to leucaena feeds, the rumen bacteria adjust and the animals can feed on the plant (especially the low-mimosine type) with no apparent untoward effect. Leucaena is a browse plant favored by goats on small farms in parts of the tropics.

Pigs are sentitive to mimosine, but in Papua New Guinea and the Philippines leucaena leaf meal has been used satisfactorily to supplement rations (up to 10 percent) for growing pigs.*

Leucaena retards sexual maturity in chickens; therefore the use of its dehydrated leaf meal in poultry feeds is limited to about 5 percent of the ration. Nevertheless, it is becoming a popular ingredient in poultry feeds manufactured in the Philippines. The leaf meal supplies protein, minerals, and vitamins. Leucaena can contain twice the carotene of dehydrated alfalfa meal, which provides the ration with vitamin A: 4-6 percent leucaena leaf meal in a poultry diet restores health to chicks (and pigs) suffering from vitamin A deficiency. Furthermore, research at the University of Hawaii has shown that feeding hens leucaena leaf meal can dramatically increase the proportion of their eggs that hatch. Compared with alfalfa meal, leucaena leaf meal has about twice as much riboflavin and vitamin K, both of which enhance egg hatchability.†

Leucaena meal is also rich in xanthophyll pigments, which color egg yolks and broiler skins a brilliant yellow. To achieve this coloration, commercial poultry feeds contain alfalfa, flower petals, or synthetic compounds. Leucaena leaf meal contains almost twice the pigmenting power of alfalfa and, in the Philippines at least, is proving much cheaper than imported alternatives.‡ To get the same depth of color, diets need contain only half as much leucaena leaf meal as alfalfa meal. The difference can then be made up with ingredients such as fat or corn that increase the diet's energy value.

*Leche, T. F., 1974. Legumes and grazing ruminants in Papua New Guinea. *Science in New Guinea* 2:30-33

†Information supplied by E. Ross.

‡Information supplied by L. S. Castillo.

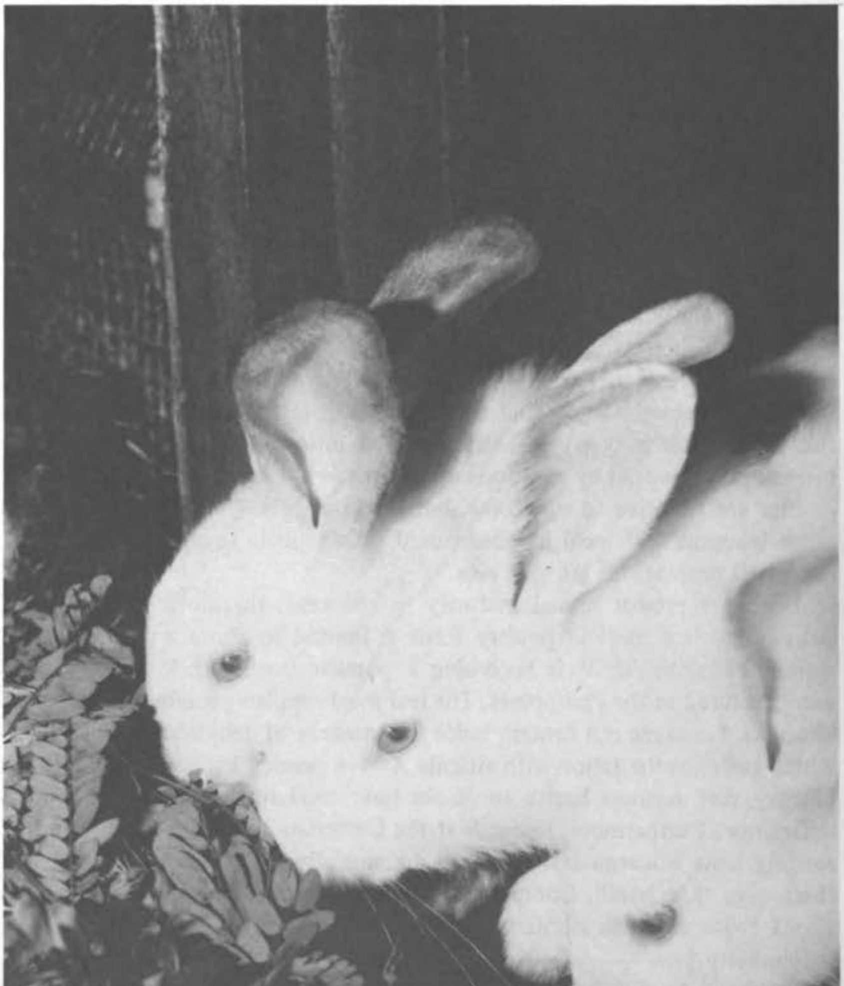


FIGURE 26 Although the presence of mimosine is a potential hazard to nonruminant animals, most of them find leucaena palatable and eat it readily. (N. D. Vietmeyer)

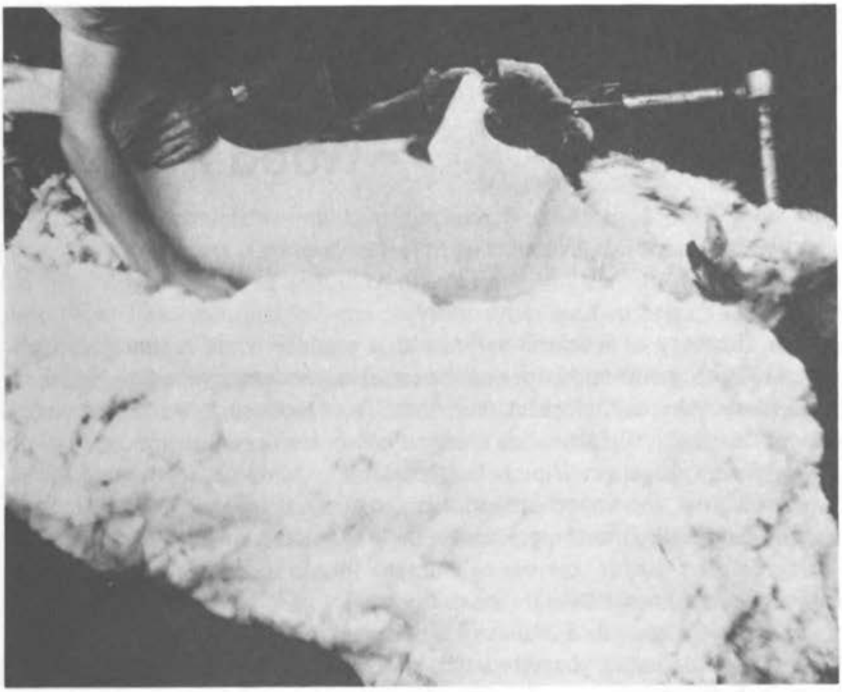


FIGURE 27 Brisbane, Australia. In experiments, the depilatory effect of mimosine in leucaena forage has been turned to benefit. Ten days after feeding sheep an exclusive diet of leucaena, a stroke of the hand is all that is needed to separate wool from the skin. Potentially, this could become a cheap way to shear sheep. No lasting effects on the sheep have been found, and the method would become practical immediately if a way to protect "bare" sheep from sunburn were available. (M. P. Hegarty)

Chapter 4

Wood Products

The discovery of leucaena varieties that produce wood is timely and important. Both wood and paper are essential in modern civilization. Furthermore, their value as industrial raw materials is increasing. Wood is virtually the only economically attractive renewable resource for construction.

For forage, short, multibranched leucaena is used, but for lumber, pulp, paper, and fuel, the important varieties are of the Salvador type, which grow tall and have little branching. Because these varieties have been available only during the past decade, the use of leucaena in manufacturing wood products is generally less known than its use as forage.

The single-stemmed, Salvador-type leucaena varieties that produce wood have several desirable characteristics in common with the bushy Hawaiian types including: rapid growth; adaptability to poor soils, drought, and windstorm; and high nitrogen-fixing capacity. But they do not have an aggressive, highly flowering, weedy nature. Because of these qualities, and because wood products are in constant demand, these leucaena varieties could become particularly important for reforesting many lowland tropical regions (see Chapter 6).

Yield

In the Philippines, dense leucaena plantations have yielded higher annual quantities of wood than any species yet measured. Other fast-growing hardwoods (for example, *Albizia falcataria, Gmelina arborea, Eucalyptus deglupta*, and *Anthocephalus chinensis*) grow with annual increments of 28-43 m^3 per ha (355-545 ft^3 per acre) in the volume of wood they produce. Annual leucaena increments have been measured from 24 to over 100 m^3 per ha (300 to over 1,250 ft^3 per acre).* Average annual increments,

*Information supplied by P. V. Bawagan. This range is broad because the specimens varied in age from 3 to 8 years, and because leucaena has so far been planted with little concern for site suitability.

however, are expected to be between 30 and 40 m^3 per ha (430-580 ft^3 per acre).

Although experience is limited, the trees seem to grow in 6–8 years to total heights of about 18 m (60 ft) (Figure 28). Vigorous trees only 8 years old can have diameters of 21–37 cm (8–15 in.) at breast height (see Figures 4 and 29).

If planted carelessly, and later uncared for, the trees often grow with crooked trunks, but if carefully planted and thinned, the continual crowding of the foliage canopy keeps the trunks straight and virtually branchless. Unlike other leucaena varieties, the Salvador types tend to branch only at the top in any case.

Where soils are deep and growing conditions favorable, leucaena's rooting habits enable its planting in very dense stands. In the Philippines and Hawaii it is being planted in dense thickets (see Figures 30 and 42) that are selectively harvested for use as poles.* Thinning the plantation in this way allows the remaining leucaena plants to thicken and grow so that their trunks become large enough for fence posts, telephone and power poles, and eventually for pulpwood and timber production.

Like their multibranched relatives, Salvador-type leucaenas coppice vigorously. Even stumps from large-trunked trees felled close to the ground will resprout rapidly (see Figure 11). Actual rates have not been measured, nor is the quality of regrowth-wood known, but it is thought that cutting cycles of 5–6 years in equatorial climates (such as in the Philippines) will result in maximum wood and pulp yields and best financial return.

Wood Properties

Initial tests suggest that leucaena wood has much commercial potential. The wood is thin barked (less than 8 percent of the bole is bark, dry-weight basis) and light colored. The sapwood is yellow-white, heartwood yellow-brown. Some samples include nodes (knots), but this seems to come mainly from trees that were poorly established and left unmanaged, resulting in branching and bent trunks. Wood from 6- to 8-year-old Salvador-type varieties, has specific gravity averaging 0.54† (Table 3); fiber dimensions are typically those of a hardwood (Table 4). It is a medium hardwood.

*A thinning schedule now projected requires planting 10,000 trees per ha (4,000 per acre), removing half the trees in the second year and half of the remainder in the fourth year, leaving plantations of 2,500 trees per ha (1,000 per acre). Normally, pulpwoods are grown with less than 1,000 plants per ha (400 per acre).

†This is similar in density to the wood from oak, ash, birch, and sugar maple.

FIGURE 28 Canlubang Estate near Manila, Philippines. Only 8 years old, this specimen of Hawaiian Giant leucaena towers to a total height of 20 m (65 ft). Although spindly, it has a diameter (at breast height) of 40 cm (16 in.). (M. D. Benge)

Specific gravity gives a rough measure of latent strength in wood samples and leucaena wood is expected to have better tensile-, compressive-, bending-, and shear-strength than less dense woods such as pine or Philippine mahogany (*Shorea* species, specific gravity 0.4). The wood is close grained and appears easily workable. It absorbs wood preservative readily and is easily treated for protection against termites.

Pulp

Salvador-type leucaena wood pulps satisfactorily, producing both paper-grade and dissolving pulps with favorable properties. Preliminary tests suggest

FIGURE 29 Canlubang, Philippines. Hawaiian Giant leucaena, 8 years old. The small grove at this location was planted by dropping seeds into a furrow plowed by water buffalo. The grove was then left without further care or thinning. Yet forestry researchers studying it in 1976 recorded the highest per annum production of wood ever measured in the Philippines. (N. D. Vietmeyer)

	No. of Trees	Site	Age Years	Specific Gravity[a]
"Hawaiian Giant" (K 28) trunk	20	Los Baños	1.5	0.52
	3	Davao	3	0.50
	3	Davao	3	0.59
	2	Canlubang	6	0.52
	1	Canlubang	7	0.54

[a]Based on oven-dry weight in grams/green volume in cm^3

TABLE 3 Density of Philippine leucaena wood. With an average specific gravity of 0.54, wood from the Hawaiian Giant strain is classified as a medium hardwood. The common Hawaiian variety (density 0.70) is more nearly a true hardwood. (Information supplied by P. V. Bawagan)

Length (L)	1.20 mm
Width (D)	0.025 mm
Lumen width (l)	0.015 mm
Cell wall thickness (w)	0.005 mm
Slenderness ratio L/D	48
Flexibility ratio $\frac{1 \times 100}{D}$	60
Runkel ratio $\frac{2w}{1}$	0.67
Runkel Group	I
Mulsteph (percent)	64
Mulsteph Group	III

TABLE 4 Average dimensions and derived values of leucaena (Hawaiian Giant) fiber. Measured on a 6-year-old specimen of cultivar K28 grown at Canlubang Estate, Philippines. (Information supplied by P. V. Bawagan and J. A. Semana)

that, compared with average Philippine hardwoods, leucaena wood can be pulped more easily. It is high in holocellulose and low in silica, ash, lignin, alcohol-benzene solubles, and hot-water solubles (Table 5)—all important benefits in pulp manufacture.

Leucaena wood fiber is shorter than that of pinewood, but it falls within an acceptable range for pulp and paper, and the relationship between fiber length and fiber diameter is good for papermaking (Table 4).* Pulp yield is high (50–52 percent).

*The Runkel ratio (twice the cell-wall thickness divided by the lumen diameter) is less than 1.

The quality of the fiber and of leucaena pulp is comparable to that of other fast-growing hardwoods. Compared to long-fiber conifer pulps, however, leucaena paper has low tearing strength, low folding endurance, and average tensile strength. Nonetheless, with its high opacity, good formation, and good printability, kraft pulp from leucaena is suited for use in printing and writing papers. Its short fibers make it less suitable for high-strength bag and wrapping paper. Some details of its paper quality are given in Table 6. Its main use would be in blends with long-fiber pulp for the production of printing and writing paper.

Leucaena wood can also be made into a dissolving pulp for the production of rayon or cellophane; already a dissolving-pulp mill that will use leucaena as feedstock is planned for construction in the Philippine province of Abra. Furthermore, leucaena wood can be converted to fiberboard (hardboard). Shortages of construction materials in developing nations make this low-cost product particularly important.

Lumber

Leucaena has a future as a source of lumber in the tropics. The wood is strong, dense, and attractive, and has easy-machining properties comparable

FIGURE 30 Batangas City, Philippines. Demonstration plot of Governor Antonio Leviste. Leucaena is one of the fastest growing useful plants known. This stand of a Hawaiian Giant strain is just 1 year old. It is characteristic of leucaena plantations that the plants on the edges lean outward. (N. D. Vietmeyer)

Sample	K28, Trunk	K28, Trunk	Average for 95 Philippine Hardwoods
Grown at	Los Baños	Canlubang Estate	
Number of Trees	2	2	
Age – Years	1.5	6.0	
Holocellulose %	72.6	71.0	63.6
Pentosans %	20.1	13.6	16.4
Lignin %	22.7	23.3	25.7
Ash %	0.9	0.8	1.5
Solubilities in:			
Alcohol-Benzene %	1.7	2.6	4.2
Hot water %	2.0	2.3	3.0

TABLE 5 Proximate chemical composition of leucaena (Hawaiian Giant K28 variety) grown in the Philippines. Compared with the chemical pulping of average Philippine hardwoods, leucaena is expected to show higher pulp yields (because of its higher holocellulose content); fewer problems caused by pitch (because of its lower alcohol-benzene solubles); and possibly less difficult recovery of pulping chemicals (because of lower ash content). (Information supplied by P. V. Bawagan and J. A. Semana)

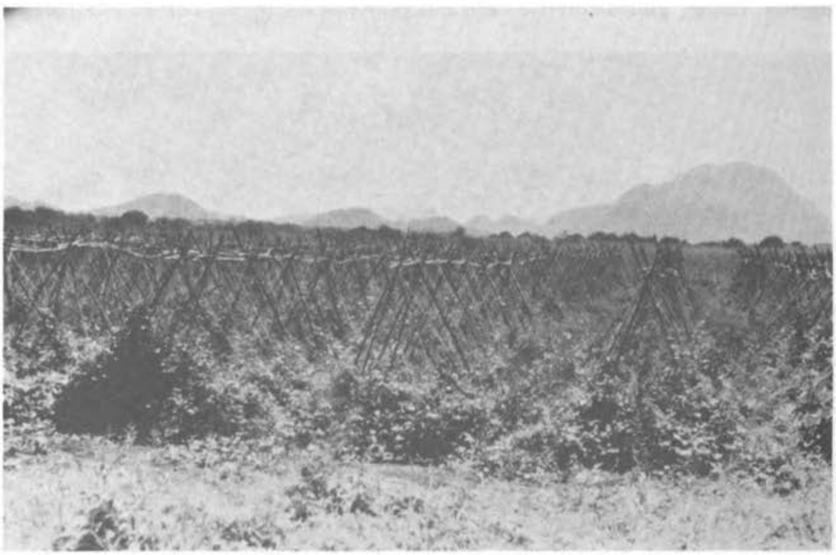


FIGURE 31 Guerrero State, Mexico. Climbing beans grown on leucaena stakes. Leucaena stems make good supports for agricultural crops. In a Davao, Philippines, plantation, one Hawaiian Giant variety has given 5 yields of banana props in just 3 years. The props were 3.8 cm (1.5 in.) top diameter and 5 m (15 ft) long. In Malawi, leucaena stems about 1.5 m (5 ft) long are used to support seed crops of twining pasture legumes. (G. Sánchez Rodríguez)

Sample	Time Processed (Minutes)	Freeness CSF-(cc)	Burst Factor	Tear Factor	Folds (double) M.I.T.	Tensile Strength (Breaking length in M)	Density g/cm
Debarked leucaena trunk, 1.5 yrs. old	46	350	82	81	500	9,100	0.78
Unbarked leucaena trunk, 7 yrs. old	66	350	76	86	800	10,800	0.75
Range for 4 fast-growing pulpwoods	22-122	350	67-81	68-82	750-1,275	10,400-13,000	0.77-0.85

TABLE 6 Properties of paper sheets made from leucaena pulp compared to four fast-growing pulpwoods (*Albizia falcataria, Gmelina arborea, Anthocephalus chinensis*, and *Spathodea campanulata*). Burst factor, tear factor, folding endurance, and tensile strength overlap those of papers made from other fast-growing pulpwoods. Leucaena is slightly superior in burst and tear strengths and slightly inferior in folding endurance and tensile strength. (Information supplied by P. V. Bawagan and J. A. Semana)

to those of hardwood species now used for lumber and plywood. Details of this use are little known as yet, but in a preliminary study of 7-year-old Salvador-type trees (Hawaiian Giant, K28), 14 logs averaging 20 cm (8 in.) in diameter and 2-3 m (7.5 ft) in length were sawn into stock 2.5 cm (1 in.) thick in a variety of widths, with a recovery of about 54 percent.*

Other Uses

The straight trunks of leucaena grown in dense plantations can be used directly as roundwood. After 2 years, poles thinned from a plantation can be used as fence posts. In rural areas they can also serve as posts, girts, girders, floor joists, or rafters for small houses and sheds. In the Philippines, they have long been used to prop ripening banana bunches to prevent them from breaking off, or the whole plant from toppling over. In Mexico, climbing vegetable crops are grown on leucaena poles (Figure 31). Moreover, it seems likely that leucaena could become a source for mine timbers and railroad crossties (sleepers) as well as telecommunication and transmission poles.

*Information supplied by P. V. Bawagan and J. A. Semana.

Chapter 5

Fuelwood

"At least half of all the timber cut in the world still serves in its original role for humans—as fuel for cooking, and in colder mountain regions, home heating. Nine-tenths of the people in most poor countries today depend on firewood as their chief source of fuel. And all too often, the growth in human population is outpacing the growth of new trees—not surprising when the average user burns as much as a ton of firewood a year. The results are soaring wood prices, a growing drain on incomes and physical energies in order to satisfy basic fuel needs, a costly diversion of animal manures from food production uses to cooking, and an ecologically disastrous spread of treeless landscape."*

For the family that needs firewood for fuel, wood is crucial to daily existence, and the price for this basic life-support is steadily increasing. The world's petroleum crisis is creating firewood scarcity of unprecedented magnitude in developing countries because "what had been the most feasible substitute for firewood, kerosene, has now been pulled even farther out of reach of the world's poor than it already was."* As a result, wood-gathering is on the rise and is being made more difficult than ever by the increasing deforestation and erosion of woodlands. Accordingly, firewood prices have risen even faster than kerosene prices.

The logical first response to this situation is to plant more firewood-producing trees, and for many areas Salvador-type leucaena varieties seem prime candidates.

Leucaena is not adapted to truly arid or mountain areas where firewood needs are greatest. However, it does grow well in semiarid and savannah regions of the dry tropics, as well as in more humid lowland tropics, where the need for firewood is still substantial. Growing leucaena in plantations, along roadsides, in shelter belts, on farms, and on unused land throughout rural areas could be one step toward relieving firewood scarcities. In rural areas, leucaena wood can not only provide energy for cooking, heating, and

*Eckholm. 1976. See Selected Readings.

cottage industries, but also can provide jobs and cash income from the production and sale of wood and charcoal to nearby urban regions.

To make any impression on the firewood crisis, wood-producing projects must be undertaken on a far greater scale than now conceived. This will be complex and difficult, thanks to the political and cultural concerns of rural peoples and the need of land for growing food. However, leucaena can be produced on some land that is unsuited to food crops. Once established, leucaena is persistent and can be harvested over and over without continual replanting, though inputs of fertilizer minerals may be needed. On Mount Makiling in the Philippines, the leucaena stands have been continuously harvested for firewood for over 55 years (see Figure 40). Today, the trees covering the slopes are as vigorous as ever.

Because their wood is more dense, Hawaiian-type leucaena strains make better firewood than the Salvador type, producing more heat when they burn.* They are well-suited to small-scale village and household use (Figure 32).

But the Salvador-type varieties grow faster and produce a greater quantity of wood, which (in addition to providing people with fuel for cooking and warmth) makes them suitable candidates for large-scale "energy plantations" grown specifically for fueling:

- Electricity generators;
- Railroad locomotives;
- Driers for fish, tobacco, grain, and other agricultural products (including, perhaps, driers for leucaena forage);
- Facilities processing cassava, sugar, rubber, or tannins from wattle bark; and
- Tin smelters, brick and charcoal kilns, sawmills, etc.

Heartwood increases as the tree matures, and leucaena's heating value improves with age, but it is thought that plantations can be harvested in cycles as short as 3-10 years.

The wood industry has long used bark and waste to generate steam and electricity. Indeed, 8 percent of Sweden's energy and 15 percent of Finland's is generated from wood even today; and in the United States more energy was generated from wood in 1974 than from nuclear power.† Thus, large-scale

*Measurements in the Philippines have shown that Hawaiian types have heating values (oven-dry) of 4,640-4,675 cal per kg (8,300-8,400 Btu per lb), while Salvador types produce 4,170-4,445 cal per kg (7,500-8,300 Btu per lb).

†This is accounted for mainly by the lumber and paper-pulp industries where bark and waste liquor are used as fuel. See National Academy of Sciences. 1976. *Renewable Resources for Industrial Materials*, page 33.

FIGURE 32 Los Baños, Philippines. Firewood from leucaena has long been used for cooking in some parts of the Philippines. The dense wood burns well, producing much heat and little smoke or ash. The small trunks and branches of this common Hawaiian-type leucaena variety are well-suited to small-scale production and use. (N. D. Vietmeyer)

leucaena-based energy plantations that grow fast, yield well, do not require high-quality agricultural land, and that coppice readily could be valuable to a developing country. In addition, wood-fueled local facilities avoid the large

Fuel	Moisture Content	Ashes	Combustion Value	
	Percent	Percent	Calories per kg	Btu per lb
Softwoods, air dry	30.0	1.2	2,700	4,830
Coffee (Robusta, dry)	9.2	2.45	3,915	7,010
Leucaena (dry)	10.9	1.62	3,895	6,970
Hevea brasiliensis (dry)	11.3	2.44	3,890	6,960
Coffee hulls	11.3	1.77	3,885	6,955
Red coffee bean peels, dry	12.0	5.5	3,500	6,265
Leucaena charcoal	..	1.0	7,250	12,980
Fuel oil	..	..	10,000	17,900
Natural gas	..	..	11,000	19,690

TABLE 7 Leucaena wood and other fuels used in plantation factories in Indonesia (taken from Dijkman. 1950. See Selected Readings).

transmission losses incurred when electrical power is supplied from distant sources.

In the Philippines, three large corporations have embarked on planting thousands of hectares of leucaena for fuelwood (see Figure 39); two will use it for standby electricity generation in case of fuel-oil shortages, and the other to produce charcoal. In Malawi, one Salvador-type variety (Hawaiian Giant, K8) is being grown as fuelwood for generating steam at a sugar factory.

Charcoal

In many countries, charcoal, formed when wood is burned in a restricted air supply, is extensively used for cooking and heating. Seventy-five percent of the wood's original energy potential is lost in the process of charcoal making, but charcoal itself has a much higher energy content (Table 7) and gives smokeless heat, thereby making it more suitable for indoor cooking.

Some countries still use charcoal to provide the industrial carbon that is obtained elsewhere from natural gas, coke, or coal. For example, part of Brazil's metallurgical industry even now uses charcoal made from eucalyptus wood.* Charcoal can be used to produce calcium carbide (for production of acetylene, ethylene, vinyl chloride, and vinyl plastics), pig iron, ferroalloys including steel, and other industrial products. For countries having no petroleum resources, acetylene appears to be a suitable basic feedstock for an

*The 3 million tons of charcoal produced annually is feedstock for 4 calcium carbide furnaces, 10 ferrosilicon furnaces, about 100 foundries, and a few small blast furnaces producing pig iron.

organochemical industry, and acetylene can be obtained from calcium carbide produced from charcoal.

Leucaena charcoal has a heating value of about 7,000 cal per kg (12,000 Btu per lb), which is 70 percent of the heating value of fuel oil (Table 7).* It can be made in simple retorts or pits, on small or large scale, and offers a potentially lucrative industry for rural regions where leucaena plantations would be located (Figure 33).

FIGURE 33 Mabuhay Vinyl Corporation, Mindanao, Philippines. Trial charcoaling of leucaena wood for the production of calcium carbide and vinyl plastics. This use of leucaena may offer a way to convert eroding tropical wastelands to productive use. It is suitable for large- or small-scale enterprises that can provide jobs and income in rural regions. In the background, leucaena covers slopes that, 18 months before, were bare, eroding, limestone soils. In that short time many of the trees have grown to over 7 m tall. (M. D. Benge)

*This is for charcoal from Hawaiian-type leucaena. Charcoal from the less dense wood of Salvador type may have a lower heating value.

Chapter 6

Soil Improvement and Reforestation

Overgrazing, poorly controlled burning, and the careless removal of tree cover for timber or firewood are part of a mindless misuse of forest resources, which results in landslides, floods, soil erosion, and dried-up streams and rivers. Looming large is the threat that all tropical forests will be replaced by degraded grasslands or bare ground. And when land is completely exposed to the tropical elements, fertile topsoil that took centuries to develop can wash away in one storm.

Worldwatch Institute reports that "Despite their key ecological roles, forests are rapidly diminishing in area throughout Africa, Asia, and Latin America. The principal causes of this deforestation are the spread of agriculture, woodgathering for use as fuel, and in some regions, irresponsible commercial timbering. Deforestation of hillsides and arid lands accentuates flooding and erosion problems. It intensifies the energy crises of the third of humanity dependent on firewood for cooking and warmth. The search for wood is more and more difficult, forcing people faced with wood shortages to shift to dried animal dung for cooking fuel. This in turn deprives the soil of needed organic matter and nutrients contained in this natural fertilizer."

Tropical forests live off their own debris. The bulk of their nutrients comes from the vegetation rather than the soil. Vigorous, year-round microorganism activity quickly decays the trees' detritus; the roots absorb the resulting nutrients as they are released; and within the plant they return to the forest canopy. If the trees are cut or burned, the roots die and nutrients then leach away to deeper soil layers and are essentially lost. With nutrients and organic debris gone, the soil surface cracks, dries in the heat, and hardens like cement, or erodes away in the rain and wind.

To replace the vegetation cover, deep-rooted, quick-growing, adaptable trees and bushes like leucaena seem ideal. In a sense, they provide a permanent mulch–a living mulch–that not only protects the terrain, but that (with care) can be continually cropped for useful products.

Soil Improvement

Leucaena benefits the soil in which it grows by:

- Increasing the nitrogen content;
- Increasing the organic matter (humus), rebuilding tilth and surface texture;
- Breaking up compacted surface layers (also deep ones);
- Improving water absorption;
- Reducing moisture evaporation in the dry tropics;
- Providing a forest cover to protect the surface against sun, rain, and wind; and
- Reducing soil slippage and erosion.

Under good soil and moisture conditions, one hectare of leucaena bushes [mowed to a height of 1 m (3 ft) every 3 months] can provide foliage containing 500-600 kg (1,000-1,300 lb) of nitrogen in a year.* In experiments, leucaena foliage was incorporated into soil around corn (maize) plants (Figure 34) and its ingredients encouraged such growth that the resulting corn yields were comparable to those in neighboring plots treated with mineral fertilizer.† This process of "green manuring" also occurs (though more slowly) with the natural leaf-fall from unmowed bushes.

Tropical temperatures, moist soil, and the small size of leucaena's leaflets encourage decay, and within 2 weeks the fallen leaves rot to form humus. Compared with inorganic fertilizers, the "slow" release of nutrients from decaying vegetation and microorganisms allow the crop a better chance to pick up the nutrients as they leach through the soil. If release is too rapid, intense tropical rainfall carries nutrients beyond the root zone before they can be absorbed. In semiarid zones, slow release is desirable as well, because moisture evaporation can produce such concentrations of fertilizer salts that roots get "burned" and plants die.

Green manures have disadvantages, however. Denitrifying bacteria in the soil have more time to convert nitrogenous compounds back to nitrogen gas that returns to the atmosphere. Largely because of this fact, it is estimated

*Measured in Hawaii, using Hawaiian Giant (K8) strain. Some experiments gave even higher amounts of nitrogen. Guevarra. 1976. See Selected Readings.

†Dijkman, 1950, states that it is common practice in Indonesia to prune and lay leucaena branches among the crop plants. Each year one hectare can provide an amount of nitrogen equivalent to that in a ton of ammonium sulfate fertilizer. See Selected Readings.

FIGURE 34 Waimanalo, Hawaii. In future, leucaena may become known as a cheap, renewable source of fertilizer. *Rhizobium* bacteria in leucaena's nodules provide the plant's foliage with much fixed nitrogen. Before and during peak growing periods, foliage is harvested and laid beside the crop plants. In about 10 days, microorganisms decompose the tiny leaflets, returning to the soil the nutrients they contain. Although perhaps 60 percent of the fixed nitrogen is returned to the air by denitrifying bacteria, the rest becomes available to the crop. (A. Guevarra)

that only about 40 percent of the nitrogen in leucaena is effective for enhancing crop growth.*

In spite of this inefficiency and the time, space, and effort needed to produce green manure, there are many areas in the tropics, particularly in remote rural regions, where fertilizer is unobtainable or too expensive; here the leucaena system may prove attractive and practical. For example, Philippine coconut growers have found that leucaena makes a good green manure and browse crop that can be interplanted among the coconut palms (Figure 35).

Leucaena's roots absorb mineral elements, such as phosphorus and potassium, from deep soil layers. These become incorporated throughout the plant's structure, including the foliage. The actual amounts depend on the extractable mineral content of the soil layers that the roots are exploiting, and possibly on the effectiveness of the associated mycorrhiza (see Chapter 2). In Hawaii, leucaena foliage harvested during one year from one hectare of land contained 44 kg of phosphorus (40 lb per acre), 187 kg of potassium (170 lb per acre), as well as calcium and micronutrients (Table 8). Also, leucaena foliage used as a green manure provides organic matter that improves the soil properties–increasing aeration, water retention, insulation, and cation-exchange capacity.

*Information supplied by J. L. Brewbaker.

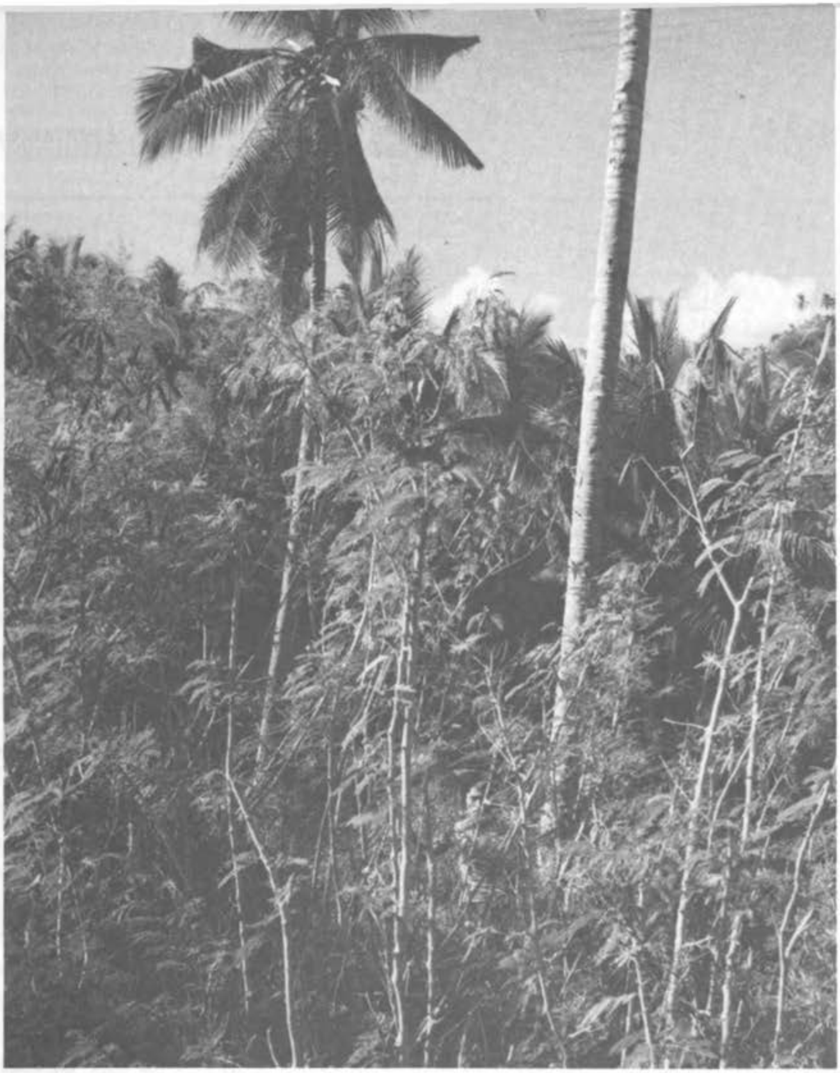


FIGURE 35 Iligan, Mindanao, Philippines. Leucaena as a fertilizer crop for coconuts. Planting leucaena beneath coconuts is being adopted rapidly in the Philippines and is recommended by the Philippine Coconut Federation. Leucaena contributes both green manure and browse for cattle. (M. D. Benge)

Reforestation

Man has deforested one-third of South America's native forests, one-half of Africa's, and two-thirds of Southeast Asia's. In the tropics, the need is urgent to protect the remaining forest cover from further damage and to reforest the now-devastated areas. Most indigenous species take 50–70 years to mature; fast-growing leguminous plants like leucaena are seen as a first line of defense: By providing an alternate source of forest products, leucaena plantations can reduce logging pressure on the forests, slowing the denudation that still continues.

Nutrient Element	Percent of Dry Weight
Nitrogen	2.2 – 4.3
Phosphorus	0.2 – 0.4
Potassium	1.3 – 4.0
Calcium	0.8 – 2.0
Magnesium	0.4 – 1.0

TABLE 8 Fertilizer elements in dried leucaena foliage (including fine stems). Values would be higher for dried leaves alone. About six bags of dried leucaena contain the same nitrogen as one bag of ammonium sulfate, and it can be produced in remote areas by small farmers for whom commercial fertilizers are often either too expensive or unobtainable.

Although it is a potentially valuable forestry species itself (see Chapter 4), leucaena can also pioneer the improvement of soil and growing conditions for other species. Replacing the cover decreases soil temperatures, reduces evaporation of soil moisture, and fosters survival and grcwth of seeds, seedlings, and succulent young plants. A pad of absorbent organic matter layering the soil surface captures rainfall; by slowing runoff, it retards erosion and makes moisture more available to all vegetation on the hillslope (Figure 36). Leucaena can be interplanted with forest species. Then, while it is enriching the soil—especially with nitrogen—it protects, shades, and suppresses the growth of vigorous grasses that otherwise stifle the young forest trees. In the Philippines young tropical hardwoods and dipterocarps interplanted with leucaena have shown growth increases of 50-100 percent.* Eventually, the forest species can overtop the leucaena, dominate the plantation, and re-establish itself in the region. When the trees are well-established, the leucaena can be harvested for wood products. Leucaena is used this way in teak, rubber, and other tree plantations.

But in reforestation it is also important that leucaena can:

- Grow on precipitous slopes;
- Survive in some nutrient-poor and otherwise unfavorable conditions;
- Provide permanent stands that can be harvested for firewood, forage, wood, or green manure without seriously jeopardizing soil protection;
- Show great persistence (once established);
- Protect against fire (see below); and
- Reduce the ravages of excessive slash-and-burn agriculture (see Chapter 7).

*This has recently been observed with mahogany (*Swietenia macrophylla*), *Acacia auriculiformis, Anthocephalus chinensis, Nauclea orientalis*, and teak (*Tectona grandis*) as well as with rambutan and other fruit trees. (Information gathered by M. D. Benge)

FIGURE 36 Iligan, Mindanao, Philippines. A once denuded hillslope reforested with leucaena. The formerly dried-up spring is running once again due to the vegetation which retards runoff and helps rainfall penetrate the soil. (M. D. Benge)

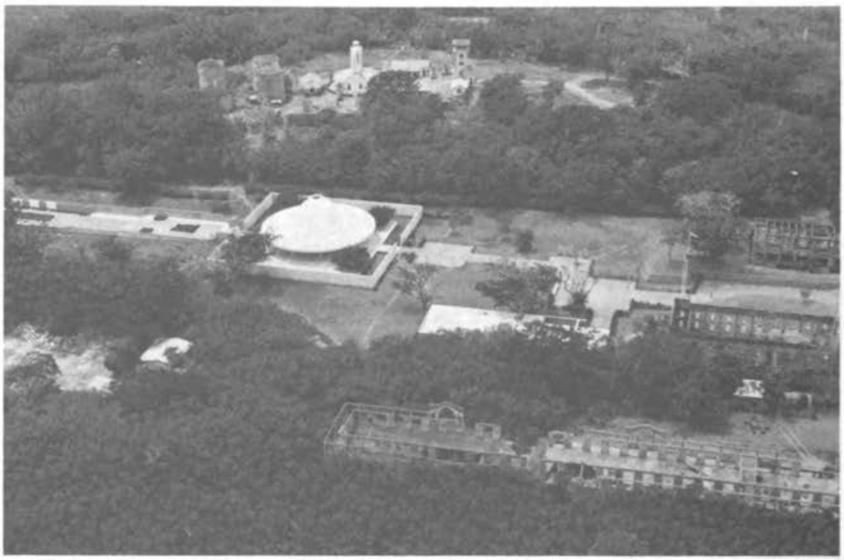
In Indonesia extensive reforestation is already being carried out using leucaena. More than 30,000 ha (74,000 acres) on the island of Flores are being planted in contour hedgerows of leucaena for the purpose of rejuvenating unstable volcanic slopes.* Plantations are also being established in the Philippines (see below).

Leucaena can be handled and propagated by standard methods. For reforestation purposes the plant has been established by aerial seeding (Figure 37), but the seedlings' slow initial growth and attractiveness to wildlife makes this inefficient. Rows of seeds planted on contours and ridges and weeded during the first few months improve leucaena establishment. If Hawaiian-type leucaena is used, its rapid and copious seed production allows it to spread down slopes, resulting in dense cover. Contour rows of Salvador-type leucaena alternated with other crops seems a promising system for research and testing (see Chapter 7).

Winds do little damage to leucaena's strong limbs, other than to temporarily defoliate them; deep roots ensure against the whole plant being torn

*Metzner. 1976. See Selected Readings.

1945



1976

FIGURE 37 World War II saw Corregidor Island at the entrance to Manila Bay bomb-pocked and denuded (above, with parachutes). Leucaena was seeded by air and has since established and become the dominant vegetation. Some foresters believe that the natural climax forest is being restored, with leucaena serving as both a nurse crop and a soil builder. (U.S. Army Office of Audio Visual and James Black Jr., respectively) out of the ground.* In fact, the plant makes excellent windbreaks (see Figure 3).

A major limitation is that leucaena grows vigorously only at lower altitudes, whereas much of the area that needs reforesting is at high elevations. Nonetheless, leucaena is recommended for consideration in rehabilitating tropical watersheds with suitable, nonacid soils at elevations less than 1,000 m (3,000 ft).

In contrast with the past, enlightened forest management today attempts to develop forests for multiple use. Nowhere is this more important than in developing countries. Multiple use requires that forests yield timber, but also that they protect and conserve soil and water, provide recreation and wildlife habitats, and, in general, benefit the populace. With its array of potential uses, leucaena is an ideal species for this role.

With most forestry trees, harvested regions lie idle for 1 or 2 years, or even more, before seedlings are planted or become established naturally and begin regenerating the forest. But leucaena begins the regeneration process immediately it is cut down: in tropical climates buds appear on stumps within days. This improves yields by shortening cutting cycles and reduces the risk of erosion, fire, or weed devastation of the area.

Leucaena's coppicing also helps the new forest withstand indiscriminate cutting (a major concern in many countries); immature trees in remote forests are often "poached" for firewood.

Removing the forest cover in the tropics rarely produces totally bare soil. Crop or pasture land may result, but all too often the precious forests are reduced to coarse grasslands of little economic value (Figure 38). These are difficult and costly to reclaim. The loss of forests to the tenacious grass *Imperata cylindrica* is a major problem in the Philippines, Indonesia, Papua New Guinea, and parts of Africa. Known variously as cogon, kunai, alang-alang, blady-grass, lalang, etc., this sharp-edged "cutting-grass" grows a dense network of roots and underground stems, crowding out other species and depriving them of moisture during the dry seasons. Removing the grasses before planting a forest is impractical; they regenerate rapidly after the area has been burned, and herbicide control is uneconomic. But, at least in some locations, leucaena can compete successfully.†

In the Philippines, planting has been done simply by burning the grass, opening a furrow with a plow pulled by a water buffalo, and dropping leucaena seeds into it. If tended carefully during the first few months, leucaena

*However, on shallow soils (such as occur in degraded grasslands or where a hardpan is near the surface) leucaena may not be able to produce a taproot. Then it becomes susceptible to tropical windstorms.

†Pendleton. 1933 and 1934. See Selected Readings.

FIGURE 38 Southern China. When tropical forests are cut or burned, nearly worthless coarse grasses often take over. Vast expanses of *Imperata* and other species cover mountain slopes throughout the tropics, as shown here. Leucaena is one of the few plants that can compete with these vigorous grasses. (R. L. Pendleton)

will grow to dominate and replace *Imperata* grassland. In about 3 years, there is a solid thicket of leucaena: the grass is dead (Figures 39 and 40).

About six million hectares of Philippine forestland have been lost to *Imperata* grass. This loss is so serious that President Ferdinand Marcos has appointed a special commission to be responsible for ensuring that these almost worthless grasslands are revegetated. Batangas Province has a nursery that daily produces 10,000 leucaena seedlings (Hawaiian Giant) that are sent out for planting all over the Philippines (Figure 41). The governor of Batangas, Antonio E. Leviste, has decreed that nurseries be set up in churchyards, cemeteries, and schoolgrounds throughout his province, and no government employee gets a paycheck until he sets up a leucaena plantation with at least 20 trees. Governor Cornelio Villareal of Capiz Province has seedling production organized in the provincial penitentiary. Three days each year (July 21, August 11, and December 15) have been officially designated leucaena planting days, when citizens plant the seedlings on watersheds serving the province's townships.

Livestock will graze *Imperata* grass, but they cannot thrive on it as a sole diet. Where it grows it dominates and crowds out all other plants, making alternative feeds unavailable. To cope with this problem, Fijian pasture agron-

FIGURE 39 Mindanao, Philippines. *Imperata*-grass hillslopes–formerly like those in the preceeding photograph–converted to an energy plantation. This is part of a 3,000-ha leucaena plantation being established by Mabuhay Vinyl Corporation to provide fuel and charcoal for industrial use. (M. D. Benge)

FIGURE 40 Paliparan area. Mt. Makiling, Philippines. Leucaena converted this area from *Imperata* grass to a productive firewood forest. Leucaena seed (Hawaiian type) was scattered among the grass in the early 1920s. Twelve years later, when this picture was taken, more than 20 m^3 of firewood was being harvested per ha (290 ft^3 per acre). Today, the region is still productive and is the main source of firewood for Laguna and surrounding districts. (R. L. Pendleton)

FIGURE 41 Batangas Province, Philippines. Nursery for Salvador-type leucaena that produces 10,000 seedlings daily.

FIGURE 42 Cebu, Philippines. Dense leucaena stands have almost no undergrowth or lower foliage, and the plant itself is fairly fire-resistant. Since there is little material that can burn readily, stands such as this may have potential as firebreaks. Belts of leucaena could be particularly useful in protecting valuable plantations of teak and other trees from fires in neighboring grasslands or forests. If harvested carefully, the leucaena could also be used for firewood or poles without decreasing the firebreak's effectiveness. (M. D. Benge)

omists have planted patches of leucaena (one ha of leucaena to six ha of grass, sometimes one in four) on the lower slopes of *Imperata*-covered hills. Cattle then graze the grass, with their diet supplemented by the leucaena (which is maintained within fenced enclosures and is fed sparingly enough that the animals don't stop eating the grass). This is a promising system for using coarse grasslands that, by themselves, are nearly useless as pastures.*

Firebreaks

In many tropical countries, grass fires constantly threaten forests. In rural areas, fire is often used to clear grassland or forests for crop planting and to capture wildlife. Nevertheless, many fires burn out of control, sometimes destroying nearby forest plantations, the products of years of effort and expense.

Leucaena cannot withstand *repeated* fire damage, but established leucaena stands shade out undergrowth, leaving little on the ground to burn (Figure 42). Further, the plants themselves remain green except towards the end of

*Information supplied by D. L. Plucknett.

the dry season in the drier tropics. Therefore, in most tropical areas a dense leucaena stand could retard the spread of grass fire. Leucaena planted along fireline strips 10-20 m (30-60 ft) wide can provide a maintenance-free permanent firebreak that seems an inexpensive way to protect forest resources.

Chapter 7

Other Uses

Shade Plant and Nurse Crop

Leucaena's importance as a crop was first recorded at the turn of the century in literature describing successful coffee-growing in Java. Grown between the coffee bushes, the taller leucaena provided a canopy that shaded the sensitive leaves from the heat and desiccation of the tropical sun. More recently it was discovered that its additional advantages as a shade crop include these points: it interferes little with the crop's roots; it carries few diseases or pests that could infect the crop; it is easily established and requires little or no maintenance; its clippings and prunings make useful forage and firewood; and, most important, it drops nutrient-rich leaves. The humus, formed from decaying leucaena foliage, is exploited for its nutrients by the crop. Leucaena provides more than shade; today, it is commonly termed a nurse plant because it fosters healthy growth in the crop it shades.

It has been used to shade and "nurse" coffee, cacao, tea, cinchona (source of quinine), mangosteen, citrus, pepper, vanilla, and seedlings of teak, other forestry species, rubber, coconut, and oil palm* (Figure 43). Though not generally used to shade bananas, leucaena may be particularly beneficial to banana plantations. In Puerto Rico it has been discovered that "bananas produced twice as high yields of marketable fruit under shade than in full sunlight because of reduced damage by leaf spot (Sigatoka) disease."†

The cheap fertilizer of past decades decreased the need for green manures and helped improve yields of the main crop. But to ride out the recent period when fertilizer was expensive, many growers relied once more on the detritus of leucaena and other legumes. When crop prices are low, or fertilizer prices high, leucaena can be a backup source for plant nutrients.

*Also, it is sometimes planted in pastures as shade for livestock, particularly around feeding and watering sites.

†Vincente-Chandler, J., F. Abruña, and S. Silva. 1966. Effect of shade trees on yields of five crops in the humid mountain region of Puerto Rico. *Journal of Agriculture of the University of Puerto Rico* 50:218-225.

FIGURE 43 The use of leucaena as shade for plantation crops. Top: cacao, New Britain. (Department of Primary Industries, Papua New Guinea) Above: pepper, Philippines. (M. D. Benge) Left: vanilla, Malang, East Java, Indonesia. (D. S. Sastrapradja)

Top: Arabica coffee, Foumbot, Cameroon. (J. L. Brewbaker) Above: Teak, Cebu, Philippines, after 55 days of drought. (D. G. Granert) Right: forestry nursery (the seedlings are leucaena too). Iligan, Mindanao, Philippines. Leucaena can be used this way to avoid the expense of building a shade-house.

As a nurse or shade crop leucaena does have limitations, however. It grows poorly on acid soils and it can seldom be used for crops grown on uplands. Although decades ago plantation agronomists in Indonesia found that *Leucaena pulverulenta* by itself or grafted to leucaena (i.e., *L. leucocephala*) would grow well at high elevations, little seems to have been done to exploit this in highlands elsewhere.

Leucaena may also prove valuable when grown *beneath* coconuts and other tree crops. In this case, bush-like types would be used and kept low either by grazing or by deliberate harvest for green manure (see Figure 35).

Agro-Forestry

There is a rising belief among agronomists and foresters that tree growing, crop production and/or animal raising should be combined to best preserve structure and fertility of fragile tropical soils. Trees protect the ecosystem, and an agricultural crop, livestock rearing, or fish culture can provide income while the trees are maturing. Combinations of many different plant and animal species seem possible, but versatile leucaena appears to be an outstanding candidate. Bamboo; eucalyptus; vegetables; root crops; corn, millet, and other grains; bananas and other fruits; as well as nuts and spices can probably be produced (at least for several years) between hedges of Salvador-type leucaena planted for timber, firewood, paper pulp, or forage. In this way, leucaena may make more efficient use of tropical slopelands, reducing erosion and forestry problems. Alternatively, Salvador-type leucaena might be planted densely and then continually thinned for use as banana props, firewood, or poles for making fish traps, supporting beans, etc. This, too, would provide income to the forester-farmer while his trees mature.

Shifting-Cultivation

Primitive man in the tropics based his livelihood on felling and burning a patch of forest, planting seeds in the ashes, and growing crops, until declining fertility and increasing pests forced him to fell a new forest patch. Today, the practice continues in hill regions of developing countries. It has been much decried by foresters, for it wastes tree resources and exposes ground to erosion. But, since governments with limited funds have no substitutes to offer, traditions prevail. Indeed, shifting-cultivation is increasing; year by year a greater amount of land is being cleared, and the time before farmers must return to a previously cropped area is lessening. There are believed to be 250

FIGURE 44 Morobe Province, Papua New Guinea. Recent research indicates that traditional slash-and-burn farming methods can be an effective way to utilize marginal lands if leucaena or other nitrogen-fixing plants are grown after crop plants have depleted the soil. When this was done in Papua New Guinea, leucaena bushes markedly increased the soil nitrogen in only 2 years, improving subsequent yields of garden crops. The root mat is particularly dense and full of nodules and there is no undergrowth, so the bushes are easy to clear. Leucaena would seem to be a promising crop for improving soil fertility quickly in lowland and coastal areas of the tropics. (R. L. Parfitt)

million slash-and-burn farmers worldwide; 100 million in Southeast Asia alone.

Papua New Guineans have integrated nitrogen fixation and soil building into their shifting-cultivation rotation. Before moving on, they plant casuarina trees or allow leucaena to reseed itself from the surrounding bush (Figure 44); both plants have *Rhizobium*-filled nodules and the soil nitrogen increases as they grow; then a deep leaf litter forms. Now, instead of waiting 10 years or more, the farmers can return to the leucaena-planted patches after only about 2 years, because during this time the percentage of nitrogen in the soil has increased adequately.*

Some researchers believe that leucaena planted densely along hillside contours may provide enough green manure to continually maintain soil fertility

*Parfitt. 1976. See Selected Readings. Actually, there is good evidence that 2,000 years ago Mayans used leucaena for the same purpose, at least in the Yucatan peninsula.

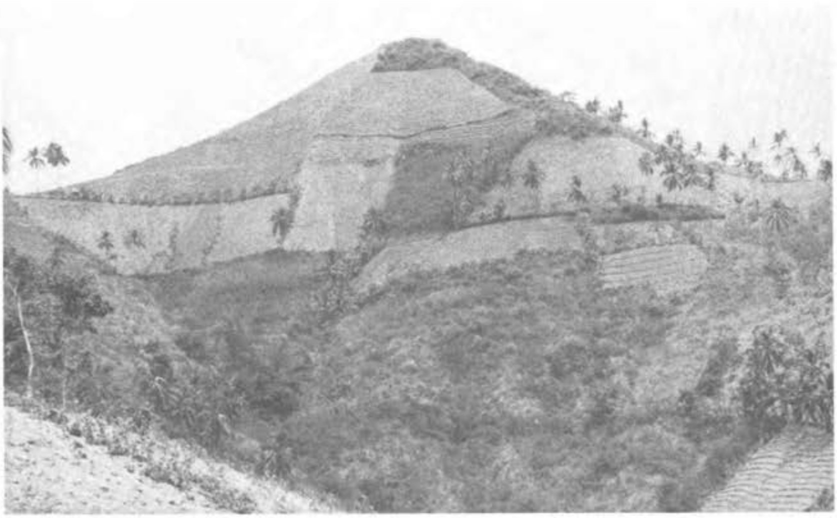


FIGURE 45 Barrio Naalad, Cebu, Philippines. For over 50 years innovative farmers have used leucaena for erosion control, soil reclamation, and fertilization on extremely steep, rocky hillsides. They plant blocks of their land with leucaena to control erosion and provide soil improvement. Some of the leaves are harvested, dried, and sold as leaf meal to local feed millers; also, most households keep goats that are fed leucaena mixed with coconut and banana leaves. After 3-6 years the blocks with leucaena are cleared (large pieces of the wood are sold for fuel) while an equal number are seeded with leucaena and left fallow. . . .

in the strips between, thus completely eliminating the need for cultivators to shift to find better soil. While reducing forest destruction, this method may reduce erosion at the cleared sites, provide income from leucaena products, and make a more sedentary way of life possible for shifting-cultivators.

An example of how some Filipino farmers exploit leucaena to create sedentary agriculture on poor hill-lands is shown in Figure 45.

Miscellaneous

In Central America and Indonesia, leucaena is used for food: young leaves and small pods are eaten raw (Figure 46), or cooked in soups, tacos, etc; mature seeds are roasted, and young dry seeds are "popped" like popcorn. Villagers make a good living selling small bundles of leucaena pods (Figure 47). However, it is an unusual food and is not recommended for extensive use because, as noted earlier, mimosine causes loss of hair. This doesn't seem to happen in Central America or Indonesia, possibly because leucaena is too

. . . Along the contour of the steepest slopes of the newly cleared blocks the farmers drive leucaena stakes into the ground, pile branches behind them, and scrape soil against the barrier so formed. This provides a terrace [varying from 0.5-1.5 m (2-4 ft) wide] in which tobacco and onions are interplanted. . . .

. . . This creates arable land out of slopes as steep as 70° that are otherwise totally unusable. (M. D. Benge)

FIGURE 46 Ciudad Altamirano, Mexico. Young leucaena pods and leaves are commonly eaten throughout much of Central America. (G. Sánchez Rodríguez)

small a part of the diet, or because the metal in the cooking pots detoxifies the mimosine.

In Central America, dye is extracted from leucaena to color wool, cotton, fishing lines, etc. (Figure 48). Pods or wood are boiled in water: young pods produce red colors; old pods and wood give varying shades of brown.

Extracting leucaena seeds with hot water also produces a gum (mucilage) in about 25 percent yield. Similar in chemical structure to gums from other legumes (such as guar gum, carob bean gum, or gum arabic), this galactomannan could possibly have commercial significance. Viscous gums of this type are used to thicken and emulsify foods such as mayonnaise, ice cream, and candies, as well as cosmetics such as hand lotions and face creams. These gums are in severely short supply due to increasing production of processed foods, coupled with drought in the Sahel region that has devastated gum arabic supplies. This makes the production of leucaena gum a worthwhile research topic. Hawaiian-type leucaena produces seeds prolifically (2-year-old

FIGURE 47 Bogor, Indonesia. Leucaena pods for sale as human food. (S. Sastrapradja)

plants in South Africa produced 10-15 pounds of pods per plant);* the pods may prove suitable for mechanical harvest and the seeds are large enough to be milled. Outside of the laboratory, gum production from leucaena has not been attempted, however.

In some areas leucaena's shiny, dark-red seeds are used to make decorative necklaces and household items (Figure 49). Various parts of the plant are reputed to have medicinal properties ranging from control of stomach diseases to use for contraception and abortion.

Leucaena, with its cascades of emerald leaves and fragrant flowers, has long been used around dwellings as an ornamental (Figure 50). But the seedlings that spring up around the plants are a constant nuisance. Now, new hybrids between leucaena and *Leucaena pulverulenta* have been developed in Australia and in Hawaii† (Figures 24 and 51) that produce no pods, seeds, or seedlings: some have pleasing shapes and promise to provide trouble-free ornamentals. In the Philippines, leucaena is being widely planted for city beautification, particularly in Manila (Figure 52).

*Pienaar, C. 1952. *Leucaena glauca. Annual Report of the Dohne Agricultural Research Station*, Republic of South Africa. Quoted in Oakes. 1968. See Selected Readings. The extraction of leucaena gum is described in Morimoto, Unrau, and Unrau. 1962. See Selected Readings.

†At CSIRO, Davies Laboratory, Townsville, Queensland, and the Department of Horticulture, University of Hawaii, Honolulu.

FIGURE 48 In Central America leucaena seeds, pods, and bark have traditionally been extracted to get yellow, red, brown, and black dyes. All colors on this rug are derived from extracts from various parts of leucaena. (G. Sánchez Rodríguez)

It is common in Central America, Mauritius, and the Philippines to see leucaena hedges. These living fences are used for boundary markers, to shade houses, for ornamental purposes, and for protecting fields and gardens from salt spray or wind damage.

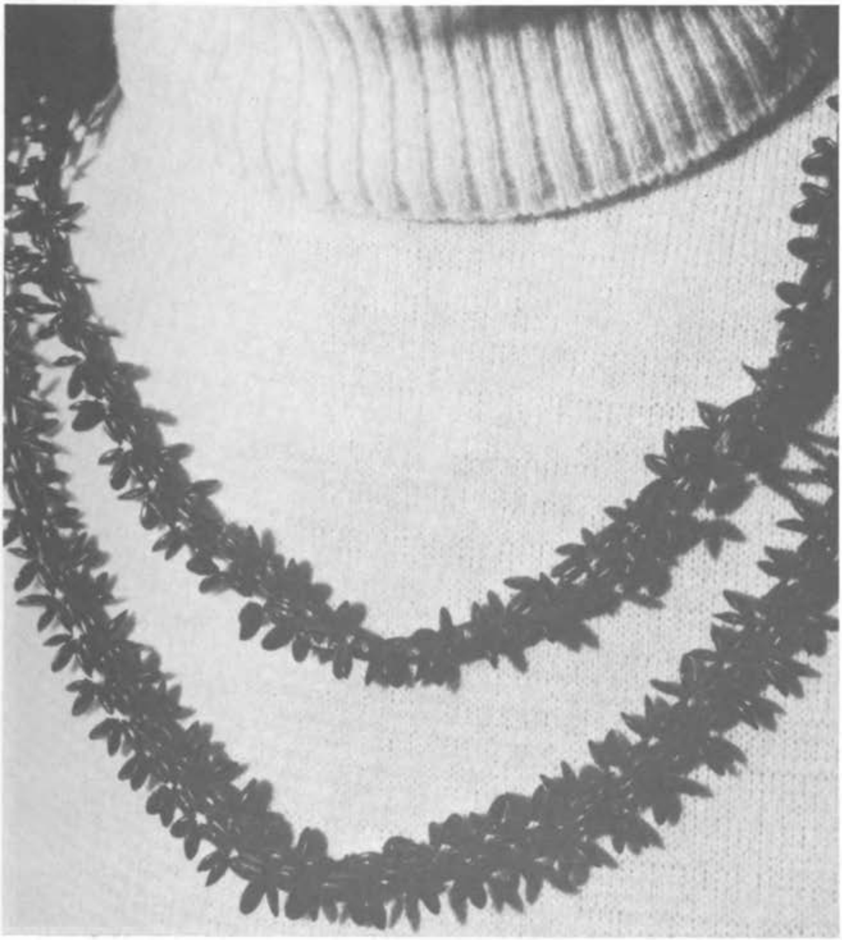


FIGURE 49 In Southeast Asia and throughout the Pacific, leucaena seeds are strung on nylon fishing line to make decorative necklaces, place mats, and doilies, some of intricate and complex design. Common varieties of leucaena set seed prolifically, and such craftwork has become an export item for some countries. (N. D. Vietmeyer)

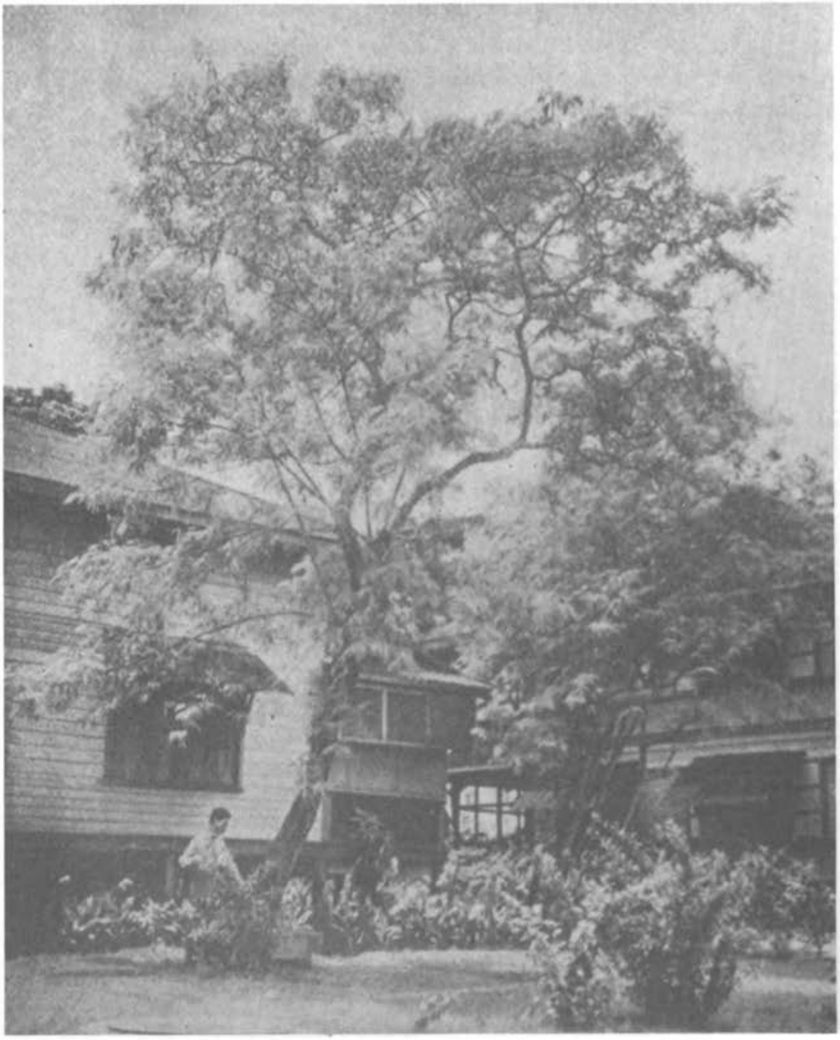


FIGURE 50 Rizal Province, Philippines, 1933. An exceptionally large Hawaiian-type leucaena used for shade and beautification. (R. L. Pendleton)

FIGURE 51 Wailua Research Center, Hawaii. Although leucaena is used as a shade plant up to elevations of 1,600 m (5,000 ft) in Papua New Guinea, for other purposes it is not a promising crop for cool tropical highlands because it grows too slowly there. However, related species like *Leucaena pulverulenta* resist frost and grow faster in cool areas. By crossing leucaena with *L. pulverulenta*, researchers hope to obtain useful hybrids that will grow vigorously at higher elevations and in cooler regions than leucaena itself. The hybrid shown here grew 12 m (40 ft) tall in 4 years. (J. L. Brewbaker)

FIGURE 52 Manila, Philippines. One-year-old Salvador-type leucaena used as an ornamental plant. In a project sponsored by the First Lady, Mrs. Imelda Marcos, Giant Hawaiian varieties are being planted in Manila as part of a citywide beautification project. (M. D. Benge)

Chapter 8

Recommendations and Research Needs

This final chapter outlines a program for research and action that will help determine leucaena's overall potential for alleviating major shortages of feed, wood, and fuel, and for solving deforestation problems. The report has detailed the plant's value for these uses in tropical countries, but experience with leucaena is limited, in most cases, to a few sites. Many tests, trials, and development studies are still needed.

The work yet to be done on leucaena challenges researchers in many parts of the world and in many disciplines, including plant and animal science, forest science, ecology, and anthropology. For philanthropic institutions and international development agencies concerned with problems of food and resource shortages, leucaena research presents an important area worthy of financial support.

Specific recommendations follow.

A Reliable Seed Supply

The panel recommends establishment of an abundant supply of high-quality leucaena seeds.

The Salvador and Peru types do not set seed prolifically and they are so new that the limited availability of seed inhibits their greater use. The establishment of seed-production orchards is now crucial. Leucaena holds such high potential for use throughout the tropics that a rush of requests for seed is anticipated. Seed-production should be scaled accordingly and organized for international distribution. Since quality control is also imperative, a system of seed certification is needed. (In the Philippines unscrupulous dealers have sold seed of the common Hawaiian type at the exorbitant prices fetched by the Salvador type.*)

To cope with these problems, a "seed authority group" composed of forest-tree and forage-crop breeders should be established to:

- Classify and standardize the naming of different cultivars;
- Select a basic set of the most promising cultivars; and
- Develop regulations for the production, labeling, certification, and inspection of all germ plasm.

A worldwide germ plasm collection should be initiated and stored at a safe location with controlled-environment seed-storage facilities. This should include not only the better-known varieties, but also species that remain untested. For instance, Central America is a treasure house of uncollected leucaena germ plasm, and the time has come to gather, catalog, and replicate seeds of all strains in the region. This is particularly important because expanding agriculture and urbanization are encroaching on many native leucaena stands; germ plasm must be collected before it is lost forever. Further, some plants are found where it is too high or too cold for most leucaena strains, and the opportunity should be grasped to obtain seeds from these plants to quickly extend the range of leucaena's utility.

Adaptability Trials

In conjunction with establishment of a seed supply the panel recommends extensive trials aimed at comparing performance of each of the most promising leucaena varieties.

Despite the promising research results described in this report, commercial experience with forest and forage varieties is restricted to small-scale uses in Hawaii, the Philippines, Indonesia, Australia, Jamaica, and the U.S. Virgin Islands. It is now imperative to set up a series of replicated trials throughout the tropics to compare the growth and performance of what appear to be the best strains.

The trials should concentrate on the same strains and should use a common methodology at each location. Forage, timber, and firewood production should all be tested. Where appropriate, the effectiveness of select strains for

*In 1975, a kilogram of Hawaiian Giant seed (approximately 18,000 seeds) was selling for about 1,500 pesos (over U.S. $200), which is equivalent to about U.S. $100 per pound.

reforestation, shifting-cultivation, and/or agro-forestry might also be considered.

Sites for the trials should be selected to test the response of the various cultivars to different soils, altitudes, latitudes, temperatures, moisture, and pests. This will indicate relative advantages and limitations of each variety and will provide the technical foundation needed before decisions to cultivate large leucaena plantations can be made sensibly.

This effort in international scientific cooperation may require a coordinating office with enough funding to distribute seeds, maintain correspondence between research groups, and collect and publish results of the trials in a series of joint papers.

In addition, local organizations concerned with forestry, forage production, and erosion control should set up leucaena demonstration plots of their own. These plots would enable researchers and officials in the area to become familiar with the leucaena plant and, if it appears warranted, to start community or national programs.

Agronomic Research Needs

The panel recommends research in areas where present uncertainties about leucaena cultivation will hinder its widespread use.

This research should include:

- Optimizing nitrogen fixation (identifying *Rhizobium* and determining the need for inoculation, the inoculum for different soil types, etc.);
- Improving growth in acid soils (studying effects of lime and lime pelleting, and the selecting and breeding of acid-tolerant *Rhizobium* strains);
- Determining specific nutrient requirements (assessing critical levels of phosphorus, calcium, sulfur, potassium, molybdenum, cobalt, zinc, and copper);
- Breeding varieties that grow vigorously at higher elevations;
- Selecting varieties for best growth under difficult conditions (including waterlogged soil, drought areas, higher latitudes, aluminum-rich soils, disease- or pest-prone areas, etc.);
- Speeding up seedling growth (using seed treatment, weed control, inoculation, fertilization, varietal selection, seasonal timing, land preparation, etc.);
- Establishing seed orchards (determining the most effective methods of seed-bed preparation, weed control, and planting and seed harvesting, handling, and storage);

- Developing farming systems for various local conditions (determining sowing rates, spacing, minimum tillage, effect of aerial sowing, and value of nursery transplants vs. direct seeding, thinning, and coppicing);
- Vegetative propagation (using cuttings, transplants, and grafts); and
- Controlling pests and diseases.

Forage Research Needs

Pasture-crop specialists and animal nutritionists throughout the tropics should include leucaena trials and research in their programs.

The most critical need in forage research is to breed low-mimosine leucaena varieties. An Australian variety with less than half the normal mimosine content, which should be available in a few years, may greatly improve leucaena's use by ruminant animals, especially cattle and water buffalo. Mimosine appears to be a metabolic by-product that is not crucial to leucaena, and crossing the plant with other low-mimosine leucaena varieties or species could lower the mimosine content to one-third of normal or less.*

Research is also needed on:

- The effects of mimosine on the ruminant and nonruminant animals as well as on the people who now eat leucaena;
- Detoxifying mimosine by heat and chemicals;
- Managing leucaena for grazing, small-farmer holdings, mechanized agriculture, or hedgerow production (determining optimum spacing, cultivation methods, harvest time, cutting heights, rotations, etc.);
- The odor that leucaena gives to milk;
- Pasture combinations incorporating leucaena; and
- Improving data on animal production.

Silviculture Research

Throughout the tropics forestry research programs should include trials with Salvador-type leucaena.

The present experimental literature, though highly promising, is inadequate to support establishment of large plantations and large-scale use of

*If mimosine content could be reduced near zero, leucaena, with its hardiness, high protein, and vigorous growth could become an important green vegetable plant for humans.

leucaena wood. Much of the information still needed can come only from trial cultivation. Comparison of experiences from scaled-up pilot plantations will provide the foundation for decisions on how to establish and utilize large plantations and will permit more accurate predictions of economic success.

In addition, basic research could yield information in some specific areas of uncertainty, making future reforestation efforts less expensive, more effective, and more widely applicable. Some particular research needs are:

- Improving present leucaena varieties (using intervarietal and interspecific crosses to produce elite types that optimize growing time, shade tolerance, wood quality, and desirable characteristics such as a straight, cylindrical bole with few knots);
- Choosing varieties and hybrids with the best qualities (fiber length and content of holocellulose, alcohol-benzene solubles, silica, etc.) for making paper, pulp, fiberboard, particleboard, and other cellulose derivatives;
- Developing management techniques to maximize wood production (determining optimum seed-handling methods, nursery practices, plantation spacing and management, rotation time, etc.);
- Improving methods for handling and processing leucaena wood (drying, preserving, sawmilling, veneering, etc.);
- Determining the most cost-effective silviculture;
- Breeding varieties suitable for reforestation at high elevations;
- Simplifying the establishment of large-scale plantations by reducing the need for ground preparation (e.g., by developing seed-pelleting and aerial-seeding techniques);
- Establishing systems for planting eroding slopes (variables to be tested include spacing, contour planting in rows or belts, ridge planting, and various land-preparation methods);
- Developing techniques that allow partial harvest of plants on erosion-prone slopes without reducing their soil-stabilizing benefits;
- Analyzing experiences with leucaena revegetation in the Philippines, Indonesia, Guam, Saipan, and Hawaii; and
- Testing belts of leucaena planted as protection around existing forest plantations.

Reforestation and Erosion Control

Where deforestation and erosion are severe, trials with leucaena should be begun immediately.

Although the previous section outlined some silvicultural research needs, enough is already known about leucaena so that in-field trials have a good chance for success. For decades, Hawaiian-type leucaena has been successfully planted to revegetate lowland hill slopes in the Philippines and some western Pacific islands (see Figure 37). Now, the less weedy Salvador and Peru types should be tested for this purpose in trials throughout the tropics.

Firewood Research

Pilot-size plantations for production of firewood, fuelwood, and charcoal should be established.

Existing leucaena varieties have immediate potential as energy sources. In-field experience with pilot-size plantations designed to produce firewood, fuelwood, and charcoal is needed. Where firewood shortages severely limit rural economic development, village or family plantations of leucaena should be tested.

However, some basic research is needed on testing the heating values of Hawaiian and Salvador types, as they vary with age. This will give a better understanding of rotation times that maximize energy production.

Charcoal-making methods are widely known, but can be improved by applying modern engineering design.*

Other Research Needs

Leucaena's value in shifting-cultivation and other uses also merits testing and research.

- Shifting-cultivation. Trials are needed on leucaena's potential role in shifting-cultivation. There is much scope for ingenuity in combining leucaena culture with existing crops. Used as a fallow crop, the plant can reduce rotation time, but a goal should be to integrate leucaena as a green manure in crop production so that shifting is no longer required and permanent sedentary agriculture is feasible.
- Green manure and agro-forestry. To use leucaena in these areas seems straightforward, but much innovation is required to integrate leucaena into a farming system with other crops. Testing of different approaches is needed.

*A newly developed, high-efficiency charcoal maker suited to developing-country use and small-size wood is described in Little, E.C.S., 1975. A kiln for charcoal making in the field. *Tropical Science* 14:261-270.

• Shade and nurse crops. The use of leucaena to shade and "nurse" plantation crops and seedling nurseries is well-known in Southeast Asia and Papua New Guinea. Its more widespread adoption is recommended.

• Windbreaks and ornamental plantings. The use of leucaena for these purposes needs no further research, only extension efforts.

• Seed gums. Basic research on the industrial potential of leucaena gum and its large-scale production could make an interesting and useful topic for student study.

• Defleecing. "Shearing" sheep inexpensively by feeding them leucaena or mimosine extracts would become practical if methods to overcome the problem of sunburn can be found (see Figure 27).

Dissemination of Information

The panel recommends that leucaena researchers undertake to publish four documents about the plant.

These publications should be:

• A newsletter. In exploring leucaena's potential as a useful crop, it is important to maintain communication among researchers working with the plant. Since they are likely to be situated in far-flung research stations, universities, missions, and villages, their findings may not be widely shared if technical journals remain the only published source of leucaena information. A newsletter would bring together results from plant, animal, and forestry sciences. It would provide rapid exchange of information and would be a forum for informal opinions, observations, and preliminary experimental data that are usually not accepted by journals.

• A planting guide. A handbook should be published with practical, step-by-step information on planting, managing, and utilizing the plant.

• An annotated bibliography. For researchers and others in the field, a complete and annotated list of literature on the plant, its production, and its use is needed.

• A monograph on the genus *Leucaena*. This is an urgent task for plant taxonomists if confusion and wasted effort are to be avoided as the use of leucaena increases.

Appendix A

Selected Readings

A list containing over 150 leucaena references is available from the Division of Tropical Crops and Pastures, CSIRO, Mill Road, St. Lucia, Brisbane, Queensland 4067, Australia.

Benge, M.D., and H. Curran. 1976. *Bayani (giant ipil-ipil* Leucaena leucocephala): *A source of fertilizer, feed and energy for the Philippines*. USAID Agriculture Development Series. United States Agency for International Development, Manila.

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Jones, R. J., C. G. Blunt, and J. H. G. Holmes. 1976. Enlarged thyroid glands in cattle grazing *leucaena* pastures. *Tropical Grasslands* 10:113–16.

Kinch, D. M., and J. C. Ripperton. 1962. *Koa haole production and processing*. Hawaii Agricultural Experiment Station Bulletin No. 129. University of Hawaii, College of Tropical Agriculture, Honolulu. 57 pp.

Matsumoto, H., E. G. Smith, and G. D. Sherman. 1951. The effect of elevated temperature on the mimosine content and toxicity of koa haole (*Leucaena glauca*). *Archives of Biochemistry and Biophysics* 33:201–211.

Mendoza, R. C., T. P. Altamarino, and E. Q. Javier. *Herbage, crude protein and digestible dry matter yield of ipil-ipil* (Leucaena latisiliqua, *C. V. Peru*) *in* hedge rows. Unpublished paper. Department of Horticulture, Pastures Division, University of the Philippines at Los Baños, College, Laguna, Philippines.

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Appendix B

Study Participants

James L. Brewbaker, Professor of Horticulture and Genetics, Department of Horticulture, University of Hawaii, Honolulu, Hawaii, USA (*Cochairman*)

Joseph C. Madamba, Director-General, Philippine Council for Agriculture and Resources Research, College, Laguna, Philippines (*Cochairman*)

Noel D. Vietmeyer, Professional Associate, National Academy of Sciences, Washington, D.C., USA (*Staff Study Director*)

Australia

E. Mark Hutton, Chief, Division of Tropical Crops and Pastures, Cunningham Laboratory, Mill Road, St. Lucia, Queensland.

Raymond J. Jones, Senior Principal Research Scientist, Commonwealth Scientific and Industrial Research Organization, Davies Laboratory, Townsville, Queensland.

Hawaii

Donald L. Plucknett, Professor of Agronomy and Soil Science, Department of Agronomy and Soil Science, University of Hawaii, Honolulu

Malawi

Savory, R., FAO/Improvement of Livestock & Dairy Industry Project, c/o UNDP, P.O. Box 613, Lilongwe. (contributed by correspondence)

Mexico

Guillermo Sánchez Rodríguez, Ingeniero agronomo con especialidad en zootecnia, Banco de Mexico, Ciudad Altamirano, Guerrero

Philippines

Arturo C. Alferez, Assistant Professor, University of the Philippines at Los Baños, College of Agriculture, College, Laguna.

Francisco C. Bandong, Chief, Animal Husbandry, Bureau of Animal Industry, Manila.

Pancracio Bawagan, Forest Product Development Specialist, Forest Products Research and Industries Development Commission, College, Laguna.

Michael D. Benge, Agro-Forestation Division, US Agency for International Development/Agriculture, Manila.

Leopoldo Castillo, Professor and Director, Dairy Training and Research Institute, University of the Philippines at Los Baños, College, Laguna.

Hugh M. Curran, Jr., Consultant, Tropical Forestry and Agriculture, Provident Tree Farms, Incorporated, Manila.

Marcelino V. Dalmacio, Science Research Supervisor, Forest Research Institute, College, Laguna.

Celso Diaz, Science Research Associate IV, Forest Research Institute, College, Laguna.

Irineo Domingo, Department Chairman and Professor, University of the Philippines at Los Baños, College of Forestry, College, Laguna.

Walter G. Firestone, Project Manager, Erosion Control Study, Greenhills, Rizal.

Arthur Garcia, Research Associate, Forest Research Institute, College, Laguna.

Brother Alois Goldberger, Forester, Abra Diocesan, Rural Development, Bangued, Abra.

Carlos Glori, Assistant Professor, College of Forestry, Mindanao State University, Marawi City.

William G. Granert, Director, USC Reforestation Project, University of San Carlos, Cebu City, Philippines

Victor Guevarra, Executive Vice-President, Mabuhay Vinyl Corporation, Iligan City.

Emil Q. Javier, Director, Institute of Plant Breeding, University of the Philippines at Los Baños, College, Laguna.

Mario M. Labadan, Operations Manager, Republic Flour Mills, Incorporated, Pasig, Rizal.

Benjamin Mahilum, Associate Professor V and Officer-In-Charge, Department of Agronomy and Soils, Visayas State College of Agriculture, Baybay, Leyte.

Antonio Leviste, Governor, Batangas City, Batangas.

Francisco A. Moog, Senior Agronomist, Bureau of Animal Industry, Manila.

Gerundio Patilos, Officer-In-Charge, Department of Forestry, Visayas State College of Agriculture, Baybay, Leyte.

Filiberto S. Pollisco, Director, Forest Research Institute, College, Laguna.

Adolfo V. Revilla, Jr., Associate Professor, University of Philippines at Los Baños, College of Forestry, College, Laguna.

Jorge Reyes, Research Assistant I, National Science Development Board, Bicutan, Taguig, Rizal.

José Semana, Senior Research Associate, Forest Products Research and Industries Development Commission, College, Laguna.

Isidro M. Serrantes, Project Director, Ipil-ipil Project, Province of Batangas.

Santiago N. Tilo, Associate Professor of Soil Science, College of Agriculture, University of Philippines at Los Baños, College, Laguna.

Cornelio Villareal, Governor, Capiz.

Felizardo D. Virtucio, Science Research Supervisor, Forest Research Institute, College, Laguna.

Neptale Zabala, Associate Professor, University of Philippines at Los Baños, College of Forestry, College, Laguna.

Singapore

Epifania V. Araullo, Senior Program Officer, Agriculture, Food and Nutrition Sciences, International Development Research Centre, Tanglin.

Taiwan

James C. Moomaw, Director, Asian Vegetable Research and Development Center, Shanhua, Republic of China

Appendix C

Researchers Working with Leucaena

The following researchers are involved in leucaena research or have had extensive experience with the plant in the past. They may be able to supply readers with advice and information.

Arturo C. Alferez, Department of Agronomy, College of Agriculture, University of the Philippines at Los Baños, College, Laguna, Philippines (animal feeding)

Edgardo Almine, Mabuhay Vinyl Corporation, Iligan City, Mindanao, Philippines (charcoal production, reforestation)

Pancracio V. Bawagan, Forest Product Development Specialist, Forest Products Research and Industries Development Commission, College, Laguna, Philippines (timber production, pulping characteristics, etc.)

C. I. A. Beale, FAO/UNDP Livestock Project, Box 613, Lilongwe, Malawi (production economics and marketing)

Michael D. Benge, Agro-Forestation Division, US Agency for International Development/Agriculture, Manila, Philippines (general uses, shifting-cultivation, reforestation)

Daniel Bolong, La Union, Philippines (animal feeding)

J. A. Breen, FAO/UNDP Livestock Project, P. O. Box 613, Lilongwe, Malawi (agronomy, processing, farming systems)

James L. Brewbaker, Professor of Horticulture and Genetics, Department of Horticulture, University of Hawaii, Honolulu, Hawaii USA (genetic improvement, general agronomy, Hawaiian Giant varieties, seedless hybrids, etc.)

Leopoldo Castillo, Professor and Director, Dairy Training and Research Institute, University of Philippines at Los Baños, College, Laguna, Philippines (feeding poultry and dairy cows)

George S. Christie, Head, Department of Human Pathology, University of Melbourne, Melbourne, Australia (mimosine pathology)

Ramon Claveran-Alonso, Head, Forage Department, Instituto Nacional Investigaciónes Agrícoles, Mexico City, D.F., Mexico (forage uses)

Hugh M. Curran, Jr., Consultant, Tropical Forestry and Agriculture, Provident Tree Farms, Inc., Room 301, Ermita Center, Roxas Boulevard, Manila, Philippines (timber, green manure, and general uses)

Marcelino V. Dalmacio, Science Research Supervisor, Forest Research Institute, College, Laguna, Philippines

Department of Agricultural Research, Ministry of Agriculture and Natural Resources, P.O. Box 30134, Lilongwe 3, Malawi (agronomy, processing for feed)

Department of Primary Industries, Konedobu, Papua New Guinea (use of leucaena to shade coffee, cocoa, teak, etc.)

Ireneo L. Domingo, Professor and Department Chairman, University of the Philippines at Los Baños, College, Laguna, Philippines (timber and reforestation)

José Antonio Gonzalez-Marin, Colegio Superior de Agricultura Tropical, Apdo postal #24, Cardenas, Tabasco, Mexico (plant nutrition)

Artemio D. Garcia, Mabuhay Vinyl Corporation, Iligan City, Mindanao, Philippines (charcoal production, reforestation)

Anacleto Guevarra, Department of Agronomy and Soil Science, College of Tropical Agriculture, University of Hawaii at Manoa, Honolulu, Hawaii 96822, USA (green manure, varietal selection)

Ron Guyton, Bahamas Agriculture Research Training Development Center (BARTDC) Andros Island, the Bahamas

M. P. Hegarty, CSIRO, Division of Tropical Crops and Pastures, Cunningham Laboratory, Mill Road, St. Lucia, Queensland 4067, Australia (forage uses)

Tai-Wei Hu, Taiwan Forestry Research Institute, Botanical Gardens, 53 Nam Hai Road, Taipei, Taiwan, Republic of China (silviculture, reforestation)

E. Mark Hutton, Chief, Division of Tropical Crops and Pastures, CSIRO, Mill Road, St. Lucia, Brisbane, Queensland, 4067, Australia (general agronomy, breeding, and animal feeding)

John W. Hylin, Department of Agricultural Biochemistry, University of Hawaii, 1825 Edmondson Road, Honolulu, Hawaii, 96833 USA (mimosine effects)

Emil Q. Javier, Institute of Plant Breeding, University of Philippines at Los Baños, College, Laguna, Philippines (varietal selection)

Raymond J. Jones, Senior Principal Research Scientist, CSIRO Davies Laboratory, Townsville, Queensland 4810, Australia (animal feeding, agronomic development, seedless hybrids, etc.)

Antonio Leviste, Governor, Batangas City, Batangas, Philippines (production of leucaena seedlings)

Benjamin Mahilum, Visayas State College of Agriculture (VISCA), Baybay, Leyte, Philippines (soils and plant nutrition)

Raymond C. Mendoza, Department of Horticulture, University of the Philippines at Los Baños, College, Laguna, Philippines (agronomy)

D. J. Minson, Division of Tropical Crops and Pastures, Mill Road, St. Lucia, Queensland 4067, Australia (nutritional value)

James C. Moomaw, Director, Asian Vegetable Research and Development Center, P.O. Box 142, Shanhua, Tainan 741, Taiwan, Republic of China (general agronomy, farming systems)

Hector Muñoz, CATIE, Turrialba, Costa Rica

A. J. Oakes, ARS, Rm. 336A, B-001, US Department of Agriculture, Beltsville, Maryland 20705, USA (forage uses and general agronomy)

Roger L. Parfitt, Soil Bureau, Department of Scientific and Industrial Research, Private Bag, Lower Hutt, New Zealand (leucaena in shifting cultivation)

Ian Partridge, Sigatoka Agriculture Experiment Station, Fiji (planting systems)

Donald L. Plucknett, Professor of Agronomy and Soil Science, Department of Agronomy and Soil Science, University of Hawaii, Honolulu, Hawaii 96822, USA (general agronomy, pasture management)

Philippine-American Timber, P.O. Box 1451, Manila, Philippines (forest products, reforestation)

Filiberto S. Pollisco, Director, Forest Research Institute, College, Laguna, Philippines (wood properties)

Kenneth O. Rachie, Centro Internacional de Agricultura Tropical, Apartado Aereo 67-13, Cali, Colombia, South America (green manure, soil amelioration)

José Ramirez Bermudez, Instituto Tecnico de Agricultura, Ministerio de Agricultura, Guatemala City, Guatemala

Ernest Ross, Animal Sciences Department, 1800 East-West Road, University of Hawaii, Honolulu, Hawaii 96822, USA (poultry feeding)

Percy Sajise, College of Sciences and Humanities, Department of Botany, UPLB, College, Laguna, Philippines (ecology)

Pedro Sánchez de la Cruz, Banco de Mexico, Villahermosa, Tabasco, Mexico (forage use)

Guillermo Sánchez Rodríguez, Banco de Mexico, Hermenejildo Galeana #1, Ciudad Altamirano, Guerrero, Mexico (general agronomy, animal feeding, reforestation and general interest)

Setijati Sastrapradja, Director, Lembaga Biology National (LBN), Bogor, Indonesia (leucaena as human food)

R. Savory, FAO/UNDP, Improvement of Livestock and Dairy Industry Project, P.O. Box 613, Lilongwe, Malawi (agronomy, processing for feed)

J. A. Semana, Forest Products Research and Industries Development Commission, College, Laguna, Philippines (timber production, pulping characteristics)

Isidro M. Serrantes, Project Director, Ipil-ipil Project, Batangas City, Province of Batangas, Philippines (nursery production, plantation management)

Dorothy E. Shaw, Microbiology Section, Department of Primary Industries, Konedobu, Papua New Guinea (*Rhizobium* inocula and plant pathology)

Winnie Solido, Mabuhay Vinal Corporation, Iligan City, Mindinao, Philippines (reforestation and charcoal production)

T. H. Stobbs, CSIRO, Department of Tropical Crops and Pastures, Samford, Queensland, Australia (nutritional value)

Makato Takahashi, 2810 Kinohou Place, Honolulu, Hawaii 96822 (agronomy)

Santiago Tilo, Department of Soils, UPCA, College, Laguna, Philippines (plant nutrition, soils)

Abraham M. Unrau, Simon Fraser University, Department of Chemistry, Burnaby 2, B. C., Canada (gums and other leucaena seed constituents)

Felizardo D. Virtucio, Science Research Supervisor, Forest Research Institute, College, Laguna, Philippines (wood products)

P. Vohra, Dean, Department of Avian Science, University of California, Davis, California 95616, USA (poultry feeding)

Sheldon Whitney, Niftal, University of Hawaii, Maui Agricultural Research Center, P. O. Box 187, Kula, Maui, Hawaii (nitrogen fixation, utilization)

H. C. D. de Wit, Laboratory for Plant Taxonomy and Geography, 37 General Foulkesweg Wageningen, The Netherlands (taxonomy)

Neptale Zabala, Associate Professor, College of Forestry, University of the Philippines at Los Baños, College, Laguna, Philippines

Appendix D

Sources of Leucaena Seeds, Inoculum, and Wood

The following may be able to supply researchers who have professional interest in leucaena with small samples of seed, inoculum, and wood for research purposes.

Seeds

Australia: CSIRO, Division of Tropical Crops and Pastures, Mill Road, St. Lucia, Brisbane, Queensland 4067, Australia (cv Peru, cv Cunningham)
Hawaii: J. L. Brewbaker, Department of Horticulture, University of Hawaii, Honolulu, Hawaii 96822, USA ("Hawaiian Giant" and other varieties)
Malawi: R. Savory, F.A.O. Livestock Project, Box 613 Lilongwe, Malawi (cvs Peru, Cunningham, Hawaiian Giant (K8 and Ivory Coast)
Mexico: G. Sánchez Rodríguez, Banco de Mexico, Hermenegildo Galeana #1, Ciudad Altamirano, Guerrero, Mexico
Philippines: Michael D. Benge, USAID/Philippines, Magsaysay Foundation Building, Roxas Boulevard, Manila. Emil Javier, Director, Institute of Plant Breeding, University of the Philippines at Los Baños, College, Laguna (cv Peru and other varieties)
USA (continental): Southern Regional Plant Introduction Station, Experiment, Georgia 30212

Inoculum

Australia: R. A. Date, CSIRO, Division of Tropical Crops and Pastures, Mill Road, St. Lucia, Brisbane, Queensland 4067
Hawaii: S. Whitney, Niftal, University of Hawaii, Maui Agricultural Research Center, P.O. Box 187, Kula, Maui, Hawaii 96790
Malawi: Department of Agricultural Research, Ministry of Agriculture and Natural Resources, P.O. Box 30134, Lilongwe 3
Papua New Guinea: D. E. Shaw, Department of Primary Industries, Konedobu, Papua New Guinea (acid and alkaline)
United Kingdom: Rothamsted Experimental Station, Harpenden, Herts, England AL5 2JQ
USA (continental): J. Burton, Nitragin Corporation, 3101 West Tuster Avenue, Milwaukee, Wisconsin 53209

Wood

While stocks last small samples of wood from Salvador-type leucaena are available from:

Hawaii: J. L. Brewbaker, address above
Philippines: Forest Products Research and Industries Development Commission (FORPRIDECOM), College, Laguna
USA (continental): N. D. Vietmeyer, Commission on International Relations (JH215), National Academy of Sciences, 2101 Constitution Avenue, Washington, D.C. 20418

Français

Résumé

De toutes les légumineuses tropicales, c'est probablement le leucaena qui se prête aux usages les plus variés. En effet, ses nombreuses espèces donnent un fourrage très nourrissant, du bois à brûler, du bois d'oeuvre et un riche engrais d'origine organique. On peut s'en servir, entre autres usages, pour reboiser les pentes dans les régions tropicales ou ombrager les cultures, ou encore comme pare-feu, brise-vent ou plante ornementale. Bien que certains arbres aient produit individuellement des quantités de bois exceptionnelles—parfois même un volume annuel sans précédent—et que le fueillage de cette plante ait permis d'enregistrer les plus fortes augmentations de poids chez le bétail nourri au fourrage, le leucaena est une essence négligée, son potentiel n'étant que très faiblement exploité.

Comme les variétés d'une dimension et d'une vigueur exceptionnelles, ou possédant d'autres caractéristiques utiles, ne sont connues et exploitées que depuis une vingtaine d'années, l'expérience acquise dans ce domaine et la documentation qui s'y rapporte sont encore peu considérables. En outre, la réputation du leucaena a souffert dans certaines régions en raison d'une variété très envahissante (elle s'est étendue à toutes les zones tropicales au cours des 250 dernières années) qui a dégénéré en mauvaise herbe. D'autre part, son extension a été retardée du fait que le feuillage contient un acide aminé rare, la mimosine, qui est toxique pour les non-ruminants lorsque la dose dans le régime alimente est de l'ordre de 10%. Le leucaena n'est pas mortel pour les ruminants comme le bétail, puisque les micro-organismes de l'estomac transforment la mimosine en dihydroxypyridine ou DHP (voir chapitre 3). La DHP peut avoir une action néfaste sur la glande thyroïde de l'animal et le bétail consommant des quantités excessives de leucaena peut souffrir d'alopécie ou d'anoréxie, et donc perdre du poids; ces affections ne se produisent pas, toutefois, si le régime est complété par d'autres aliments.

Leucaena* est le nom usuel du *Leucaena leucocephala*. Certaines variétés sont des arbustes à branches multiples qui, arrivés à maturité, atteignent 5 m.

*Prononcé leusena. Dans le présent rapport, "leucaena" désigne uniquement le *Leucaena leucocephala* à l'exclusion des autres espèces du genre *Leucaena*. La documentation d'avant 1960 utilise le nom botanique de *Leucaena glauca*.

en moyenne; d'autres sont des arbres à tronc unique qui peuvent atteindre 20 m. Originaires de l'Amérique centrale (Figure 1), certaines espèces ont été répandues dans cette région il y a des centaines d'années déjà par les civilisations Maya et Zapotèque. Le nom d'Oaxaca lui-même (qui désigne le cinquième état le plus étendu du Mexique ainsi qu'une grande ville moderne) est dérivé d'un mot indigène "uaxin" signifiant "là où pousse le leucaena" (Figure 2).

En 1565, après la conquête du Mexique, les conquistadors espagnols établirent des relations commerciales avec les Philippines: chaque printemps, une caravelle partait d'Acapulco sur la côte ouest du Mexique pour traverser le Pacifique. Au cours des 250 années pendant lesquelles durèrent ces relations, le leucaena parvint jusqu'aux Philippines, emporté probablement pour servir de fourrage.

La variété "Acapulco" est une plante vivace, robuste, dont la croissance est vigoureuse et la floraison abondante. Elle s'est solidement implantée aux Philippines, à Guam et dans d'autres îles espagnoles de l'ouest du Pacifique. Les habitants découvrirent rapidement qu'elle constituait un très bon bois à brûler; plus tard, les planteurs constatèrent que le café, le cacao, le quinquina, le poivre, la vanille et d'autres cultures aimant l'ombre croissaient mieux sous la voûte de feuillage que forme cette variété. Le leucaena fut en conséquence introduit dans les plantations des Indes néerlandaises (aujourd'hui l'Indonésie), de la Papouasie Nouvelle Guinée, de la Malaisie et d'autres pays de l'Asie du sud-est. Au XIX^e^ siècle, on l'introduisit à Hawaï, à Fiji, en Australie du nord, en Inde, en Afrique orientale et occidentale, et aux Antilles. Aujourd'hui, cette variété est répandue dans toutes les régions tropicales.

La variété qui connaît à l'heure actuelle une extension si considérable est issue du type Acapulco (appelé désormais type "hawaïen"); ce n'est qu'à une date récente que les autres variétés très nombreuses de plasma germinatif répandues dans toute l'Amérique centrale ont été recueillies et étudiées.

Le leucaena est un genre de légumineuse et, comme les autres membres de cette famille, peut s'associer très profitablement à des bactéries du sol du genre *Rhizobium*. Celles-ci pénétrent dans les jeunes radicelles et se multiplient pour former des nodosités à la surface de la racine. Le *Rhizobium* est capable d'absorber de grandes quantités d'azote atmosphérique en présence dans le sol et de le transformer en composés azotés organiques et inorganiques. Le procédé par lequel un azote inutilisable autrement est converti en composés que la légumineuse peut absorber pour former des protéines, s'appelle "fixation de l'azote". Le leucaena, qui est généralement pourvu de nodosités volumineuses et prolifiques, n'exige qu'une quantité d'engrais azoté faible ou nulle, parce que le *Rhizobium* à lui seul fournit des composés azotés suffisamment abondants pour assurer une croissance normale. C'est ainsi que le leucaena parvient très bien à se développer dans certains sols dont la teneur en azote est trop faible pour permettre la croissance d'un grand nombre d'autres cultures.

Les nodosités apparaissent sur les radicelles dans les couches superficielles aérées, mais le leucaena est aussi pourvu d'une racine pivotante qui traverse les couches plus profondes et absorbe l'eau et les minéraux situés à un niveau que ne peuvent atteindre un grand nombre de plantes cultivées. C'est une autre raison pour laquelle la plante peut se développer là où d'autres meurent. Certaines zones du Yucatan et de l'Oaxaca ont des saisons sèches si longues que le nombre d'années où les récoltes sont mauvaises dépasse celui où elles sont abondantes; pourtant, ces régions sont l'habitat naturel du leucaena, car celui-ci survit en puisant de l'eau dans les couches profondes du sous-sol.

Les principaux usages du leucaena sont les suivants:

Fourrage

Dans les régions tropicales à basse altitude, le leucaena peut fournir de grandes quantités de protéines s'il est cultivé dans des terres bien drainées, fertiles, et récolté régulièrement pour servir de foin ou de fourrage (Chapitre 3).

Convenant surtout au bétail, au buffle et à la chèvre, le leucaena est une plante fourragère très appétissante, digeste et nourrissante. Le boeuf et le bétail laitier s'en accomodent parfaitement et peuvent s'en nourrir exclusivement jusqu'à ce que le seuil de toxicité de la mimosine soit atteint. Cet inconvénient peut être évité pendant un certain temps ou éliminé totalement si le régime est complété par d'autres espèces de fourrage.

La résistance de cette plante à la sércheresse, sa robustesse, en font une essence très prometteuse, capable d'accroître la production de viande et de lait dans les régions tropicales arides.

Les travaux entrepris pour créer de nouvelles variétés à très faible dose de mimosine sont déjà très avancés et celles-ci se révèlent très prometteuses comme plante fourragère tropicale débarrassée de sa toxicité.

Bois

Les variétés de leucaena arborescentes, découvertes récemment, croissent rapidement et produisent du bois dont les dimensions sont suffisantes pour fournir du bois d'oeuvre et des sciages. On est encore assez mal renseigné sur sa qualité, mais les premiers essais sont encourageants. Le bois de leucaena constitue une source potentielle importante de pâte à papier, de rondins (poteaux, etc.) et de matériaux de construction (Chapitre 4).

Combustible

Le leucaena fournit un bois de combustion et un charbon de bois excellents. Il est exploité depuis longtemps aux Philippines pour cette raison et les nouvelles variétés sont si productives qu'on les cultive déjà pour qu'elles servent de combustible aux générateurs électriques, aux usines et aux installations de traitement des produits agricoles. Le bois possède une densité et une capacité calorifique exceptionnelles pour un arbre à croissance rapide; en outre, comme les souches repoussent rapidement (pour former des taillis), cette plante "défie la hache du bucheron". En tant que telle, elle pourrait constituer un combustible renouvelable dans les régions qui se prêtent à sa culture (Chapitre 5).

Amendement des terres

Le leucaena contribue à enrichir le sol et à faire pousser les plantes voisines; en effet, son feuillage contient autant d'azote que les engrais et la chute naturelle des feuilles le restitue au sol situé autour de l'arbre (Chapitre 6). Des expériences récentes ont prouvé que si le feuillage est recueilli et placé autour d'autres plantes cultivées, le rendement de celles-ci s'accroît pour atteindre presque celui qu'on obtiendrait avec des engrais commerciaux.*

En outre, les racines très vigoureuses du leucaena ameublissent les couches imperméables du sous-sol, améliorant la pénétration d'humidité et freinant le ruissellement des eaux en surface. Les éléments nutritifs des couches plus profondes sont peu à peu déposés à la surface par la décomposition des feuilles et d'autres parties de la plante; les organismes dans le sol prolifèrent et l'humus se constitue.

En tant qu'engrais végétal renouvelable destiné aux régions rurales des tropiques, le leucaena mérite d'être soumis à des tests plus nombreux.

Reboisement

Capable de se développer sur des pentes raides, dans des sols marginaux ou des régions connaissant une saison sèche prolongée, le leucaena est un arbre de choix pour le reboisement des forêts destinés à couvrir des bassins fluviaux, des pentes et des pâturages, qui ont été dénudés par le déboisement ou par des incendies. Par exemple, le leucaena peut s'implanter dans des sols pauvres envahis par des herbes grossières, phénomène courant dans beaucoup de régions tropicales qui ont été déboisées ou surexploitées par l'agriculture (Chapitre 6).

*Guevara, 1976. Vour Textes choisis.

Autres usages

En Amérique centrale et en Indonésie, les jeunes gousses et les graines constituent un aliment important. Bien que la mimosine provoque la chute des cheveux chez l'homme, son effet est très limité à petite dose. En outre, on peut fabriquer des perles avec les graines et différentes teintures peuvent être extraites des gousses, des feuilles et de l'écorce. Une voûte de feuillage de leucaena s'emploie communément pour ombrager les cultures telles que le café, le cacao, le quinquina, et les protéger d'un ensoleillement excessif. Le leucaena sert aussi de brise-vent, d'ornemental pour donner de l'ombre et d'arbre décoratif le long des routes. De plus la plante peut contribuer à modifier les méthodes d'assolement (brûlis) car, en fertilisant le sol, elle peut réduire le temps de jachère requis entre les plantations.

Désavantages

Outre la toxicité de la mimosine déjà mentionnée, le leucaena présente certains désavantages et sa croissance exige certaines conditions spéciales.

La plante ne pousse avec vigueur qu'à basse altitude; à Hawaï, son rythme de croissance ralentit au-dessus de 500 m., mais l'altitude à laquelle on observe un ralentissement sensible est bien plus élevée dans les pays proches de l'équateur (voir chapitre 2).

Bien que le leucaena puisse *survivre* et même proliférer dans un grand nombre de sols et d'environnements marginaux (voir chapitre 2), son rendement n'est exceptionnel que dans des régions fertiles, bien drainées, où la pluviosité, ou l'irrigation, est suffisante. Le phénomène est particulièrement frappant lorsque la plante est intensément exploitée pour servir de fourrage ou d'engrais végétal. Il l'est moins dans les cas où la plante sert au reboisement, à la lutte contre l'érosion et à la production de bois.

Comme toute herbe ou légumineuse, le leucaena exige que les minéraux soient présents dans le sol dans des proportions équilibrées; il faut donc prêter une attention particulière aux éléments nutritifs absorbés (surtout le phosphore, le soufre, le calcium, le molybdène et le zinc). Même dans des conditions favorables, le broutage et l'abattage continuels du feuillage et du bois privera la plante de certains éléments nutritifs essentiels; celle-ci aura alors besoin d'engrais.

Il existe certains types de sols pauvres où le leucaena ne peut survivre aisément. Par exemple, il s'accomode mal de sols acides; il faut alors recourir au chaulage et à l'addition de variétés spéciales de *Rhizobium*, de même qu'à des engrais contenant du molybdène, du phosphore, du soufre et du calcium, pour que la plante puisse se développer normalement. Celle-ci atteint donc son plein rendement dans des régions à sols non acides. Le leucaena croît difficilement dans des sols à haute teneur d'alumine et pour y survivre exige des engrais phosphatés et du calcium; ainsi entretenue, la plante peut atteindre un rendement satisfaisant.

Comme les plantules croissent d'abord lentement, il faut prendre des précautions pour en assurer la survie: des mauvaises herbes trop envahissantes ou des conditions climatiques défavorables peuvent anéantir totalement une plantation.

La nature prolifique du leucaena de type hawaïen crée des problèmes dans les endroits où les arbres ne sont pas abattus régulièrement. C'est le cas notamment à Guam. Le charbon de bois de leucaena était autrefois un combustible très recherché pour la cuisson des aliments, mais depuis l'électrification de l'île, la plante s'étend librement, dégénérant en massifs impénétrables qui ne présentent que des inconvénients. On ne pense pas que le problème se posera avec le leucaena arborescent de type salvadorien.

Español

Resumen

De todas las plantas leguminosas tropicales, probablemente sea la leucaena la que ofrece mayor variedad de aplicaciones. Gracias a sus numerosas variedades, la leucaena puede producir forraje nutritivo, leña, madera para construcciones y un buen fertilizante orgánico. Entre sus múltiples aplicaciones figuran la de volver a vegetar las laderas de los montes, establecer estructuras para cortar el viento o los incendios, dar sombra y ofrecer ornamentación. Aunque ciertos árboles de leucaena han dado cantidades extraordinarias de madera–en realidad, algunos de los volúmenes anuales mayores que se han registrado nunca–y aunque gracias a la planta se han conseguido algunas de las ganancias de peso máximas en la alimentación del ganado vacuno por medio de forraje, continúa siendo un cultivo descuidado sin que se hayan aprovechado plenamente todas sus posibilidades.

A cause de que las variedades poseedoras de tamaño o vigor excepcionales o de otras cualidades ventajossas se han descubierto o explotado tan solo durante las dos últimas décadas, la experiencia es todavía limidata y la bibliografía escasa. Además, la fama de la leucaena ha sufrido en algunas zonas debido a que una de las variedades (extendida por todos los trópicos durante los dos y medio últimos siglos) se ha convertido en maleza. Por otra parte, el desarrollo de la leucaena se ha visto retardado debido a que su follaje contiene un aminoácido poco común, mimosina, que es tóxico para los animales no rumiantes a un nivel de alrededor del 10% por ciento en la dieta. La leucaena no es mortal para los rumiantes, como el ganado vacuno, puesto que los microorganismos que se hallan en el estómago convierten la limosina en dihidroxipiridina (DHP). (Véase el Capítulo 3.) la DHP puede afectar desfavorablemente a la glándula tiroides del animal, y el ganado vacuno que consume una cantidad excesiva de leucaena puede sufrir de mal apetito, caída de pelo y la consiguiente pérdida de peso, pero esto no ocurre cuando hay otros forrajes que complementan la dieta.

La leucaena* es el nombre común de la *Leucaena leucocephala*. Algunas de las variedades son arbustos con ramas múltiples de un promedio de cinco

*En este informe, "leucaena" se refiere únicamente a *L. leucocephala* y no a otras especies del género *Leucaena*. En las publicaciones anteriores a 1960 se utiliza el nombre botánico *Leucaena glauca* para la planta.

metros de altura cuando la planta alcanza plena madurez. Otras variedades son árboles de un solo tronco que crece hasta 20 metros. Originaria de Centroamérica (Figura 1) algunas de las variedades fueron extendidas por toda la región hace miles de años por las civilizaciones maya y zapoteca. En realidad, el nombre Oaxaca (el quinto estado de México en superficie y una ciudad moderna) se deriva de la palabra precolombina "uaxin", que significa "el lugar en que crece la leucaena" (Figura 2).

En 1565, después de la conquista de México, los conquistadores españoles organizaron el comercio con las Filipinas: cada primavera salía un galeón de Acapulco en la costa occidental de México con rumbo a las Filipinas a través del Pacífico. En algún momento durante los 250 años que esto continuó la leucaena llegó a las Filipinas, probablemente llevada como forraje.

La variedad "Acapulco" es un tipo robusto, persistente y de crecimiento vigoroso que florece abundantemente. Se estableció firmamente en Filipinas, Guam y otras posesiones insulares españolas del oeste del Pacífico. La gente local aprendió pronto que servía para hacer buena leña; más adelante, los propietarios de plantaciones descubrieron que el café, cacao, quinina, pimienta, vainilla y otros cultivos que crecen en la sombra se establecían bien debajo del follaje de esta variedad de leucaena. En consecuencia, se introdujo la leucaena en las plantaciones de las Indias Orientales Holandesas (ahora Indonesia), Papua Nueva Guinea, Malaya (Malasia) y otros países de la región sudoriental de Asia. En el siglo XIX se llevó a Hawai, Fiji, Australia septentrional, India, Africa oriental y occidental y a las islas de la región del Caribe. Actualmente se puede decir que se halla extendida por todos los trópicos.

La variedad que se difundió tanto desciende del tipo Acapulco (conocido ahora como el tipo "Hawaiano"); la riqueza de otras variedades de leucaena extendidas por toda Centroamérica siguieron sin recogerse y casi desconocidas hasta hace poco tiempo.

La leucaena es una especie de la familia Leguminosae y, al igual que la mayoría de las demás leguminosas, puede formar una asociación mutuamente beneficiosa con bacterias del suelo del género *Rhizobium*. Estas bacterias penetran en las raicillas jóvenes y se multiplican para formar nódulos en la superficie de la raíz. Los *Rhizobium* de los nódulos son capaces de absorber grandes cantidades de gas nitrógeno del aire que hay en el suelo, transformándolo en compuestos orgánicos e inorgánicos que contienen nitrógeno. Este proceso, que convierte el gas nitrógeno no aprovechable en compuestos que pueden ser utilizados por las leguminosas para formar proteínas, se conoce como "fijación de nitrógeno". La leucaena suele tener nódulos grandes y prolíficos y requiere muy poco o ningún fertilizante de nitrógeno porque los *Rhizobium* ofrecen por sí solos compuestos nitrogenados en cantidad suficiente para un crecimiento normal. Esto permite a la leucaena prosperar en algunos suelos en los que el nivel de nitrógeno es insuficiente para mantener el crecimiento de la mayoría de los demás cultivos.

Los nódulos ocurren en las raicillas en las capas superficiales y aireadas del suelo, pero la leucaena desarrolla una raíz primaria que penetra en las capas profundas del suelo y aprovecha el agua y los minerales por debajo de la zona a la que llegan las raíces de muchas plantas explotadas agrícolamente. Esto contribuye también a que pueda desarrollarse en lugares en que no lo hacen otras plantas. Ciertas partes de Yucatán y Oaxaca tienen unas estaciones secas tan prolongadas que el número de años en que hay mala consecha es mayor al de años en que se obtiene una cosecha normal; con todo, este es el habitat original de la leucaena; sobrevive aprovechando la humedad de las capas profundas del suelo.

Forraje

En las tierras bajas de los trópicos pueden producirse con buen rendimiento y económicamente grandes cantidades de proteínas obteniéndolas de árboles de leucaena cultivados en suelos con buen desagüe y fértiles y recolectados periódicamente como heno o forraje (vease el Capítulo 3).

El forraje de leucaena es indicado principalmente para el ganado vacuno, búfalos y cabras y es apetitoso, digestible y nutritivo. El ganado vacuno, tanto el de engorde como el lechero, lo come con provecho y puede vivir de él exclusivamente hasta que ocurre la toxicidad relacionada con la mimosina. Ese momento puede retrasarse o eliminarse por completo suplementando la dieta con otros forrajes.

La tolerancia que tiene la planta a la sequía y su resistencia hacen que ofrezca grandes posibilidades para aumentar las disponibilidades de carne y leche en los trópicos secos.

Las nuevas variedades bajas en contenido de mimosina, que ahora se hallan en etapa adelantada de desarrollo, ofrecen grandes promesas para el futuro como forrajes aptos para los trópicos.

Madera

Las variedades recientemente descubiertas de leucaena arbórea crecen rápidamente y proporcionan madera de un tamaño que puede utilizarse con fines de construcción. Aunque son escasos los detalles que se conocen sobre su calidad, las pruebas iniciales son alentadoras. La madera de la leucaena tiene buenas posibilidades para convertirse en una fuente importante de pulpa y papel, maderos redondos (por ejemplo, palos y postes) y materiales de construcción (Capítulo 4).

Combustible

La madera de leucaena es excelente como leña y para hacer carbón vegetal. Hace mucho tiempo que se utiliza para este fin en Filipinas, y las nuevas variedades son tan productivas que ya se están plantando para producir combustible para generadores eléctricos, fábricas e instalaciones elaboradoras de productos agrícolas. La madera tiene una densidad excepcionalmente alta y gran valor calórico si se tiene en cuenta que es un árbol de rápido crecimiento; y debido a que los tocones de la planta vuelven a crecer con facilidad (matorral), la planta "desafía al leñador". Dadas esas condiciones, podría convertirse en un combustible renovable en las zonas que satisfagan sus requisitos agronómicos (Capítulo 5).

Mejora del suelo

La leucaena contribuye a abonar el suelo y beneficia a las plantas cercanas debido a que su follaje puede compararse con el estiércol desde el punto de vista de su conteido de nitrógeno, y las hojas que caen devuelven éste al suelo debajo de los arbustos (Capítulo 6). Experimentos recientemente efectuados en Hawai han demostrado que si se recolecta el follaje y éste se echa a otras plantas agrícolas que crezcan cerca, el aumento de rendimiento que se obtendrá de ésta se acercará al que se logra mediante fertilizantes comerciales.*

Además, las raíces expansivas de leucaena desintegran capas del subsuelo impermeables, lo cual mejora la penetración de la humedad y disminuye la escorrentía en la superficie. Los elementos nutritivos de las capas profundas se depositan paulatinamente en la superficie al descomponerse las hojas y otras partes de la planta; aumentan los organismos que viven en el suelo y se reconstituye el humus o mantillo.

Teniendo en cuenta que la leucaena, en su calidad de abono verde, ofrece un recurso renovable para las regiones rurales de los trópicos, conviene sin duda someterla a nuevos ensayos.

Repoblación forestal

La capacidad de la leucaena para medrar en las laderas inclinadas, en suelos marginales y en zonas con estaciones secas prolongadas hace que ofrezca muy buenas posibilidades para restablecer la floresta de las cuencas hidráulicas, laderas y prados que se han visto privados de ella a causa del desmonte o tala o de incendios. Por ejemplo, la leucaena puede arraigar en suelos degradados dominados por yerbas gruesas, característica que es común en muchas regiones tropicales que han sido deforestadas o agotadas por la agricultura.

*Guevarra 1976. Véase Lecturas Seleccionadas.

Otras aplicaciones

En Centroamérica e Indonesia las vainas tiernas y las semillas de la leucaena son un alimento importante. Aunque la mimosina provoca la caída del cabello en los seres humanos, si se come con moderación produce escasos efectos. Otros productos son adornos hechos con las semillas imitando cuentas y tintes extraídos de las vainas, hojas y corteza. El follaje de la leucaena se utiliza extensamente para dar sombra a cultivos como el café, cacao y chinchona o quino para protegerlos contra la excesiva luz solar. La leucaena se ha utilizado también para establecer estructuras que corten el viento y como planta ornamental que da sombra y a lo largo de las carreteras. Además, la planta puede ser importante para modificar los métodos de cultivo y evitar los que agoten la tierra, pues, al mejorar la fertilidad del suelo, la leucaena puede reducir el tiempo de barbecho necesario entre dos plantaciones (Capítulo 7).

Limitaciones

Además de la toxicidad por causa de la mimosina que ya se ha mencionado, la leucaena tiene varias limitaciones y exigencias especiales.

La planta crece vigorosamente únicamente en tierras bajas; en Hawai, su crecimiento se retarda a elevaciones superiores a 500 m., aunque la altitud a la que se observa el retardo del crecimiento es mucho mayor en los países cercanos al Ecuador (véase el Capítulo 2).

Si bien la planta puede *sobrevivir* y aun crecer vigorosamente en muchos suelos y medios marginales (véase el Capítulo 2), su rendimiento excepcional ocurre únicamente en suelos fértiles con buen desagüe y en los que la precipitación o irrigación son adecuadas. Esto es así especialmente cuando la planta se explota intensivamente para forraje o abono verde. Es menos importante con países de repoblación forestal, erosión del suelo y producción de madera.

Como todas las leguminosas y yerbas, la leucaena exige que haya un equilibrio mineral razonable en el suelo, de manera que es muy importante prestar la debida atención a los elementos nutritivos que deben aportarse (especialmente fósforo, azufre, calcio, molibdeno y zinc). Aun en condiciones favorables, el continuo ramoneo o corte y extracción de la madera o follaje privará a la leucaena de algunos elementos nutritivos de vital importancia por lo tanto, es necessario fertilizar.

Hay varios tipos de suelos malos en los que la leucaena no puede sobrevivir con facilidad. Por ejemplo, se adapta mal a los suelos ácidos; la adición de cal en forma de pellas y la adición de una raza especial de *Rhizobium* así como de fertilizante que contenga molibdeno, fósforo, azufre y calico es necesaria para lograr que arraigue. Por consiguiente, las principales posibilidades que ofrece la planta es para regiones con suelos no ácidos. La leucaena crece también mal en suelos que contengan alúmina y exige una fertilización cuidadosa con fosfato y calcio si se quiere que sobreviva y crezca, pero con la fertilización es posible obtener un buen rendimiento.

Debido a que los plantones de leucaena crecen con lentitud, al principio se complica su arraigue: las malas yerbas que crezcan vigorosamente o las malas condiciones meteorológicas pueden provocar el fracaso total de la plantación.

El carácter prolífico de la leucaenas de tipo hawaiano plantea problemas en lugares en que la planta no se recolecte periódicamente. Esto ha ocurrido, por ejemplo, en Guam. El carbón vegetal de leucaena fue en otra época popular para cocinar, pero al electrificarse la isla la planta crece ahora sin trabas, produce marañas densas como si se tratara de maleza y se ha convertido en un estorbo. No se prevé que vaya a ocurrir esto con las leucaenas arbóreas de tipo Salvador.

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