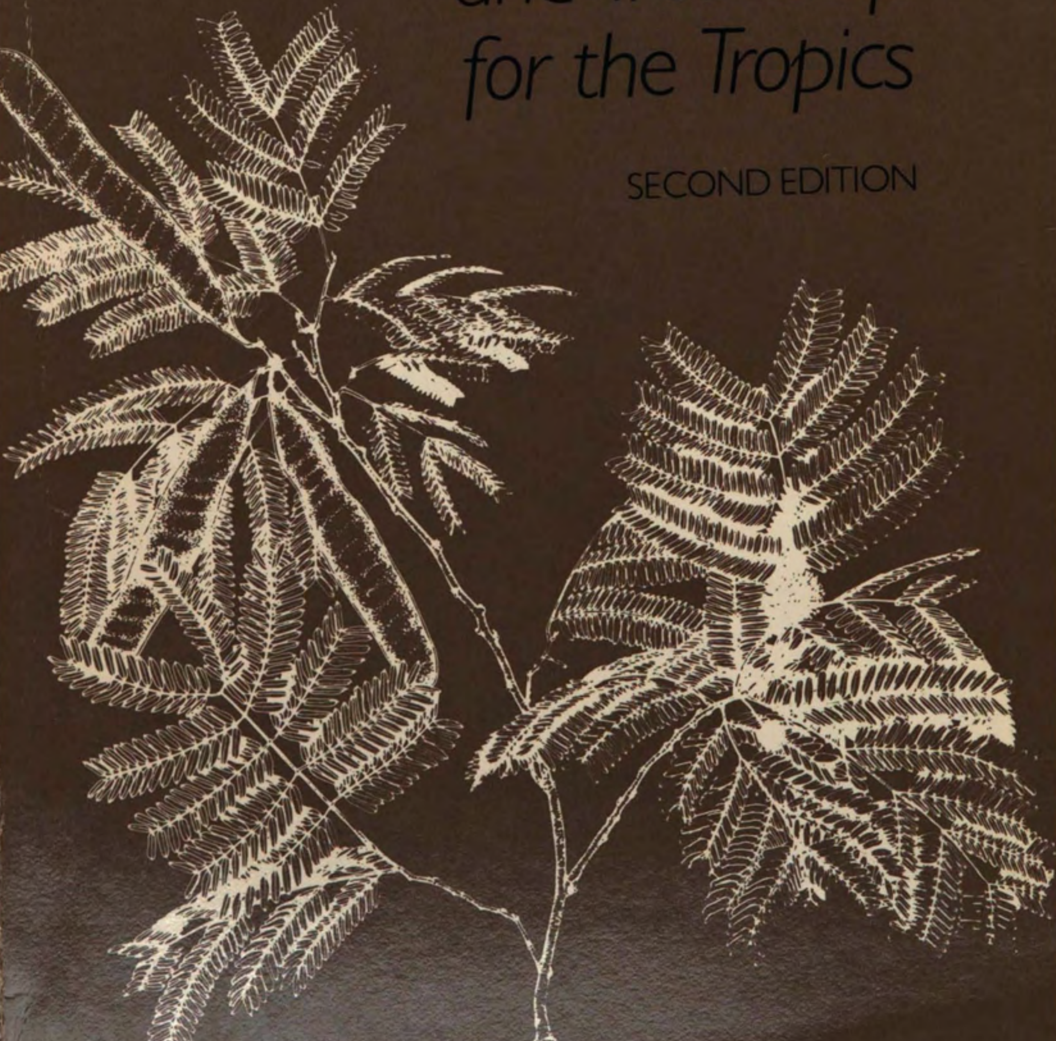
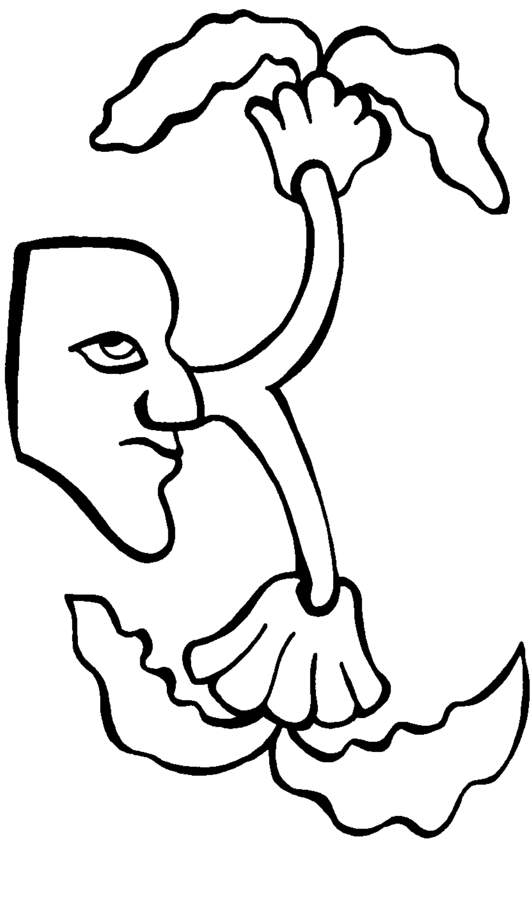
INNOVATIONS IN TROPICAL REFORESTATION

Leucaena: Promising Forage and Tree Crop for the Tropics

SECOND EDITION





The earliest historical reference to leucaena, west-central Mexico, circa 1550. This Nahuatl pictograph (as well as the one facing page 1), with pods clearly visible, represents "uaxin," meaning "the place where leucaena grows." The Spanish mistranscribed the word uaxin as "oaxaca." Today, Oaxaca is the name of both a state and a city in Mexico, and leucaena still grows there. (Drawings copied from the Codex Mendoza.)

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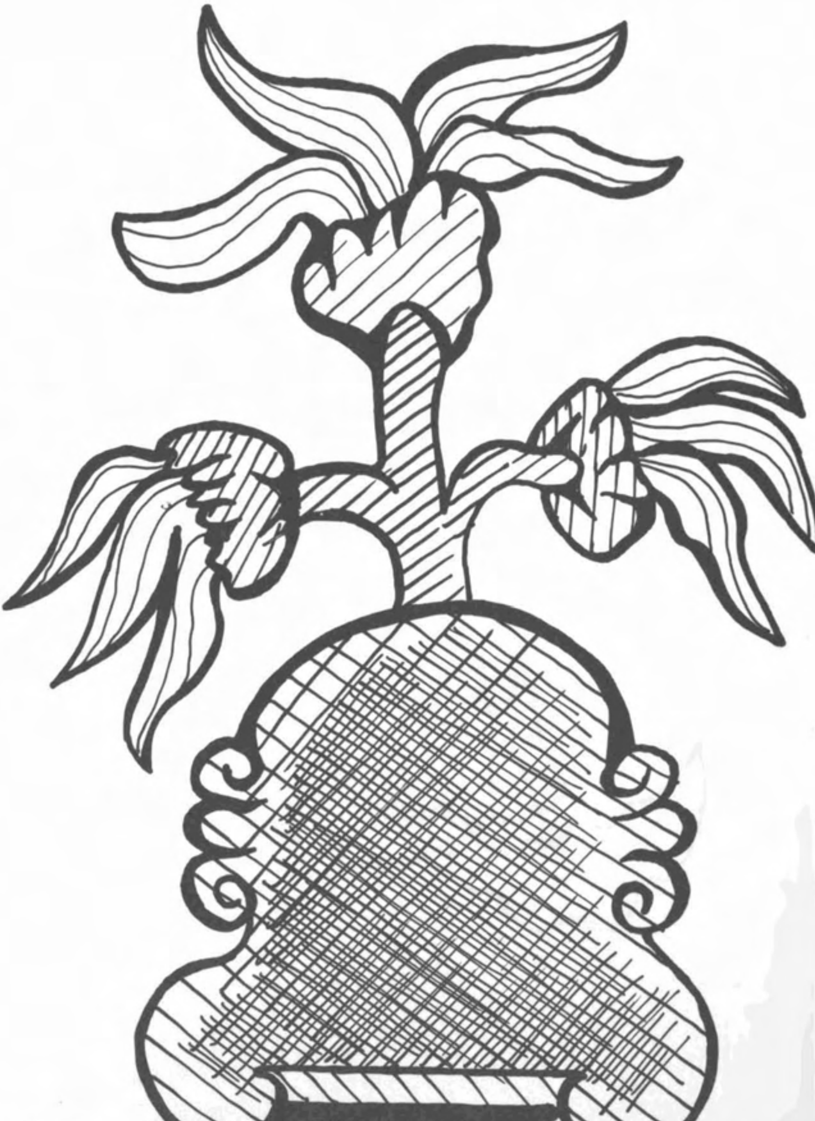


1 Introduction and Summary

Leucaena is a tropical tree with a wide assortment of uses. Increasingly, foresters and farmers in the tropics are exploring its potential, and the area planted to leucaena is expanding rapidly.

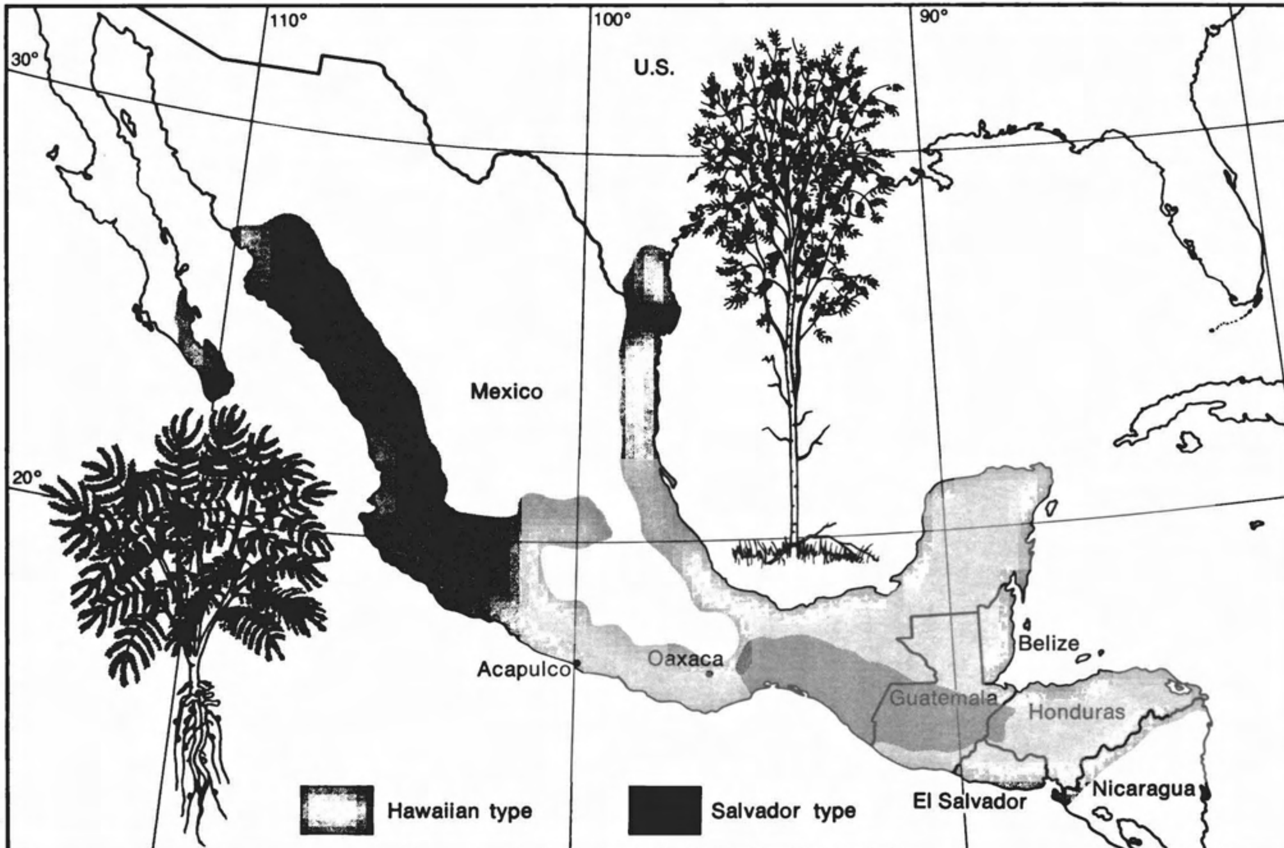
Under optimum growing conditions leucaena stands have yielded extraordinary amounts of wood—indeed, among the highest annual totals ever recorded. Leucaena also makes quality forage and is responsible for some of the highest weight gains of cattle in the tropics. Its additional uses include revegetation of hillslopes, provision of windbreaks, firebreaks, and shade, and roadside beautification.

Leucaena* is the common name for *Leucaena leucocephala*. Some strains are many-branched shrubs with average heights of 5 m at maturity; others are trees that grow taller than 20 m. The species originated in Central America, and some of its varieties were spread throughout the region by pre-Columbian civilizations. Indeed, the name Oaxaca (Mexico's fifth largest state and a prominent modern city) is derived from the Zapotec word "uaxin," meaning "the place where leucaena grows."

After their conquest of Central America, the Spanish organized trade with the Philippines. Each spring from 1565 to 1825, one or two galleons left the port of Acapulco on Mexico's west coast and crossed the Pacific. Sometime during those 250 years, leucaena seed reached the Philippines, probably as a result of leucaena's use as fodder for animals on board.

The leucaena variety from Acapulco (now called "common type") is a rugged, persistent shrub that produces seeds abundantly. It became firmly established in the Philippines, Guam, and other Spanish island possessions. Local people soon learned that it was vigorous and made good fodder and firewood. In some places it got out of hand and became a weed. Later, plantation owners found that coffee, cacao, cinchona, pepper, vanilla, and other shade-loving crops grew well beneath an overstory of leucaena. Because of this, during the nineteenth

*Pronounced loo-*see*-na, but variously called loo-*kee*-na, loo-*kay*-na, loo-ka-*eh*-na, loo-*say*-na, loo-*kuy*-na. In this report, "leucaena" refers only to *Leucaena leucocephala* and not to other species of the genus *Leucaena*. Literature published before 1960 uses the botanic name *Leucaena glauca* for the plant.



Originating in the midlands of Guatemala, Honduras, El Salvador, and southern Mexico, leucaena was spread throughout the coastal lowlands by pre-Columbian Indians. The common type is a rapidly flowering, many-branched shrub, while the giant type is a single-trunked tree that may reach 20 m in height. Today, specimens of the giant variety, which has large pods, can be found scattered throughout western Mexico, where leucaena pods are a traditional food. (Adapted from the first edition of this book by Encyclopaedia Britannica, Inc.)

century leucaena seed was carried to the Netherlands East Indies (now Indonesia), Papua New Guinea, Malaya (Malaysia), other countries of Southeast Asia, Hawaii, Fiji, northern Australia, India, East and West Africa, and islands of the Caribbean.

Although this bushy leucaena has long been found throughout the tropics, a wealth of other leucaena types remained scattered throughout Central America, virtually unrecorded. However, in the 1960s James Brewbaker, a University of Hawaii agronomist, collected and solicited seed of "giant-type" strains from Central America. In Hawaii these strains grew into tall trees, quite different from the shrubby "common type."

Leucaena is a species of the family Leguminosae and, like most other legumes, forms mutually beneficial partnerships with soil bacteria of the genus *Rhizobium*. These bacteria penetrate young rootlets and multiply to form nodular swellings that serve as factories for nitrogen fixation. The rhizobia they contain absorb nitrogen gas from air in the soil and transform it into nitrogen-containing organic and inorganic compounds. This process converts otherwise unusuable gas into nitrogenous compounds that fertilize the plant. Thus, for average growth leucaena usually requires no fertilizer, and it can thrive in some nitrogen-poor soils that are inadequate to sustain many other crops.

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

A summary of leucaena's main uses follows.

Forage

In the lowland tropics, leucaena grown on well-drained, fertile soils, and regularly mowed or clipped, produces large quantities of foliage. For ruminant animals such as cattle, water buffalo, and goats, this is palatable, digestible, and nutritious. Consequently, leucaena is a promising candidate for increasing meat and milk production in both the humid and monsoonal tropics.

Leucaena's development as a forage has been slowed because of fears about the mimosine in its foliage. This amino acid causes weight loss and ill health in nonruminants such as pigs, horses, rabbits, and poultry when leucaena is fed at levels above about 7.5 percent (dry

Forage. Although it is a tree, leucaena is a promising forage crop for cattle, goats, water buffalo, and some other ruminant animals. The animals browse the stems and leaves, giving no chance for thick woody stems to develop. Keeping animals out until the plants are 1 or 2 m high produces a 3-dimensional block of forage in which the livestock find feed from ground level to eye level. This makes for a very productive pasture and has led to some of the highest meat and milk production ever recorded in the tropics; in Australia some fields are still in production after 17 years of periodic grazing. (J. Perez-Guerrero Z.)

matter) of the diet. However, in most parts of the world ruminants, which have stomach microorganisms that render mimosine harmless, can eat leucaena without ill effect. At present, ruminants in Australia, Papua New Guinea, and perhaps some other Pacific islands and African countries lack the appropriate rumen bacteria and suffer nutritional disabilities after feeding on high levels of leucaena. The appropriate bacteria are being introduced into these locations so that ruminant animals worldwide should soon be able to eat leucaena extensively without harm (chapter 4).

Wood

The treelike leucaena varieties from inland Central America that became available after 1963 grow rapidly and yield a medium hardwood. The wood is of useful size for lumber, and these varieties have the potential to become major sources for roundwood (for example, poles and posts), timber and other construction materials, and for pulp and paper.

Leucaena wood also makes good firewood and charcoal. In the Philippines, common leucaena has been used for cooking and heating

probably since the days of the earliest Acapulco galleons. The new giant varieties are so productive that they are being planted in large tracts to provide fuel for electric generators, internal combustion engines (via producer gas), and factories. The wood has a high calorific value for a fast-growing tree, and because the stumps regrow readily (coppice), the plant "defies the woodcutter" (chapter 5).

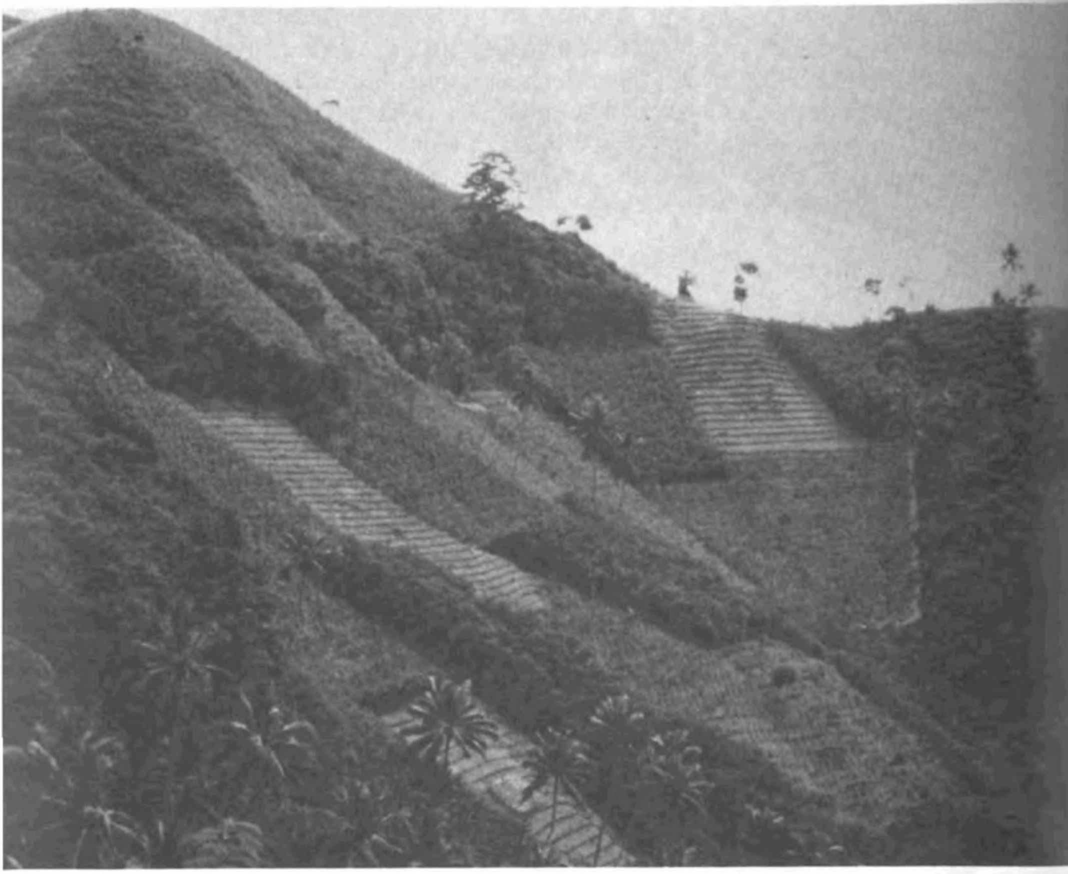
Reforestation

Leucaena's ability to thrive on poor soils and in areas with long dry seasons makes it a prime candidate for restoring forest cover to watersheds, slopes, and other lands that have been denuded of trees. It competes vigorously with coarse grasses, a common feature of many degraded tropical areas that have been deforested or depleted by excessive agriculture (chapter 6).

Soil Improvement

Through natural leaf drop, leucaena enriches and fertilizes soil. Its foliage rivals manure in nitrogen content. Experiments in Hawaii and

Wood. One-year-old giant leucaena, Batangas City, Philippines. Leucaena is one of the fastest growing trees ever recorded. Populations in the range of 5,000–10,000 trees per hectare produce straight stems and encourage rapid diameter growth. Leucaena stems at close spacings are remarkably self-pruning, with a low rate of forking. Trees on good sites like this one can obtain diameters of 6.5 cm, heights of 11 m, and total woody biomass yields of 80 dry metric tons per hectare at age 3.0 years. (N.D. Vietmeyer)



Halting shifting cultivation. Because it is a legume, leucaena's roots carry nitrogen-fixing bacteria that symbiotically provide it with nitrogenous compounds that fertilize its growth, make it adaptable to many barren sites, and benefit the soils in which it grows. On the island of Cebu in the Philippines upland farmers plant leucaena to regenerate worn-out soils. For at least 60 years they have rotated their crops among leucaena-enriched blocks, thereby producing abundant crops without cutting down new forest. (World Neighbors)

the Philippines have shown that leucaena foliage placed around corn can boost corn yields with increases similar to those achieved with manure or inorganic fertilizer.*

Leucaena's aggressive taproot system helps break up compacted subsoil layers, both improving the penetration of moisture into the soil and decreasing surface runoff. Moreover, nutrients are drawn from deep strata by the roots and deposited on the surface through decay of fallen leaves and twigs. As a result, under a stand of leucaena soil organisms increase and topsoil humus rebuilds.

Leucaena's ability to restore soil fertility could be particularly important in slash-and-burn cultivation, since a crop of leucaena greatly reduces the fallow period needed between crops (chapter 6).

*Information from J. L. Brewbaker.

Shelterbelt. Leucaena is a versatile species with particular promise in tropical villages because it provides an array of uses: shade, shelter, forage, wood, fuel, soil improvement, and sometimes food. (Taken near Pune, India, N.D. Vietmeyer)

Other Uses

In some rural areas of Central America and Southeast Asia, people eat young leucaena leaves and seeds. Few problems occur, but the potential for mimosine toxicity makes the practice risky. In Indonesia, a food called tempe lamtoro is made of fermented leucaena seeds. It lacks mimosine, probably owing to the combination of washing, cooking, and fermenting involved.

Throughout the Pacific Basin beadlike decorations are made from leucaena seeds. In Mexico red, brown, and black dyes are extracted from the pods, leaves, and bark. In much of the tropics an overstory of leucaena is used to shield plantation crops such as cacao, coffee, and cinchona from excessive sunlight. Leucaena trees are also used as windbreaks, hedges, shade trees around homes, supports for vanilla and other viny crops, and as roadside ornamentals (chapter 7).

Limitations

In addition to its mimosine toxicity, leucaena has some special limitations and requirements.

Because the plant is killed by heavy frost, its use is restricted mainly to frost-free areas. It is also limited to low elevations. In Hawaii, for instance, its growth rate is slowed at elevations higher than 500 m. In countries closer to the equator the altitude at which growth is slowed is much higher, but leucaena is nonetheless a tree for lowlands.

Although the plant survives and may outperform most trees in marginal soils and environments, its exceptional yields occur mainly in areas where soils are reasonably fertile and well-drained and rainfall and temperature are adequate.

On certain soils leucaena grows poorly. Its main potential appears to be for areas with near-neutral or alkaline soils. For example, it displays weak growth in the vast areas of the tropics that have acidic, calcium-poor oxisols with a pH below 5 and high levels of exchangeable aluminum.

Like other crops, leucaena requires a reasonable mineral balance in the soil. Calcium, phosphorus, sulfur, potassium, and magnesium are particularly important. Even under favorable conditions, continuous browsing or excessive removal of foliage depletes the soil of such vital nutrients; fertilization is then required.

Leucaena seedlings grow slowly at first and this complicates plan-

Soil Enrichment. In the Visayas region of the Philippines corn yields average only 0.66 tons per hectare—the lowest in the Philippines. Now government incentives help farmers to interplant leucaena with corn. The leucaena hedgerows, placed 2–3 m apart, help control erosion, provide green manure, and increase crop yields. Reportedly, after at least 2 years, corn yields in the area have risen to an average of 1.3 tons per hectare. (M.D. Benge)

Fuel. Firewood from leucaena has long been used for cooking. The dense wood burns well, producing much heat and little smoke or ash. It has been estimated that at least half the wood cut in the world is used as fuel for cooking and heating. Filling the vast and growing fuelwood shortages in the tropics is one of the most important of leucaena's potentials. On good sites wood can be cut for household fuelwood from 2-year-old leucaena trees grown in dense stands of 20,000 plants per hectare. (N.D. Vietmeyer)

tation establishment. Aggressive weeds, termites, ants, rodents, or adverse climatic conditions can lead to total planting failure. Further, browsing animals may prove so fond of leucaena that it cannot be established without careful fencing or protection during the first year.

In locations where the common leucaenas are not harvested regularly their free-seeding nature results in thickets or dense, weedy tangles that make the plants a nuisance. This has occurred in Hawaii and Guam, where common leucaena grows unchecked because charcoal is no longer used for cooking. Only the giant- and Peru-type varieties should be introduced to new areas, because they produce fewer seeds and are therefore less weedy.

On steep, unstable slopes large blocks of leucaena are not recommended because the bare soil beneath the trees can encourage sheet erosion.

Other Leucaena Species

Of the 10 *Leucaena* species, only *L. leucocephala* has been widely distributed and evaluated. Today, interest in other *Leucaena* species is rising. *Leucaena diversifolia* and *L. shannoni* show promise on acid soils. *L. pulverulenta* offers drought tolerance and lower mimosine content as well as frost tolerance and very hard wood. Both *L. diversifolia* and *L. esculenta* seem promising for use at higher elevations than *L. leucocephala*.

These and other varieties also can serve as fuelwood and fodder trees, and most of them are able to produce hybrids with *L. leucocephala*. Such hybrids may in future be used for increasing the range and productivity of leucaena itself (chapter 9).

2 Experiences with Leucaena

The widespread testing and use of leucaena throughout the tropics and subtropics in recent years are shown pictorially in this chapter.

The first pictures show leucaena's rapid rate of growth in various trials on favorable sites. The later ones demonstrate the innovative uses of leucaena that various researchers and villagers are developing.

Lubumbashi, Zaire. Growth after three rainy seasons. (Variety, K8; height 9m, diameter 21 cm, altitude 1,200 m.) (C. Brasseur)

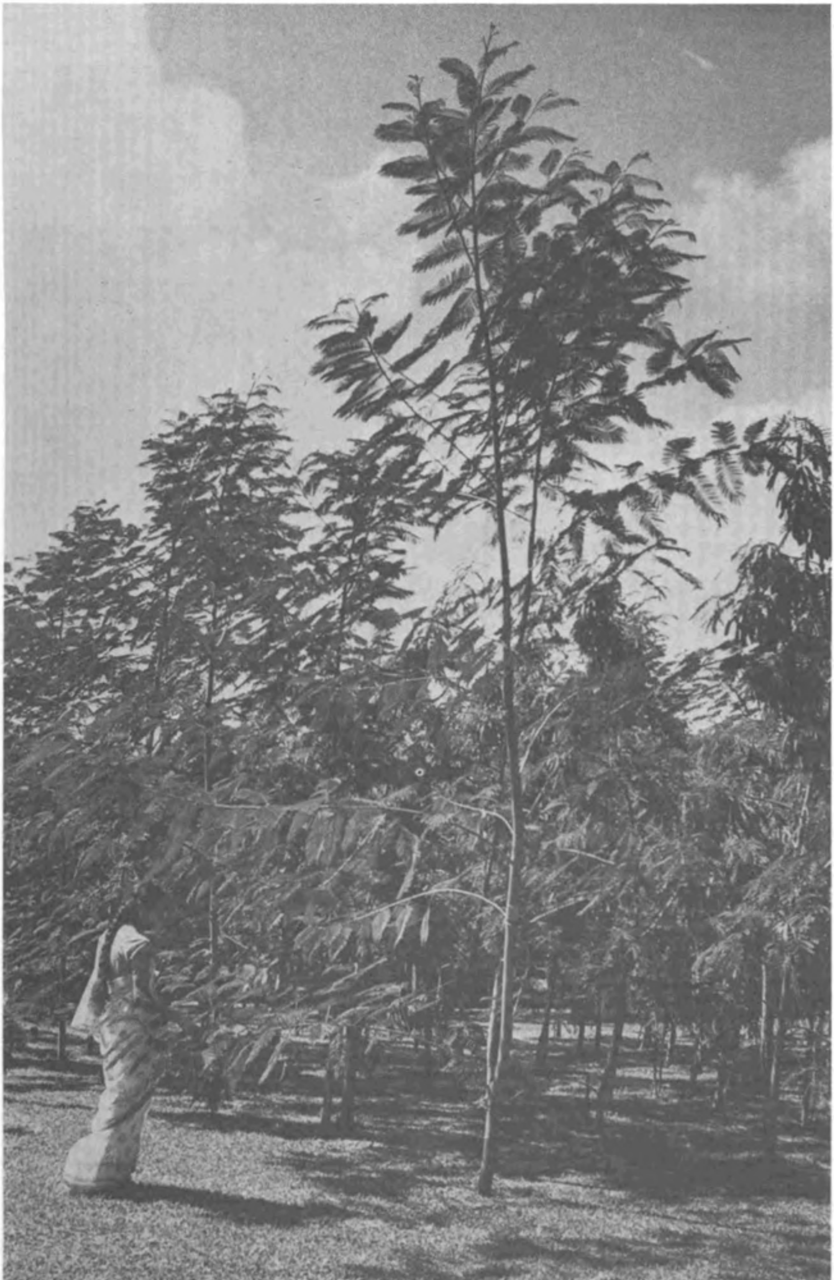
Port-au-Prince, Haiti. Three years' growth. (Inter-American Development Foundation)

Waimanalo, Hawaii. Three years' growth. (J.L. Brewbaker)

Urulikanchan, near Pune, India. Four-and-a-half years of growth (see also pictures pages 7, 20, and 21). Thin, rocky soil. (N.D. Vietmeyer)

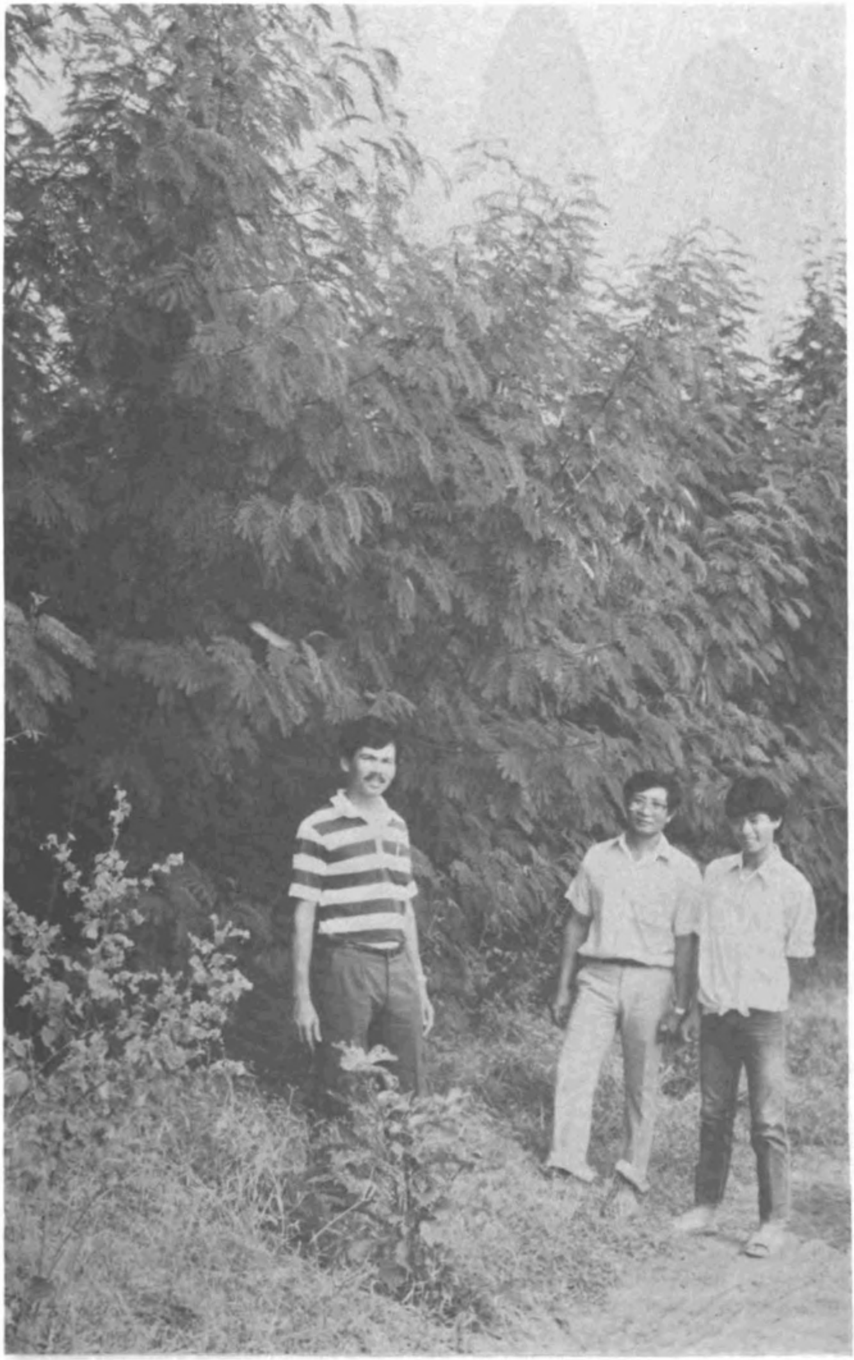
Kerala, South India. Approximately one year's growth. Height 5–6.5 m. (B.M. Gregorius, Archbishop of Trivandrum)

East Java, Indonesia. One-and-a-half years' growth, near Trewas. Height 8 m, diameter 9 cm. (D.I. Nicholson)



Reduit, Mauritius. One year's growth. The trees were given a small amount of fertilizer at time of planting, and with no further care they reached a height of 5.5 m in 9 months. This area receives 1,500 mm annual rainfall. (A.M. Osman)

Near Bangkok, Thailand. Three months' growth. (N.D. Vietmeyer)



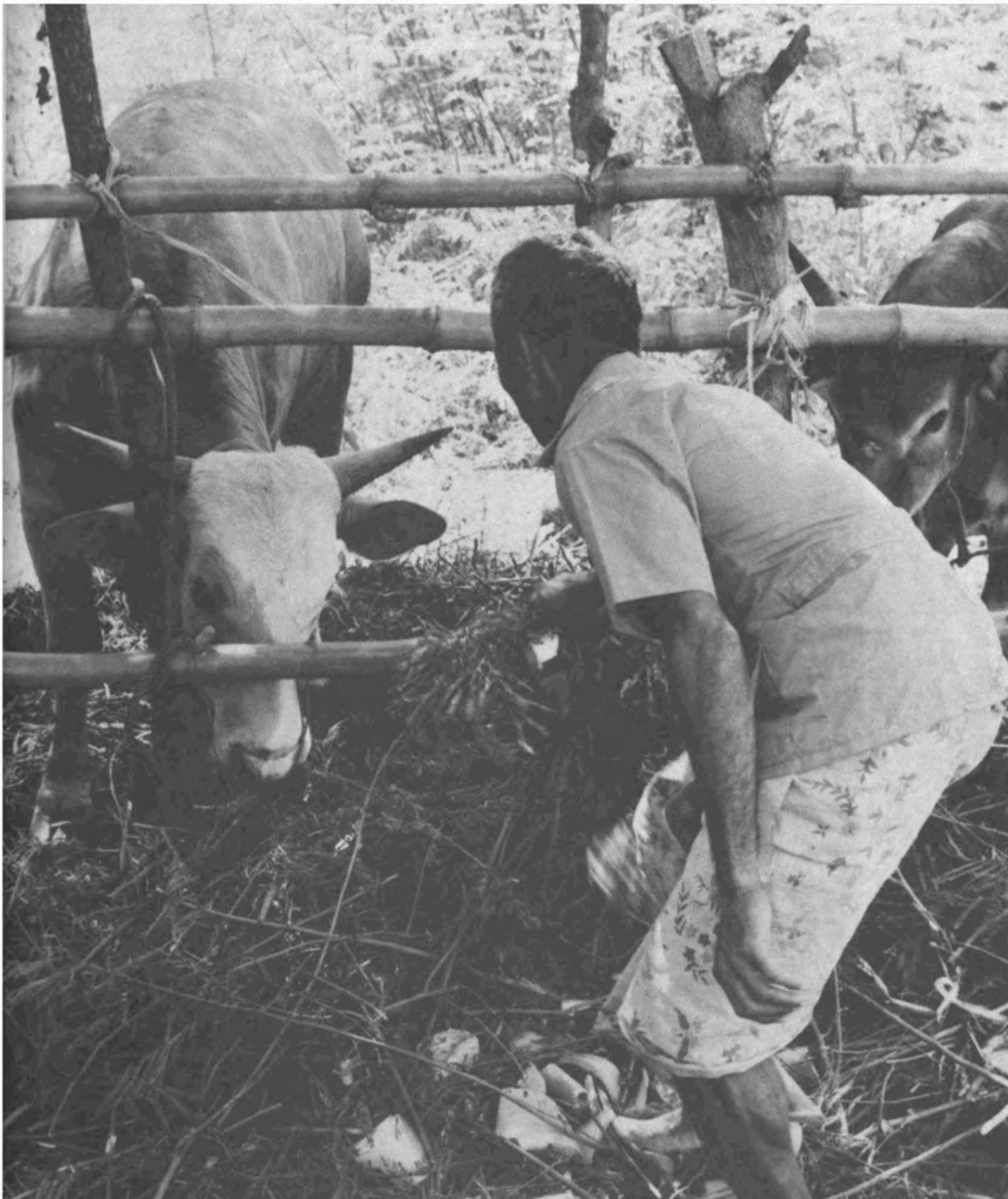
Chiang Mai, Thailand. One year's growth. (C.S. Kauffman)

Near Pune, India. Forest cloaks the rocky, marginal land (see also page 14). Leucaena stands 10–15 m tall over the sparse soil of the Deccan. In this area the trees reach 9.5–10 m in height in 2 years, and the Bharatiya Agro-Industries Foundation (BAIF) has planted more than 100 hectares of leucaena. This has created a green, shady, and attractive forest. Inside, beekeeping is thriving, and a continuous stream of villagers passes through, buying sticks and stumps for firewood, leaves for forage, or billets for lumber. What was bare land is now a productive forest. In addition, BAIF has provided 400,000 seedlings to schoolchildren of the neighborhood and has sold about 40 tons of seed to the Indian government and to state forestry services. As a result, leucaena is now being planted all over India . . .

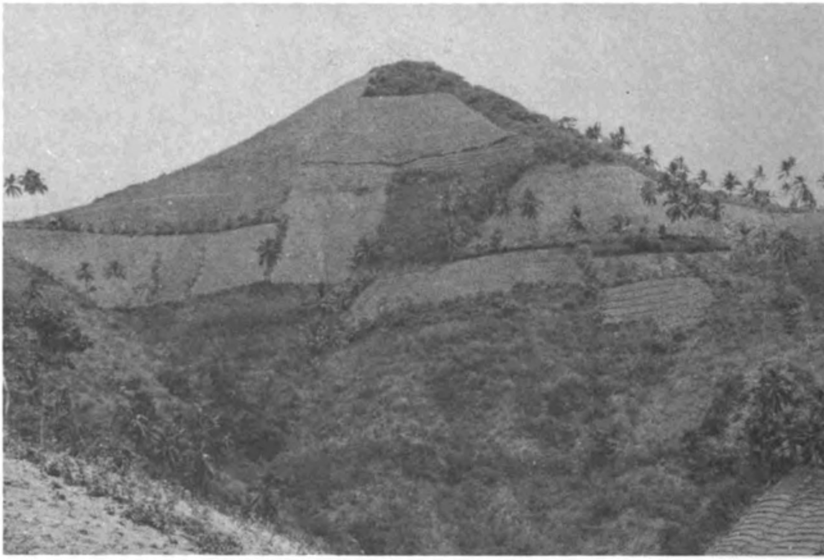
. . . Each day for several years BAIF has fed 3 tons of foliage to about 300 adult cattle and 350 calves—25–30 percent of the daily rations. Most plants are harvested every 40 days in the rainy season (within which time the shoots have grown 1 m or more as shown here), producing 70–85 tons of forage per hectare per year. (N.D. Vietmeyer and N. Hegde)

Sikka, Indonesia. On the island of Flores, as in many parts of Indonesia, slash-and-burn cultivation has been the predominant method of farming the steep hillsides. The idea of planting leucaena hedgerows to maintain soil fertility was introduced on a small scale as a food-for-work program following a drought. As crop yield increased, and as more forage and wood became available, the value of this farming system became evident. The farmers then requested that the program be continued and even expanded. Now more than 20,000 hectares of Flores farmland are lined with leucaena hedgerows, and the trend to denuding more natural forest is decreasing . . .

. . . Villagers have also developed a unique agroforestry system. Leucaena trees are girdled by cutting a 20 cm wide ring of bark from the tree 1.5 m above the ground. Then, upland rice, corn, and other food crops are planted. The leucaena leaves wither and fall within a short time; therefore, the trees provide soil nutrients and do not shade the food crops during the growing season. New growth emerges below the girdle and a single strong sprout is allowed to form a new tree. The dead part of the stem above the girdle is harvested for fuel or stakes. (M.D. Benge and K.A. Prussner)



Amarasi, West Timor. Originally planted in Amarasi in the 1930s, leucaena has provided the basis for smallholder raising and fattening of banteng (which look like cattle but are a different species; see companion report *Little-Known Asian Animals with a Promising Economic Future*). The successful establishment and use of leucaena in this single district has sparked what can only be called a "leucaena revolution." All over Timor several varieties of the plant are now being used extensively by villagers for erosion control and reforestation. In addition, a cut-and-carry system of feeding leucaena to livestock has developed. All of this is the basis of a radical transformation that is converting shifting agriculture to more permanent forms of cultivation. (J.J. Fox)



Barrio Naalad, Philippines. For more than 60 years innovative farmers on the island of Cebu have used leucaena for erosion control, soil reclamation, and as a fallow crop on their extremely steep, rocky hillsides. Some of the leaves are harvested, dried, and sold as leaf meal to local feed millers; others, mixed with coconut and banana leaves, are fed to household goats. After 3–6 years the blocks fallowed with leucaena are cleared (large pieces of the wood are sold for fuel), while an equal number of worn-out blocks are seeded with leucaena and left fallow . . .

. . . Along the contour of the steepest slopes the farmers drive leucaena stakes into the ground, pile branches behind them, and scrape soil against the barrier so formed. This provides a level land (usually a terrace only 0.5–1.5 m wide) in which tobacco and food crops are planted. This innovative use of leucaena creates arable land out of slopes as steep as 70° that are otherwise too erodable or too dangerous to work in. (See also picture page 6.) (M.D. Benge)

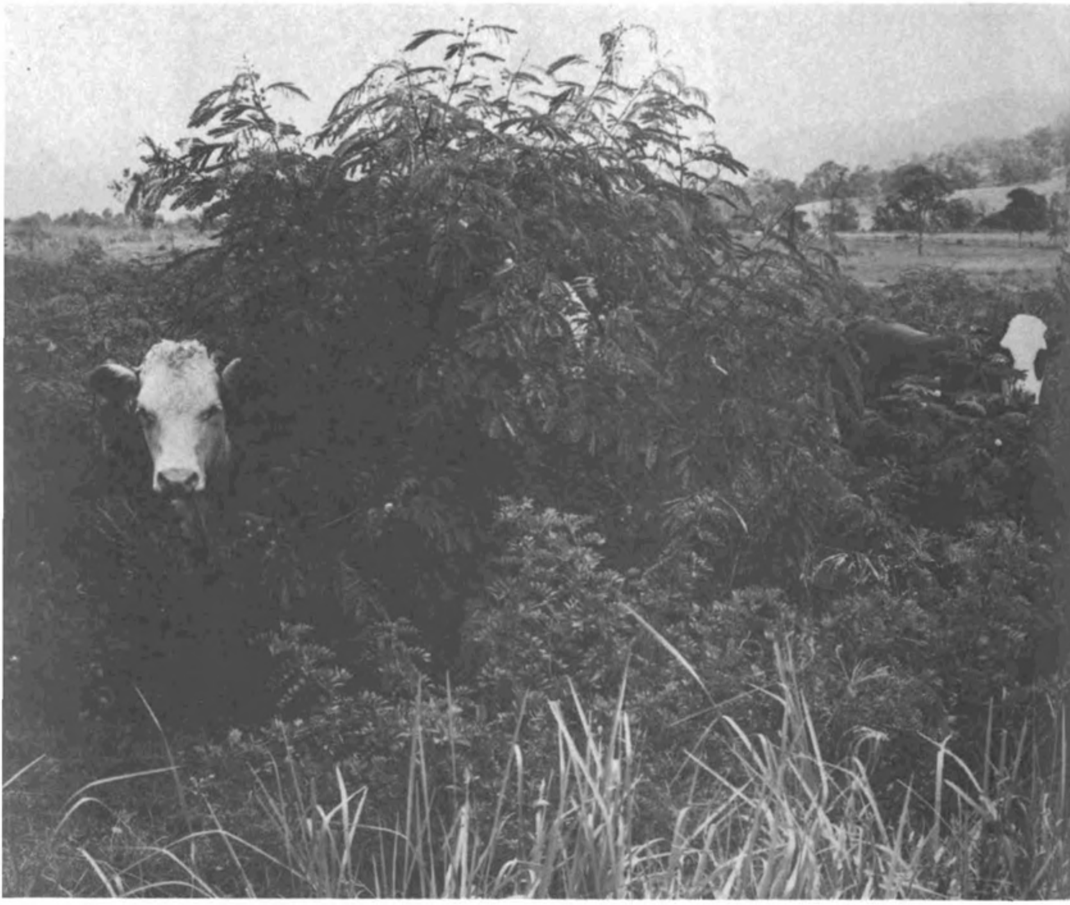
Bolinao, Philippines. This power plant, soon after construction, is part of a $350 million electrification project that is based on burning leucaena trees to generate electricity. This scheme offers an attractive model for many countries and points the way towards reversing the destruction of the earth's forest cover. Leucaena, known locally as ipil-ipil, is the dominant species grown in the several plantations that have been established so far. During the next 5 years, the Philippines proposes to erect more leucaena-fired power stations. It is said that each could potentially supply 15,000 rural homes with electricity at an annual saving of more than 26,000 barrels of crude oil. The project is formulated to help slash-and-burn farmers. Each is provided a loan for housing and initial living expenses and is encouraged to join farming cooperatives that sell wood to the power plants. These, in turn, will eventually be handed over to the cooperatives under contraact to sell excess energy to the national grid. (V. Denton)

Taipei, Taiwan. In 1975 the Forestry Research Institute introduced the giant leucaena from the University of Hawaii and conducted acclimatization experiments. Because of the excellent adaptability and surprising annual growth rate, these new varieties have attracted the attention of Taiwan's pulp and paper industry. Since then, some 10,000 hectares of leucaena have been successfully planted. (K.H.K. Chen)

Sete Lagoas, Brazil. South America has 800 million hectares of tropical acid soils (oxisols and ultisols) whose pH is 5.5 or less and whose subsoils are high in aluminum and low in calcium. These acid soils comprise 68 percent (573 million hectares) of the whole country of Brazil, for example. Nitrogen-fixing trees are needed for such areas, not only for the wood and forage they provide, but because they raise soil organic matter, nitrogen content, and general fertility. Near Brasilia, leucaena is being selected to grow in a dark red latosol typical of the extensive acid areas of central Brazil. The soil and environmental conditions place considerable stress on the leucaena populations, and it is hoped that the selections and hybrids being made will be adapted to most of the acid soil areas found elsewhere in the tropics. Picture shows leucaena (Cunningham variety) planted in acid soil (pH 5.5). (E.M. Hutton)

Addis Ababa, Ethiopia. The International Livestock Center for Africa (ILCA) has developed a fence woven from living leucaena. "Leuca-fence" is made by spacing leucaena seedlings 5–15 cm apart. After approximately 1 year (when the stems are 1–3 cm diameter at waist height), about two-thirds of the saplings are topped at a height of 1–1.5 m above ground level. Strong branches are bent and woven horizontally through the vertical stems. These "rails" are overlapped for added strength. To weave the second, third, and fourth rails, the stems are notched with a cutlass, bent over to about 20 cm above the previous rail, and again woven horizontally. The majority of trees remain alive, making a permanent, durable, living fence (left). Leaves and shoots that regrow from the fence can be grazed by animals, while the upper branches can be periodically cut and used for forage, stakes, or firewood. Leuca-fence has been successfully tested at Ibadan, Nigeria. There, West African dwarf sheep were fitted with triangular neck yokes to prevent these very small animals from wriggling through (right). (Sumberg, J.E. 1983. Leuca-fence: Living fence for sheep using *Leucaena leucocephala*. World Animal Review 47:49)

Ibadan, Nigeria. The International Institute of Tropical Agriculture (IITA) has for several years developed a method for planting giant leucaena as an intercrop with corn, yams, and rice. It is referred to as "alley cropping." In the growing season the trees are kept cut and pruned so they do not shade the nearby crops. The resulting leaves and twigs are used as a nitrogen-rich mulch, the larger branches for poles or fuel. In the dry season the trees are allowed to regrow and draw nutrients from deep soil levels. The benefits build up over time. On an infertile, sandy soil at IITA, alley cropping has given corn yields of more than 3–5 tons per hectare in the second season, without added fertilizer. This is four times Africa's average corn yield. IITA researchers believe that alley cropping could solve the agricultural quandary of the tropics: how to get continuous yields of food and fuel from the same plot of ground using only hand tools and without other inputs or degrading the soil. (IITA)



Samford, Queensland, Australia. As the result of intensive research, Australian researchers seem well on the way to making the heavy use of leucaena as forage a safe and well-understood procedure for all regions where leucaena will grow. The amino acid mimosine, which is found in leucaena, breaks down in the digestive systems of grazing animals to a toxic compound called DHP, which may affect thyroid glands and cause animals to lose hair and to grow slowly. In 1982, however, Australian researchers discovered a microbe that detoxifies DHP in the animal's stomach. Studies had shown that whereas Australian goats excrete large amounts of DHP after grazing leucaena, Indonesian and Hawaiian goats excreted almost none in their urine. Microbes cultured from the stomach fluid of goats from Hawaii were taken to Australia, and a steer that had been fed entirely on a diet of pure fresh leucaena for one week to produce toxic symptoms was dosed with it. The symptoms rapidly disappeared, indicating that the microbes can be introduced to Australian herds to overcome the mimosine and DHP problems that formerly inhibited the widespread use of leucaena in improved pastures there. It is believed that most countries outside the South Pacific already have the beneficial microbes. (T.H. Stobbs)

3 The Plant

Leucaena is a genus of Central American shrubs and trees with 10 recognized species.* Although all species probably have value for the tropics, only *Leucaena leucocephala* (Lam.) de Wit has been exploited extensively so far.

Leucaena leucocephala has been recorded in the literature under several other botanic names.† Its most universal common name is "leucaena," but many countries use local names.‡

Genetics

The nomenclature of *Leucaena leucocephala* is confused. Because the tree's many varieties differ enormously in size and form, some have incorrectly been given individual scientific names. There are more than 800 known varieties,§ which are classified broadly into three types:

• Common type‖: short, bushy varieties to 5 m in height that flower when very young (4–6 months old). This type is from coastal Mexico and is now spread widely throughout the tropics. It flowers year-round, since seasonal daylength changes are not needed to initiate flowering. The continuous flowering produces abundant seeds, and

*Botanical literature of the past 2 centuries contains claims for 55 species, but the only valid ones appear to be *L. collinsii, L. diversifolia, L. esculenta, L. lanceolata, L. leucocephala, L. macrophylla, L. pulverulenta, L. retusa, L. shannoni,* and *L. trichodes*. The remainder are suspected to be synonyms for these. (More detail is given in Brewbaker, 1983.)

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

‡Including ipil-ipil and giant ipil-ipil (Philippines); yin hur hwan (Taiwan); lamtoro (Indonesia); guaje, yaje, and uaxin (Latin America); koa haole (Hawaii); tangantangan (Guam); horse tamarind, white popinac, and leadtree (in various former British colonies); kubabul and subabul (India); and tan-tan and jumbey throughout the Caribbean.

§Brewbaker, Plucknett, and Gonzales. 1972. Hutton and Gray, 1959.

‖In the first edition of this book this was called the "Hawaiian type." It is the variety the Spanish originally collected near Acapulco (see chapter 1).

Leucaena (*Leucaena leucocephala*). (Drawing by Avery Ahana Youn, supplied by D.L. Plucknett)

this leucaena can become an aggressive weed. Its yield of wood and foliage is low. It was used in the past to revegetate tropical hillslopes, provide firewood and charcoal, and shade plantation crops. In most cases its use should be discontinued in favor of the varieties discussed below.

- Giant type*: tall, treelike plants to 20 m in height with large leaves,

*In the first edition of this book this was called the "Salvador type."

pods, and seeds, and thick, almost branchless trunks. The "giants" flower seasonally, usually twice a year, and are poor seeders. Originally from the inland forests of Central America and Mexico, they have been studied only in the last two decades. They often produce more than twice the biomass of the common type. Some extremely high yielding giant cultivars now being planted for timber, wood products, and industrial fuel (see chapters 5 and 6) are known as "Hawaiian giants" or by James Brewbaker's designators, K8, K28, K67, etc.

- Peru type: medium-sized trees to 10 m, but with extensive branching even low on the trunk. They produce little trunk, but very high quantities of foliage. The Peru type is promising for forage. Nevertheless, if giant types are cut back to induce branching, their forage yield is often as great, and Australian research has produced hybrids between Peru and giant that are also promising forage types.

The genetic diversity of leucaena offers the plant breeder much promise for enhancing desirable characteristics. It has already been observed that the arboreal habit is dominant over the shrubby one.

Foliage and Roots

Leucaena is an evergreen. However, in hurricane-strength winds, frosts, or prolonged drought it sheds its tiny leaflets and rides out the adversity bare of foliage. Both leaves and leaflets fold up in response to moisture stress (for instance, during the hottest part of the day), cool temperatures, or darkness.

While still small, leucaena develops a substantial taproot to reach water before the young plant is caught by drought. Seedlings often have a taproot almost as long as the plant is tall. Lateral roots are usually sparse on adult plants, and in fertile soils they often grow downward at a sharp angle.

Small horizontal laterals that occur near the soil surface usually carry nitrogen-fixing *Rhizobium* nodules, 2–15 mm in diameter. They are occasionally multilobed and are bright pink inside. Present indications are that annual nitrogen fixation by leucaena is often in the range of 100–200 kg nitrogen per hectare.*

In principle, nitrogen fixation occurs only if the correct *Rhizobium* strain is present in the soil. But the strain that leucaena uses is not specific to the plant. Seed inoculation, therefore, is normally not needed, even in areas where leucaena is unknown—especially if other

*Information from J. Halliday. This is equivalent to 500–1,000 kg ammonium sulfate per hectare per annum.

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)

leguminous trees, such as species of *Mimosa*, *Sesbania*, *Gliricidia*, and *Calliandra*, grow in the area.

Specific *Rhizobium* strains are now available for testing under special soil conditions; for example, CB 81 and CIAT 1967 are available for use in acid soils and NGR 8 or NGR 35 for use in alkaline soils.

In addition to *Rhizobium*, the fine roots and root hairs are also usually infected with a beneficial mycorrhizal fungus. Its vast network of hyphae aids the plant in obtaining and making more efficient use of mineral nutrients. This helps leucaena to grow in soils low in minerals such as phosphorus.

Reproduction and Growth

Leucaena's flowers are small, fluffy, white balls. They are usually self-pollinated and produce thin, flat, almost straight pods that hang like fingers in drooping clusters. Translucent and green when young, the pods redden and harden with age, eventually splitting along both edges to eject their 15–30 seeds. The flat, shiny brown, teardrop shaped seeds have an impervious, waxy coat and must be treated to ensure quick and uniform germination.*

Seed viability is high, and as long as weeds, ants, and rodents are kept in check the seeds can be successfully planted by hand or by machine. Such direct seeding is the cheapest method for establishing leucaena.

Sowing should be done when soil is moist, normally at the beginning of the rainy season. Giant leucaena varieties usually have larger seeds (about 20,000 seeds per kg) than the common type. A normal seeding rate is about 5 kg per ha. Seeds should not be planted deeper than 1–2 cm. Germination occurs in 6–8 days.

Although leucaena seedlings eventually grow quickly, they are often slow starters. They can be smothered early in life by fast-growing weeds. This complicates establishment and often causes total failure of the planting. The seeds can be sown into furrows by hand, by seed drills, or by hand jabbers. In impoverished soils, fertilizers such as simple superphosphate (which provides phosphorus, sulfur, and calcium), potash (potassium), or dolomite (calcium and magnesium) are needed to promote adequate growth in 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 forest, free of weeds and often free of leucaena seedlings. If both giant and common types grow together, the taller giants exert a "birth control" over the shorter common type, shading it until eventually it dies out.

Characteristically, on the periphery of dense stands the plants lean outward, and as the seeds drop, germinate, and grow, the forest expands.

Leucaena coppices readily. Stumps from plants of almost any age and variety quickly resprout new shoots. Coppice regrowth is even more vigorous than seedling growth because the new shoots are served by a developed root system. New shoots of giant varieties have reached 6 m in 12 months.†

This coppicing ability allows rapid and repeated harvests of firewood, timber, or forage. In Hawaii, some hedges have been trimmed at least twice a year for more than 40 years. In Indonesia and the Philippines,

*A method that gives 80 percent germination within 5 days involves treating the seeds with hot (80°C) water for 3–4 minutes. The seed may then either be sown or sun dried and stored for later sowing.

Treating seeds with concentrated sulfuric acid for 15–20 minutes also ensures a high germination, and it kills fungi and other pathogens on the seed. This treatment can be followed by sticking rhizobium in peat on the seeds with gum arabic and then pelleting the seed with rock phosphate. Good field establishment is obtained with this pelleted seed in soils devoid of leucaena rhizobia (information from E. M. Hutton).

†Information from J. L. Brewbaker.

Waimanalo, Hawaii. Resprouted stumps only 2.5 years old. After leucaena is cut, its stumps sprout, and because their root system is already established, they regrow new trunks even faster than the original seedlings. (J.L. Brewbaker)

leucaena trees are sometimes girdled and used as poles to support yams and other climbing plants; the coppice regrowth from below the girdling is harvested for green manure or forage. After the yams have been harvested, the dead poles are cut for firewood and the coppice regrowth is cut back to a single stem and allowed to grow a new pole for the following year's yams.

When leucaena's growth gets out of hand, the plants can be killed with standard herbicides or by painting diesel or herbicidal oils on stumps cut near ground level.

Environmental Tolerance

Leucaena's hallmark is successful growth in a wide range of environments. It withstands large variations in rainfall, sunlight, salinity, and terrain, as well as periodic inundation, fire, windstorm, slight frost, and drought. On the other hand, it is restricted to the tropics and subtropics, and within that huge region to elevations below about 500 m. At higher elevations the plant continues growing, but without its lowland vigor. The altitude where growth retardation becomes noticeable varies with latitude. For instance, it is lower in Hawaii than in more equatorial nations such as Indonesia and the Philippines.

Rainfall

Leucaena grows best where annual rainfall is 1,000–3,000 mm. In general, the plant survives dry seasons lasting 8 months and occasionally even 10 months. It can survive in dry areas. It is the dominant vegetation on Honolulu's Diamond Head, where annual rainfall is only 250 mm, but in such areas it may not yield well on an annual basis.

Although leucaena is a drought-tolerant plant, long dry seasons greatly reduce productivity, and irrigation may dramatically increase yields. Supplemental irrigation is especially important during seedling establishment and can mean the difference between success and failure.

Good growth is obtained throughout the year in areas with subsoil moisture that the deep roots can reach. However, long periods of rainfall and standing water normally inhibit growth. (Nevertheless, good leucaena growth has been obtained on some waterlogged soils in Thailand.)

Sunlight

When moisture, temperature, and nutrients are adequate, yields are directly related to light. Leucaena grows best in full sun; it thrives under high light intensities. Although it tolerates partial shade, it grows only slowly in heavy shade. Specimens are often completely suppressed by the shade of high forests, but they are slow to die, and in newly opened clearings they spring up aggressively.

Temperature

Heavy frost kills leucaena, but occasional light frost only defoliates it, and with returning warm temperatures the plant bursts with greenery once again. Following medium frosts that kill the above-ground parts, the trees grow back from the basal crown as a multibranched shrub.

Soil

As mentioned, leucaena's roots reach deep for nutrients and water and allow the plant to tolerate a wide array of soil conditions. Leucaena is found thriving in soils with textures varying from rock to heavy clay to coral. It frequently grows from almost vertical cliffs. It has considerable salt tolerance and often survives in exposed coastal areas, sometimes down to the high water mark.

Unaided, leucaena grows well only in neutral or alkaline soils, growing best at pH 6.0–7.7. It often displays outstanding growth on coral or limestone outcroppings.

Much of the tropics has acidic weathered soils, high in exchangeable aluminum and often deficient in phosphorus, calcium, magnesium, sulfur, molybdenum, and zinc. Since leucaena grows poorly on acidic soils, it is not a good choice for reforesting such sites.

Where surface or subsoil acidity is below pH 5.5, the tree's roots are stunted and growth is slow. Nevertheless, in areas with very acid soils (pH 4.2–5.0) farmers can grow vigorous leucaena trees on small areas by digging holes, mixing the excavated soil with dolomite and animal manure or fertilizer (preferably single superphosphate), and replacing the soil before planting the seedlings. This results in vigorous productive trees that can be cut repeatedly.*

The actual levels of mineral nutrients that leucaena requires for best growth are as yet unknown.

Weed Control

Weeds are a major cause of failure or slow establishment. Their control is essential for reliable results. Regular weeding until plants are 1–2 m tall gives best results. On large areas, the use of herbicides is an option. So far, no entirely satisfactory herbicide for all soil and climatic situations is available.

* Information from E. M. Hutton. Dolomite is essential to neutralize the effects of acidity and aluminum, and it supplies the vitally important calcium and magnesium.

Insects

The most serious insect pests attack young seedlings. Mound-building ants have caused severe damage in some regions by eating the leaves and bark of young seedlings.

Although inchworms and twig borers have been noted on the trees, few chewing insects attack mature leucaena. Newly planted seedlings, however, can be severely set back by twig borers. Scale insects attack individual trees in stands in Taiwan and can kill them in times of drought. An occasional problem on seedlings and young shoots is caused by the mealy bug *Nipaecoccus vastator*, but normally it is kept under control by predatory insects.

One widespread insect pest is a seed weevil that attacks the young pods and eats the developing seeds. However, this is usually of little economic consequence unless the trees are being grown for seed production.

Seed yield also can be greatly reduced by the larva of the moth *Ithome lassula*, which feeds on the flower heads. This pest has been reported from Australia, Florida, India, and Java, and it could be present in other areas.*

Diseases

The most serious disease attacking leucaena today is a fungal gummosis, reported in India and Sri Lanka. The causal agent is believed to be *Fusarium semitectum*. Although most giant types are resistant, some leucaena cultivars are seriously affected. Another bark canker has occurred in Hawaii and Taiwan and is caused by *Phytophthora dreschleri*.

A fungus that attacks seeds and young pods of the giant types has been found in the Philippines. Borer insects introduce this fungus into the pods, and it can be controlled with systemic insecticides. Other fungal diseases such as damping-off can occur in wet soils, especially among the densely packed seedlings in a nursery.

Camptomeris leucaenae, a leaf-spotting fungus, has caused defoliation, especially under shaded conditions, in parts of Central and South America. Although the disease rarely causes the trees to die, it can affect forage yield and quality. No control measures have yet been reported, but malnourished plants are more susceptible to attack than

*Beattie, 1981.

well-nourished ones, and the severity of the attack is reduced with adequate fertilizer applications.* Some other *Leucaena* species (*L. diversifolia* and *L. shannoni*, for instance) and their hybrid crosses with leucaena itself are resistant.†

A bacterial pod blight or rot has been found in Belize, Panama, Colombia, Brazil, and Peru.‡

Pests

Seedlings of all leucaena varieties are avidly consumed by snails, feral livestock, rats, rabbits, deer, wallabies, monkeys, and other wildlife. Sometimes much perseverance (or fencing) is needed to get a plantation through the early stages.

*Lenne, 1981.
†Information from E. M. Hutton.
‡Lenne, 1981.

4 Animal Feed

Much of the tropics suffers from acute seasonal shortages of animal feed, and the scarcity of high-protein forage and digestible nutrients is a chronic concern. Leucaena's leaves, flowers, green pods, buds, and new shoots are all eaten by livestock. Further, with controlled browsing, leucaena fields can maintain high yields and survive heavy stocking.

Nowhere is the forage shortage worse than in the seasonally dry tropics. Here leucaena pastures are particularly promising. Where dry seasons are up to 8 months long, the scraggly bushes are often among the most efficient forages. Deep roots allow the plants to remain green and productive long after shallow-rooted grasses and pasture legumes have withered. Thus, with leucaena, a pasture's carrying capacity continues longer into dry seasons than shallow-rooted forages, and when the rainy season returns leucaena recovers rapidly and pastures can be restocked earlier.

Once leucaena plants reach a height of 1 m they can be browsed. In this way they get no chance to grow into trees, and their inherent vigor and coppicing ability show up not in wood but in the masses of new foliage that appear.

Young or mature, green or dry, the foliage is eagerly sought by livestock and wildlife, particularly when green feeds are scarce. Animals can feed on the standing bushes. Alternatively, the foliage can be harvested by hand or machine and carried to the animals, dried into a leaf meal, or fermented to silage.

Animals also eat the bark and often strip soft stems down to the bare white trunk. Luckily, leucaena is not thorny, and its strong, pliable stems do not snap easily when animals bend or trample them.

Leucaena pastures continue producing year after year, especially when soils are good. However, like any other crop, leucaena requires replacement of soil nutrients that are removed in order to sustain yields over long periods of time.

Forage Yield

Leucaena yields compare favorably with those of the finest forage legumes. For example, under favorable conditions, alfalfa (lucerne)

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

produces 8–9 tons of dry matter per hectare, and under dry-land conditions it averages 2–3 tons. By comparison, leucaena's annual yields of edible dry matter (leaves and fine stems) per hectare are generally between 6 and 18 tons, dry weight (20–80 tons, fresh weight).* The giant varieties tend to produce the most forage under infrequent cuttings (every 8–12 weeks, for example); the Peru type may be equally or more productive under more frequent harvests (4–6 weeks).

*These yields are based on results reported by Takahashi and Ripperton, 1949; Kinch and Ripperton, 1962; Brewbaker, Plucknett, and Gonzalez, 1972; Guevarra, 1976; and Brewbaker, personal communication (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.

Leucaena is suited mainly to ruminant species such as cattle, water buffalo, and goats. (World Neighbors)

In the dry tropics, leucaena yields are reduced because the plants are stressed during the dry season. However, forage can be increased by irrigation or by allowing giant leucaena varieties to reach at least 10 cm in diameter (at approximately 1.5 years of age) before introducing animals to the pastures. Such trees develop taproots that often reach the water table, thereby allowing them to obtain adequate water during dry seasons.

Nutritive Value

Leucaena foliage (leaflets plus stems) contains both nutrients and roughage and makes a ruminant feed roughly comparable to alfalfa forage.

When dried, the leaflets readily fall off, providing a feed that is 25–30 percent protein, even after correcting for mimosine nitrogen.* In

*The amino acid mimosine is considered protein, so leucaena's protein content is normally overestimated by several percentage units, depending on the variety and stage of growth.

Not only is leucaena useful in pastures where livestock 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 Illocos Sur, the Philippines, a farmer hauls leucaena home to a dairy cow. (F.A. Moog)

Malawi, Thailand, and the Philippines, leaflets are sun dried both for local forage and for export to Europe, Japan, and Singapore. It has been found that dried leaves can be compressed into feed pellets without milling and without adding water, molasses, or other binders.

Leucaena's protein is of high nutritional quality. Its amino acids are well balanced, much as in alfalfa. The leaves are also a rich source of carotene and vitamins. Their provitamin A content, among the highest ever recorded in plant specimens, yellows the fat of leucaena-fed cattle, which consumers consider undesirable in some countries. This does not happen with goats, and in chickens fed leucaena the yellowing of the skins and egg yolks is a desirable characteristic.

Depending on the soil minerals available to the root system, leucaena foliage can be an exceptional source of calcium, phosphorus, and other dietary mineral nutrients. However, it is generally deficient in sodium (0.01–0.03 percent of the dry matter), and some plant material grown in Australia has been found low in iodine.*

*R. J. Jones, 1979.

The *in vivo* digestibility of leucaena leaves and stems is similar to that of other legumes (50–70 percent). The leaflets alone are about 70 percent digestible.

Management

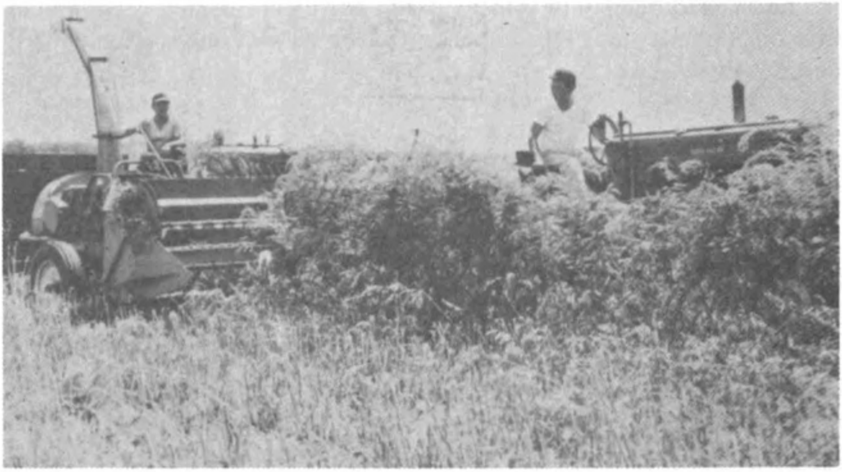
Leucaena can be grown for forage in uncultivated stands scattered across pastures, in intensively cultivated pastures, in hedges along property lines and roadsides, or in blocks that increase grassland productivity by acting as "protein banks." The best forage production appears to be at densities of 75,000–140,000 plants per hectare. Row spacing can be 75 cm for hedgerow or manual harvest methods, but must be wider when harvesting is mechanized and when grasses are interplanted.

The plants can be harvested using machinery developed for crops such as alfalfa. The herbage can be fed fresh, sun dried, or as the dehydrated product of a commercial forage dryer. With this adaptability, leucaena can meet the needs of small farmers both in rural areas and on the periphery of cities, as well as the needs of feedlot operations and tropical rangeland ranches.

It is advantageous to incorporate grass into leucaena diets, either by rotating the animals between leucaena and grass pastures or by interspersing leucaena among fast-growing pasture grasses—a combination that makes a highly productive two-level pasture. Leucaena's growth is compatible with the most vigorous of grasses, such as pangola (*Digitaria decumbens*), brachiaria (*Brachiaria decumbens*), and guinea grass (*Panicum maximum*). Under heavy grazing the combination remains well balanced, so that neither the leucaena nor the grass dominates. In Malaysia, leucaena/*Brachiaria brizantha* pastures have remained in balance for 3 years; in northern Australia, experimental leucaena/pangola grass pastures have retained balanced proportions over 4 years; and in southeast Queensland, Australia, pastures combining leucaena and Rhodes grass (*Chloris gayana*) have been grazed for more than 20 years and have retained a good balance.

Supplementing chopped sugarcane with chopped leucaena (about 20 percent) gives good live-weight gains in weaner cattle and good milk yields in dairy cows.* Steers fed chopped sugarcane supplemented with leucaena have gained 0.6 kg per day.†

*Information from R. Preston. See also Siebert, Hunter, and Jones, 1976.
†Siebert, Hunter, and Jones, 1976.



Waimanalo, Hawaii. Although leucaena grows naturally as a tree or shrub, young plants can be mowed close to the ground as if it were pasture forage like alfalfa or clover . . .

. . . After mowing, the plant's inherent vigor shows up in a massive production of shoots and leaves. Each year three or four harvests can be obtained this way. (Reprinted from Kinch and Ripperton, 1962. See Selected Readings.)

Direct seeding is the recommended way of planting forage. Transplanting seedlings is worthwhile only under adverse conditions because the large numbers of seedlings needed for forage plantings becomes expensive. However, in very poor soils or under high moisture stress, transplanting may be wise.

Both overgrazing, which cuts forage yield, and undergrazing, which lets plants grow too tall for cattle to reach, must be guarded against. However, if the trees get too high they can be easily chopped back. Cattle and goats will bend branches over with their bodies to feed on topmost foliage.

Feeding Cattle

Cattle may be slow to accept leucaena when first introduced to it. However, they soon browse it in preference to grass, which often results in complete defoliation. Although this does not harm the plants, it is important to give them a chance to recover, by removing the animals.

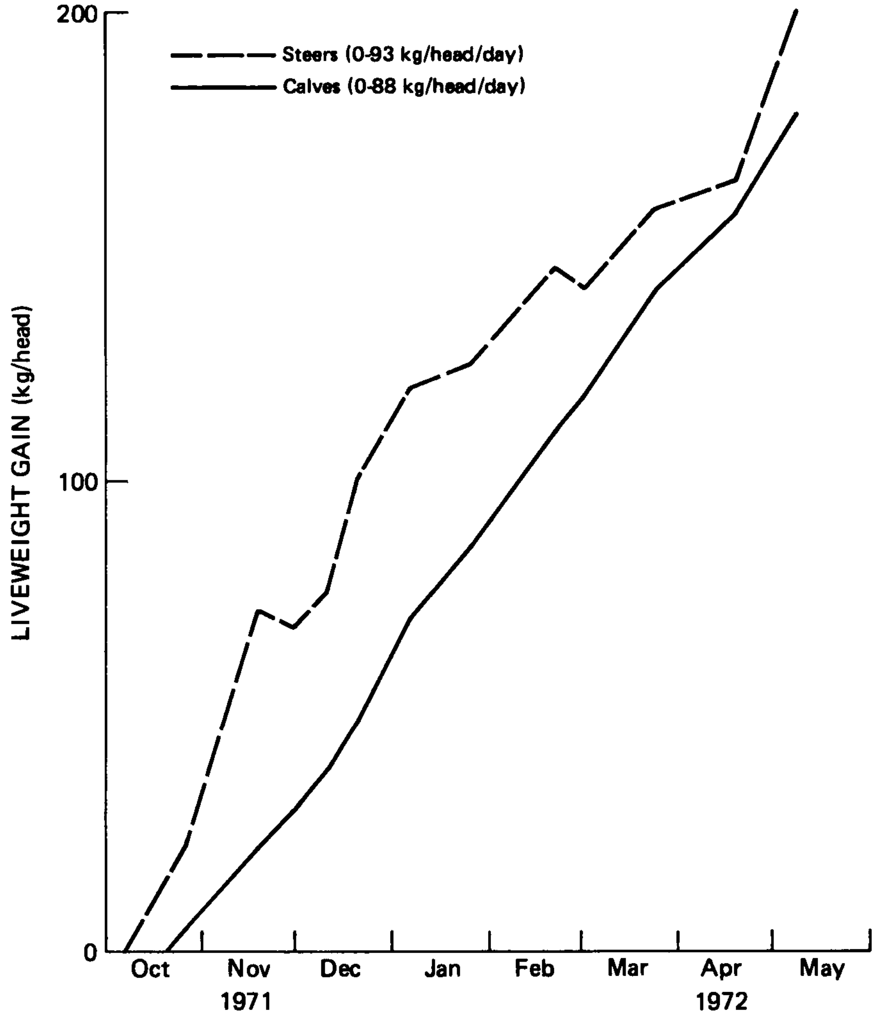
With their vigorous growth and high nutritive value, leucaena pastures can support heavy stocking. They have demonstrated some of the highest animal productivities of any tropical pasture. Interplanted with guinea grass, leucaena pastures often carry up to 2.5 cattle per hectare. In favorable locations, leucaena/grass pastures (1:1 ratio) can support six or more steers per hectare.

Live-weight gains in cattle feeding on leucaena-based pasture can be high. Where rainfall is good (1,100–1,200 mm), annual gains of 300–400 kg per hectare have been achieved. Under irrigated conditions, annual gains on leucaena/pangola pastures have reached 830 kg. Extremely high live-weight gains have been recorded in southeast Queensland over short periods. Young steers grazing a leucaena/nandi setaria pasture near Brisbane gained up to 1 kg per day during the main summer season.*

Leucaena-fed cows produce an attractive milk, slightly yellowed by carotene. Milk yields recorded on leucaena pastures are often higher than those achieved on other legume-based tropical pastures. Leucaena taints the milk, but any undesirable odor can be removed by pasteurization or avoided entirely by taking the cows off leucaena pastures 2 hours before milking.

In northern Australia, annual milk production can be 5,000–6,000 liters per hectare.† On the island of Kauai in Hawaii, the Mahelona

*Information from R. J. Jones.
†Information from the late T. H. Stobbs.



Samford, Queensland, Australia. Steers and calves have shown exceptional liveweight gains on a mixed pasture of leucaena and nandi setaria grass. 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 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, owing to cooler weather, the pasture could not maintain its optimum productivity. A mineral supplement was used to complement the diet. (Information supplied by R.J. Jones.)

Cebu City, Philippines. A shipload of leucaena meal at the General Milling Company's dock. Several Philippine feed mills have become large buyers of leucaena leaf meal for use in animal feeds. Thousands of families of 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 feed mills. The meal, used in local poultry rations, is also exported to Japan. (R. Savory)

Dairy stocked cows on leucaena/guinea grass pasture (1:1 ratio) for 12 years. At six animals per hectare, the dairy each year obtained more than 9,700 liters of milk and 400 kg of liveweight gain per hectare.*

Mimosine

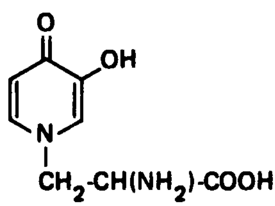
Leucaena contains the amino acid mimosine, a chemical known to cause hair loss and affect fetal development in nonruminants. In the leucaena types now available, mimosine comprises 3–5 percent of the dry matter. In general, mimosine has raised more concern than is justified. Fear of its effects has for years been a barrier to leucaena's wider use as forage. Today, much of this fear is being dispelled. Ruminant animals in Indonesia, India, Hawaii, and several other countries have been shown to thrive without ill effect on diets of 100 percent leucaena plus a salt supplement.

*Plucknett, 1970. (Each animal consumed 12–14 kg of leucaena and were fed about 5.5 kg of concentrates and 2 kg of molasses daily.)

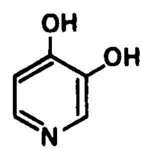
Effect on Ruminants

It is now known that in most parts of the world ruminants rarely have problems with mimosine because microbes in the first stomach (rumen) alter mimosine to another compound, 3, 4-dihydroxy pyridine (DHP), which is then broken down further into nontoxic compounds. However, in Australia and a few other countries DHP is not degraded because the requisite microbes are absent. Even where this is true, diets containing 30 percent or less of leucaena appear to be safe for cattle. But feeding leucaena more extensively leads to goiter (enlargement of the thyroid gland); the animals become listless, their appetites and weight gains are depressed, they produce excessive saliva, and some hair falls out. Pregnant animals may also produce weak offspring with enlarged thyroid glands.

This DHP problem has occurred only in Australia, Papua New Guinea, and perhaps in Africa. Researchers are now transferring to these areas the rumen microbes that degrade DHP in ruminants elsewhere. Already the problem has been overcome experimentally in Australia.*



Mimosine



3,4-dihydroxypyridine

Effect on Other Animals

The effects of mimosine on leucaena-fed sheep can be dramatic. Ten days after eating large amounts of leucaena for the first time their fleece falls off.

Leucaena browse is favored by goats and is used on small farms in parts of the tropics. It is safe to feed the plant to goats, particularly at moderate dietary levels.

In nonruminant animals leucaena should not be used as a *major* portion of the diet. Although most of them eat leucaena with relish, they are less able to tolerate mimosine than are ruminants. Horses lose hair from their manes and tails, and pregnant mares may abort when leucaena is fed at levels above 10 percent in the diet. Rabbits

*Information from R. Jones and R. G. Megarrity.

Brisbane, Australia. In experiments, the depilatory effect of mimosine in leucaena forage has been turned to benefit. Ten days after introducing sheep to 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, but Australian chemists have created even better compounds, and most work on leucaena has been set aside. (M.P. Hegarty)

may lose hair and produce small litters. Pigs show delayed sexual maturity and reduced litter size. Poultry can also show delayed sexual maturity, along with slow growth and reduced egg production. These difficulties are all traceable to mimosine, although effects on poultry are compounded by the presence of tannins.

Despite these problems, in Papua New Guinea and the Philippines leucaena leaf meal has been used satisfactorily to supplement rations (up to 10 percent) for pigs. And in the Philippines and Thailand leucaena is a popular ingredient of commercial poultry feeds.

For poultry, leucaena meal supplies protein, minerals, and vitamins. It also contains twice the carotene (a source of vitamin A) of dehydrated alfalfa meal. Putting 4–6 percent leucaena leaf meal in a poultry diet restores health to chicks (and pigs) suffering from vitamin A deficiency. Carotenes are the yellow pigments that make egg yokes and broiler skins yellow, and leucaena meal has about twice the pigmenting power of alfalfa.

Furthermore, research at the University of Hawaii and in the Philippines has shown that feeding hens leucaena meal can dramatically increase the proportion of eggs that hatch. Apparently this is because compared with alfalfa meal, leucaena meal has about twice as much riboflavin and vitamin K, both of which enhance egg hatchability.* However, the amount of leucaena meal in poultry feeds must be kept below about 6 percent (dry weight) of the ration to avoid the effects of mimosine.

*Information from E. Ross.

5 Wood Products

Both wood and paper are essential to modern life, and their value as industrial raw materials is increasing. Wood, for example, is virtually the only economically attractive renewable resource for construction. Accordingly, the discovery of giant leucaena varieties that produce high volumes of wood is timely. Because of the rapid growth, and because wood products are in increasing demand, the giant leucaenas could become particularly important throughout the lowland tropical regions.

Wood Yield

In many parts of the tropics, densely planted leucaena stands have yielded high annual quantities of wood (see chapter 2). Average annual increments vary, but many sites have yielded 40–50 m^3 of wood per hectare per year. The wood is denser than that of other fast-growing tropical hardwoods such as *Albizia falcataria, Gmelina arborea, Eucalyptus deglupta*, and *Anthocephalus chinensis*, which grow with similar speed.

Where soils are suitable and rainfall is well distributed throughout the year, leucaena can reach heights of about 18 m in 4–8 years. Vigorous trees can have diameters* of 21–37 cm after only 8 years of growth.

If planted carelessly and later uncared for, the trees often have crooked trunks. But if giant types are densely planted and carefully thinned, the crowding keeps the trunks reasonably straight and virtually branchless.

Where soils are deep and growing conditions favorable, leucaena's rooting habits enable very dense plantings. Where markets exist for small-diameter wood, leucaena plantings can be made at 10,000 or

*All diameters in this report were measured at breast height.

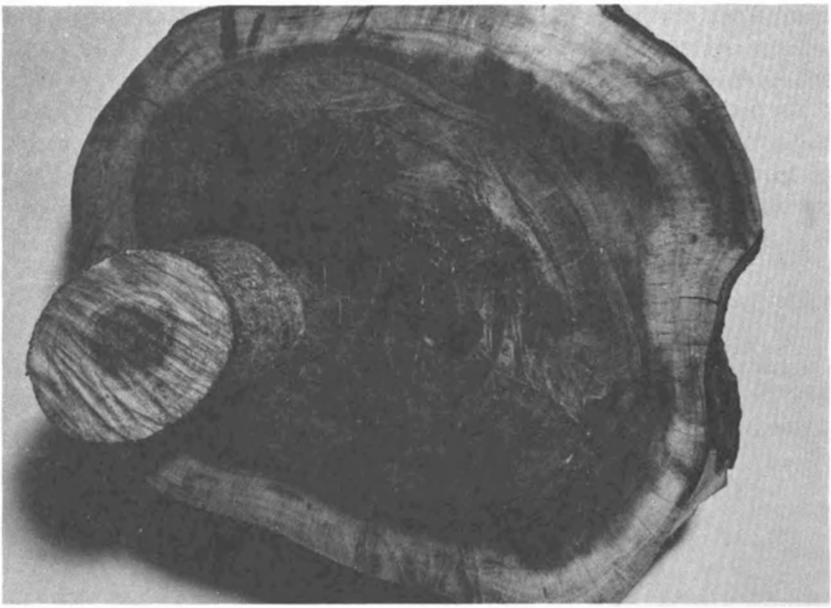
Canlubang Estate near Manila, Philippines. Most leucaena specimens now seen in plantations are relatively young, but the tree can grown to large size—heights of more than 20 m and diameters of more than 50 cm. Only 8 years old, this specimen of Hawaiian giant leucaena towers to a total height of 20 m. Although spindly, it has a diameter (at breast height) of 40 cm. (M.D. Benge) more trees per hectare. The stands can then be thinned, allowing the remaining trees to grow trunks large enough for fence posts, pulpwood, and eventually for lumber.

As noted, leucaena coppices well. Even large-trunked trees felled close to the ground will resprout rapidly. In equatorial climates (such as in the Philippines), cutting cycles of 4–6 years are being used commercially to produce wood and pulp.

Wood Properties

Leucaena trees are thin barked. On trees more than 5 years old, less than 8 percent of the bole is bark on a dry-weight basis. The sapwood is yellow-white, the heartwood yellow- to reddish-brown.

Canlubang, Philippines. Giant leucaena, 8 years old. The small groves at this location were 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)



The common type of leucaena, now widespread throughout the tropics, falls far short of the size of newly discovered giant-type varieties. The smaller cross section shown here is the stem of an average-size common type, and the larger (diameter 28 cm) is that from an 8-year-old giant type. (N.D. Vietmeyer, specimens of M.D. Benge)

Some wood samples have nodes (knots), but these seem to come mainly from poorly managed trees that have ended up branchy and bent. Bole wood from 6- to 8-year-old Hawaiian giants has specific gravity averaging 0.54. This is similar in density to oak, ash, birch, and sugar maple, and leucaena wood also has similar tensile, compressive, bending, and shear strengths. Fine textured and easily workable, leucaena wood absorbs preservatives and can be treated for protection against termites.

Pulp

Tests suggest that leucaena is among the best tropical hardwoods for paper and rayon manufacture. The wood processes satisfactorily, producing pulps that are high in holocellulose and low in silica, ash, lignin, alcohol-benzene solubles, and hot-water solubles—all important characteristics for pulp manufacture. The low lignin content, in particular, should be an economic advantage. Pulp yield is high, 50–52 percent.

The fiber in leucaena wood is shorter than that in softwoods (conifers), but it falls within an acceptable range for pulp and paper. The relationship between the fiber length and fiber diameter is good for papermaking.*

The quality of giant leucaena pulp is comparable to that of other fast-growing hardwoods. Compared with paper from softwood pulps, however, leucaena paper has low tearing strength, low folding endurance, and only average tensile strength. Its short fibers make it less suitable for high-strength bag and wrapping paper. Nonetheless, with its high opacity and good printability, kraft pulp from leucaena is suited for use in printing and writing papers.

In Taiwan leucaena wood is made into a dissolving pulp for the production of rayon. Leucaena wood can also be converted to fiberboard (hardboard), which is important because this construction material is often in short supply in developing nations.

Lumber

Leucaena wood is strong, dense, and attractive, and has machining properties comparable to those of many hardwood species now used for lumber and plywood. In the Philippines the wood is increasingly being used in parquet flooring. In India a small demonstration house, together with all its furniture and fittings, has been made from the wood of leucaena trees only 2 years old.

Other Wood Uses

Leucaena can be used directly as roundwood. Poles thinned from a plantation after 2 years can be used as fence posts or bean poles. They can also serve as posts, girts, girders, floor joists, or rafters for small houses and sheds. In the Philippines, these poles have long been used as props to prevent banana bunches from breaking off or the whole banana plant from toppling over. It seems likely that leucaena could also become a source for mine timbers and railroad crossties (sleepers).

Energy

As a result of the high price of petroleum, wood gathering is on the rise. Unprecedented firewood scarcities are occurring in developing

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

Kanchanaburi, Thailand, 1982. Leucaena wood grown and gathered for fueling a pottery kiln. (R. Van Den Beldt)

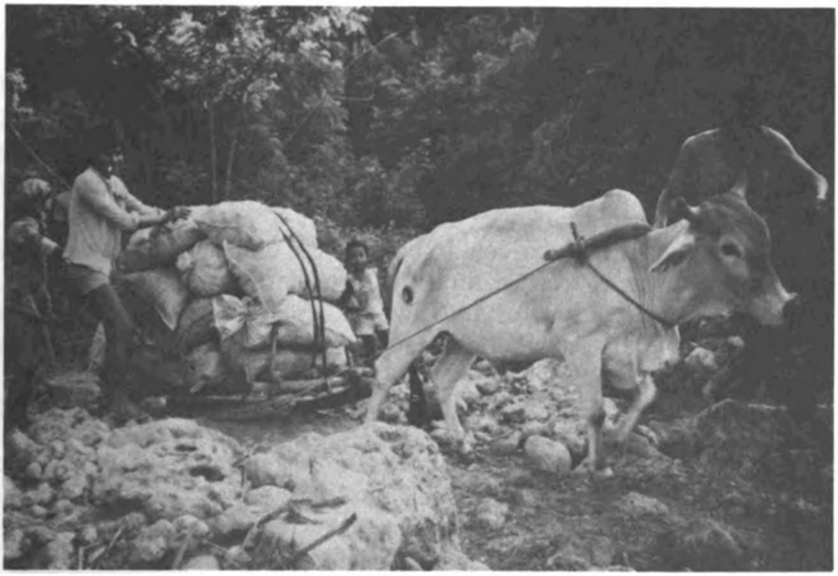
countries. There is an ever-increasing shortage of trees near settlements, and in many areas firewood prices have risen even faster than kerosene prices.

A logical first response is to plant more trees, and for many areas leucaena seems a prime candidate. Plantations can be harvested for firewood in cycles as short as 3–5 years. Wood from giant leucaenas 2–4 years of age has a heating value of 4,640 kcal per kg. Heartwood, and therefore the heating value, increases as the tree matures.

Leucaena is well suited to small-scale village and household fuel use. On Mount Makiling in the Philippines, extensive stands of the common type have been continuously harvested for firewood for more than 60 years. Today, the trees covering the slopes are as vigorous as ever.

Leucaena is also a candidate for large-scale "energy plantations" grown specifically for fueling:

- Brick and charcoal kilns;
- Sawmills;
- Electric generators;
- Railroad locomotives;
- Driers for coconut, fish, tobacco, grain, forage, and other agricultural products; and



Illocos Sur, Philippines. Hauling charcoal out of leucaena forest that now covers hills formerly barren and lost to *Imperata* grass. (N. D. Vietmeyer)

- Facilities processing cassava, sugar, or rubber.

Major programs for fueling generators through energy plantations have been started in the Philippines and are being considered for Honduras and other countries. The Philippine government is planting leucaena for this purpose on thousands of hectares. The wood will replace oil in elecricity generation and will also produce charcoal for fueling producer gas generators that power vehicles, boats, and irrigation pumps.* Philippine calculations indicate that with leucaena 1 hectare of good land can produce the net energy equivalent of 25–30 barrels of oil per year.†

Although leucaena is poorly adapted to very arid or high-altitude areas where firewood shortages are often great, it does grow well in humid lowland tropics where the need for firewood is also substantial. The tree also grows satisfactorily in some semiarid and savanna regions of the dry tropics, although not with the same rapidity as in more equable areas.

*See companion report, *Producer Gas: Another Fuel for Motor Transport.*
†Information from Frank H. Denton. Dr. Denton has described the Philippine experience with growing leucaena for "dendrothermal" electricity generation in his 1983 book *Wood for Energy and Rural Development: The Philippine Experience*, privately published but available from the author at 3181 Readsborough Court, Fairfax, Virginia 22031, USA.

Charcoal

In many countries, charcoal is used extensively for cooking and heating. Although as much as 65 percent of the wood's energy potential can be lost in its manufacture, charcoal has a much higher energy content than wood and is more suitable for indoor cooking because of its smokeless burning.

Some countries use charcoal to provide the industrial carbon that is obtained elsewhere from natural gas, coke, or coal. For example, charcoal made from eucalyptus wood supports much of Brazil's metallurgical industry, where a lack of coal and high transportation costs make it practical.

Leucaena charcoal has a heating value of about 7,000 kcal per kg, which is 70 percent of the heating value of fuel oil.

6 Soil Improvement and Reforestation

Overgrazing, overburning, careless timbering, and excessive firewood collecting are all part of a misuse of forest resources. Ultimately, the results are landslides, floods, soil erosion, and dried-up streams and rivers. The threat looms large that all tropical forests will soon be replaced by bare ground or degraded grasslands. And when land in the tropics is deforested, fertile topsoil that took centuries to develop can wash away in a single storm.

Tropical forests live off their own debris. Their nutrients come mainly from rotting vegetation, not from the soil. If the trees are cut or burned, the nutrients leach or wash away and are essentially lost to that site. This leaves the ground unprotected, and the soil often dries and hardens like cement or is swept away by rain and wind.

To restore vegetative cover to such sites, robust nitrogen-fixing trees like leucaena seem ideal. Deep-rooted, quick-growing, and adaptable, leucaena not only protects the terrain but, with care and good management, can be continually cropped for useful products.

Soil Improvement

Leucaena benefits the soil by:

- Increasing nitrogen content;
- Rebuilding tilth and surface texture with the organic matter (humus) it contributes;
- Breaking up compacted soil layers, thereby improving aeration and water absorption and reducing runoff;
- Insulating the soil from sun, rain, and wind; and
- Reducing soil slippage and erosion.

Leucaena is so good at improving soil that it can be grown as a "fertilizer crop." Tropical temperatures, moist soil, and the small size of leucaena leaflets encourage rapid decay, and within 2 weeks the fallen leaves rot away to form humus.

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

The foliage contains about 4 percent nitrogen, and under good soil and moisture conditions 1 hectare of leucaena bushes (mowed to a height of 1 m every 3 months) can provide foliage containing 500–600 kg of nitrogen a year. In experiments, leucaena leaf meal incorporated into soil around corn (maize) plants encouraged such growth that the resulting corn yields were comparable to those in neighboring plots treated with mineral fertilizer. A yield increase of 1 ton of corn required only 1 ton (dry weight basis) of leaf meal, the equivalent of 4 tons of freshly harvested foliage.*

In Goias, Brazil, yields of dry beans have been increased 30–50 percent by growing the bean plants between leucaena hedges 4 m apart, cutting the hedges twice a season, and incorporating the cut material in the soil.† In Indonesia, it is common practice to prune leucaena and lay the branches among the crop plants. One hectare of leucaena, it is reported, can provide an amount of nitrogen equivalent to a ton of ammonium sulfate fertilizer each year.‡

*Measured in Hawaii, using Hawaiian giant (K8) strain. Some experiments gave even higher amounts of nitrogen. Guevarra, 1976.
†Chagas, 1981.
‡Dijkman, 1950.

This process of "green manuring" also occurs naturally (though more slowly) with the natural leaf fall from unmowed bushes. Stands of 10,000 trees per hectare annually drop about 8.5 tons (dry) of litter per hectare, or about 100 kg of nitrogen.

Like animal manure, leucaena foliage is most effective if it is incorporated in the soil. Even then, denitrifying bacteria convert nitrogenous compounds to nitrogen gas, which is unavailable for plant use. Largely because of this, only about 65 percent of nitrogen in leucaena is available for crop growth.*

In spite of this nitrogen loss 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 growing of leucaena for manure may prove attractive and practical.

Leucaena provides more than just nitrogen: mineral elements such as phosphorus and potassium, absorbed by the roots from deep soil layers, become incorporated into the foliage. In Hawaii, leucaena foliage harvested during 1 year from 1 hectare of land contained 44 kg of phosphorus and 187 kg of potassium, as well as calcium and micronutrients.

Reforestation

In the tropics, there is an urgent need to protect the remaining forest cover from further damage and to reforest the now-devastated areas. By providing alternate sources of forest products, plantations of fast-growing leguminous trees such as leucaena could slow the daily progress of forest denudation.

In Indonesia, extensive reforestation with leucaena is already being carried out. More than 20,000 hectares on the island of Flores are being planted in contour hedgerows of leucaena for reforestation, soil erosion control, fertilizer, forage, and wood production. Leucaena has even been established by aerial seeding for reforestation purposes.† Reforestation plantations are also being established in the Philippines.

Although a potentially valuable species itself, in many sites leucaena also improves the growth of other trees. In Indonesia and the Philippines, interplantings by leucaena have increased growth of young tropical hardwoods and dipterocarps by 50–100 percent.‡ Eventually,

*Information from J. L. Brewbaker and C. Evensen.

†See *Sowing Forests from the Air*, a companion report.

‡This has 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 from Djikman, 1950, and M. D. Benge.)

Papua New Guinea. 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. (N.D. Vietmeyer)

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

Mt. Makiling, Philippines. Leucaena converted this area from *Imperata* grass to a productive firewood forest. Leucaena seed (common type) were scattered among the grass in the early 1920s. Twelve years later (as shown here) more than 20 tons of firewood was being harvested per hectare. (R.L. Pendleton)

Today, the region is still productive and is the main source of firewood for Laguna and surrounding districts. (M.D. Benge) such forest-climax species overtop the leucaena, dominate the plantation, and reestablish themselves in the region.

Grown as a pioneer or nurse corp interplanted with slower growing, shade-tolerant species, leucaena can fully stabilize a site, but grown by itself on unstable slopes it can promote sheet erosion by shading out most grasses and understory plants.

Reclaiming Grasslands

Removing the tree cover in the tropics rarely produces bare soil. Instead, the sites are usually reduced to coarse grasslands of little economic value.

The loss of forests to the tenacious grass *Imperata cylindrica* is a major problem in the Philippines, Indonesia, Papua New Guinea, Sri Lanka, and parts of Africa. Known variously as cogon, kunai, alang-alang, blady-grass, or lalang (among other names), 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 season. These areas are difficult and costly to reclaim. Suppressing the grasses is complicated because they regenerate rapidly after the area has been burned, and herbicide control is uneconomic.

A vast amount of abandoned agricultural land now lies under such tropical fire-climax grasses. This land is often good for leucaena, and in the Philippines, Taiwan, Java, Bangladesh, Thailand, and numerous other places the tree is being grown on such sites.

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, the trees will grow to dominate. In about 3 years there is a solid thicket of leucaena and the grass is dead.

Although livestock will graze *Imperata* grass, they cannot thrive on it as a sole diet, for it is very low in protein. And because it crowds out all other plants, alternative feeds are often unavailable. To cope with this, Fijian pasture agronomists have planted patches of leucaena (usually 1 hectare of leucaena to 6 hectares of grass, although sometimes 1 in 4) on the lower slopes of *Imperata*-covered hills. Cattle then feed on the grass, but supplement their diet with the leucaena, which is maintained within fenced enclosures and fed sparingly enough that the animals don't stop eating the grass. This is a promising system for exploiting coarse grasslands that, by themselves, make inadequate pastures.

Dense leucaena stands have almost no undergrowth or lower foliage, and the plant itself is fairly resistant to ground fires. 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. (M.D. Benge)

Firebreaks

Grass fires constantly threaten forests in many tropical countries. Often they are deliberately set to clear the land for crops or to capture wildlife. Many fires spread out of control and destroy forest plantations, the products of years of effort and expense.

Leucaena will burn, especially if the trees are older than 5 years, and it cannot withstand *repeated* fire damage. But established leucaena stands shade out undergrowth, leaving little for ground fires to feed on. Further, the plants themselves remain green except towards the end of the dry season in the drier tropics. Therefore, a dense leucaena stand can retard fires that creep through the grass. A wall of flame driven by wind or slope may take out the first 3–5 m of a plantation, but then the fire is suppressed. The burned leucaenas resprout from the root collar, and seeds germinate so that soon the damaged trees are replaced. A band of leucaena 10 m wide (or even wider) on slopes can thus serve as a firebreak. It is a maintenance-free, relatively permanent, and inexpensive way to protect forests from fires.

7 Other Uses

Shade Plant and Nurse Crop

Leucaena has been used to improve production of plantation crops such as coffee, cacao, tea, cinchona (source of quinine), citrus, teak and other shade-loving timber species, and rubber, coconut, and oil palm. Planted between the rows, the taller leucaena shade the heat-sensitive crops from the sun while allowing enough light through for good growth. Moreover, the fall of the nutrient-rich leaves fertilizes the crop. Leucaena provides more than shade; it is now commonly termed a nurse plant because it fosters healthy growth in the crop it shades.

It is believed that in most cases leucaena roots interfere little with those of the crop and that the leucaena carries few diseases or pests that could infect the crop.

The cheap fertilizer of past decades decreased the need for nurse plants, but now many growers once more rely on the detritus of leucaena and other legumes. Whenever crop prices are low or fertilizer prices high, leucaena can be a backup source for plant nutrients.

Agroforestry

Leucaena growing can be combined with food crop production and animal raising. The tree is sometimes planted in pastures to shade livestock, particularly at feeding and watering sites. It is also grown as a living support for pepper, vanilla, and passionfruit vines.

Combinations of many different plant and animal species seem possible for raising with the versatile leucaena. For instance, vegetables, root crops, grains, fruits, nuts, and spices can probably be produced (at least for several years) between leucaena planted for timber, firewood, paper pulp, or forage. The combination makes efficient use of land.

Leucaena may also prove valuable when grown *beneath* coconuts and other tree crops that allow considerable light to pass. In this case,

Leucaena as a shade for plantation crops. Picture shows leucaena shading cacao plants, Western Samoa. (Yasuhiro Kumagai and Kapeneta Tupai)

the leucaena would be kept low either by grazing or by deliberate harvest for green manure so as not to interfere with the main crop's light.

Shifting-Cultivation

There are believed to be some 240 million slash-and-burn farmers in the tropics.* They spend their lives felling and burning patches of forest, planting seeds in the ashes, and growing crops until declining

*National Research Council, 1982. *Ecological Aspects of Development in the Humid Tropics*. National Academy Press, Washington, D. C.

Leucaena as a support for vine and climbing crops. Picture shows grape vines supported on living leucaena trees at Edinburg, Texas. (C.O. Foerster)

fertility and increasing pest activity force them to move on and fell a new forest patch. The practice has been much decried by foresters, for it wastes tree resources and exposes ground to erosion. But traditions prevail, partly because governments with limited funds have no substitutes to offer. Indeed, the rate of shifting-cultivation is increasing; year by year a greater amount of land is cleared, and where new land is unavailable the time before farmers must return to a previously cropped area is lessening.

Some Filipino, Indonesian, and Papua New Guinea farmers have integrated leucaena into their shifting-cultivation rotation. Before moving on from the worn-out sites, they plant leucaena. Then, instead of waiting 10 years or more, they can return after only about 2 years, by which time the nitrogen in the soil has increased adequately. There is some evidence that 1,500 years ago the Mayans used leucaena for the same purpose, at least in the Yucatan peninsula.

In Fiji, slash-and-burn farmers seek out leucaena stands to clear and then plant food crops, recognizing that these are sites of high fertility.

In the Philippines, Naalad farmers near Cebu have used leucaena as a fallow cover crop to rejuvenate the soil and as a firewood and forage source for more than 60 years.* Planted in dense blocks, leucaena provides enough green manure to eliminate the need for the cultivators to shift to new sites. In addition to making a settled way of life possible for slash-and-burn farmers, this practice also reduces

*Benge, 1976.

Leucaena as an ornamental. As part of a citywide beautification project, leucaena has been widely planted in Manila. (M.D. Benge)

forest destruction and soil erosion and provides income from leucaena products.

Living Fences

In Central America, Mauritius, and the Philippines, leucaena hedges are common. These living fences are planted for boundary markers, forage sources, shade for houses, ornamentals, and protection for fields and gardens from salt spray or wind damage.

Miscellaneous

Leucaena is used for food in Central America and Indonesia. On Java, leucaena seeds are fermented into tempe or are eaten as sprouts or beancake. Indonesians also eat young leucaena leaves and pods, particularly in soups, and they roast the mature seeds. Villagers in Mexico sell small bundles of leucaena pods that are eaten raw or in soups or tacos. However, leucaena is not recommended for extensive use as human food because, as noted earlier, mimosine can cause loss of hair in nonruminant animals and it may have some adverse effects on humans.

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

Extracting leucaena seeds with hot water produces about a 25 percent yield of gum (mucilage). Similar in chemical structure to that from other legumes (such as guar gum, carob bean gum, or gum arabic), this galactomannan could have commercial significance.

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

In the Philippines, leucaena is being widely planted for highway and city beautification. The seedlings that spring up around leucaena plants, however, are a constant nuisance and the heavy leaf litter is undesirable in some locations. New hybrids between leucaena and *Leucaena pulverulenta* have been developed in Australia and Hawaii that produce few pods, seeds, or seedlings.* Some have pleasing shapes and promise to provide ornamentals that are less troublesome.

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

8 Other Leucaena Species

Although agronomists in Indonesia observed in the early 1900s that *Leucaena pulverulenta* would grow well at high elevations either by itself or grafted on leucaena (*L. leucocephala*), little effort has been made to exploit this species and others of the genus. Yet most *Leucaena* species are used for browse or farm fuelwood in their native habitats and often for shade, fence trees, posts, and fuelwood.

Nine *Leucaena* species are recognized in addition to *L. leucocephala*. They grow from the highlands of Texas to the coastline of Ecuador and extend greatly the range of adaptability of leucaena itself. Recent tests show that these can be crossbred with leucaena, thereby forming a major gene reservoir for its further improvement.*

Hybrids can be used to contribute new genetic variation to leucaena but can also be used directly. It is predicted that future leucaena cultivars will represent combinations of these species, much like the modern sugarcanes that are also high in chromosome number and highly variable in the tropics.

Species of primary interest are illustrated and described on the following pages.

*Brewbaker, 1983.

Leucaena diversifolia. Two years' growth in trials at 1,100 m elevation at Alajuela, Costa Rica. (N.D. Vietmeyer)

Leucaena diversifolia (Schlecht.) Benth.

A pink-flowered tree with tiny leaflets, it displays great diversity of form, has wide natural distribution, and occurs to 2,000 m elevation in Central America.

Advantages:

- Quick growing
- Low mimosine content
- Grows at high elevations
- Produces more wood than *L. leucocephala* at high elevations
- Good seed yields
- Some lines are tolerant of acid soils

Disadvantages:

- Less useful for low altitudes and hot, humid climates
- Seems rather susceptible to drought

Leucaena esculenta (J.L. Brewbaker)

Leucaena esculenta (Moc. and Sesse) Benth.

A large tree of highland Mexico, it grows to 10–18 m high, with long leaves, fine leaflets, reddish stems, and corky bark.

Advantages:

- Cold tolerant (occurs naturally at 1,000–2,200 m elevation in Mexico)
- Low mimosine content
- High wood yields

Disadvantages:

- The thick corky bark in some lines can be a nuisance
- Slow growth
- Low seed yields

Leucaena macrophylla (J.L. Brewbaker)

Leucaena macrophylla Benth.

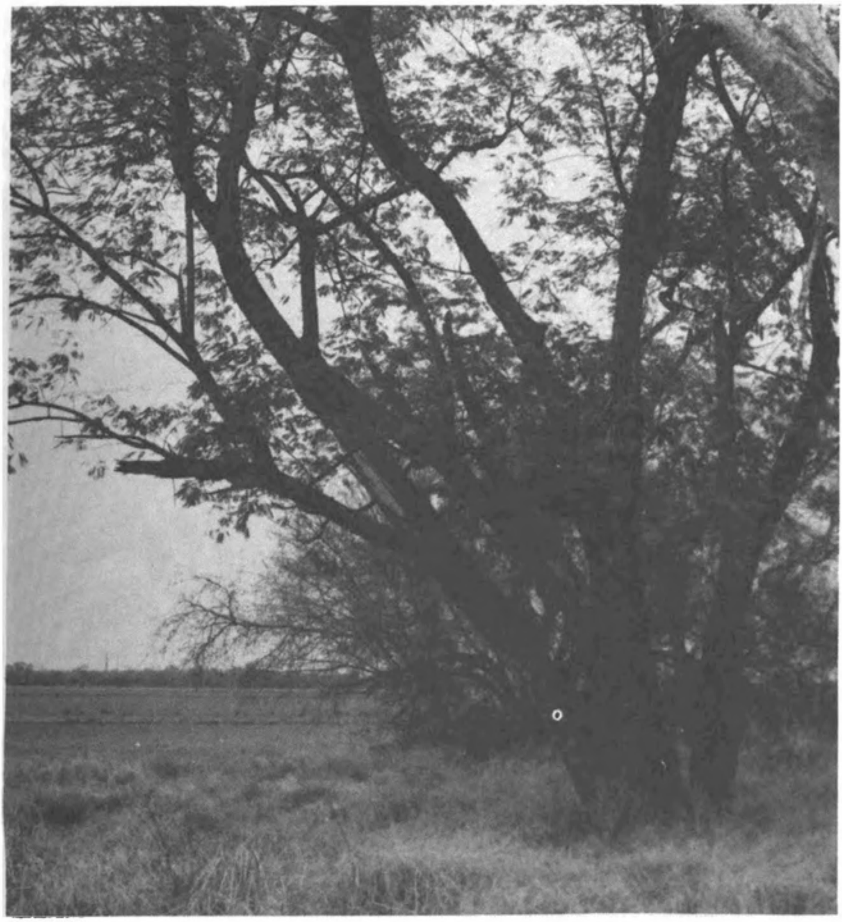
A shrub or tree of dry lowland Mexico, it has very large leaflets and rapid growth.

Advantages:

- Grows in droughty to wet situations
- Can be fast growing
- Some lines are acid-soil tolerant

Disadvantages:

- Large leaves with low forage yield
- High mimosine content



Leucaena pulverulenta, near Edinburg, Texas. (P. Thoma)

Leucaena pulverulenta (Schlecht.) Benth.

A tall tree of northeast Mexico and south Texas, it has small leaves and tiny leaflets.

Advantages:

- Cold tolerant (found growing native to 35° N latitude)
- Drought tolerant
- Very dense wood; excellent fuel
- Makes promising hybrid with *L. leucocephala* (shows aggressive growth with good form)

Disadvantages:

- Slow growth
- Natural outcrossing within species

Leucaena shannoni **(J.L. Brewbaker)**

Leucaena shannoni Donn. Smith

A shrub or small, umbrella-shaped tree found in southern Mexico and Central America.

Advantages:

- Good pollen source for bee pasture
- Excellent soil cover (umbrella shape; tree spreads over large area and almost weeps)
- Erosion control

Disadvantages:

- Low forage yields
- Poor seed production

Four other Leucaena species offer additional possibilities for use in the tropics or as parents for important leucaena hybrids:

- *Leucaena retusa*—a bright-yellow flowered shrub of the southern United States and northern Mexico, enduring snowy winters at up to 2,000 m elevation. It hybridizes with leucaena, but has an untypically slow growth, brittle wood, and an unusual nitrogen-fixing bacterium.
- *Leucaena lanceolata*—a shrub of western Mexico that is widely used as animal browse. It is heat and drought tolerant and has broad leaves like *L. macrophylla*. It also is highly variable because of cross-pollination.
- *Leucaena collinsii*—an elm-shaped small tree of southern Mexico, adapted to middle altitudes (500–1,500 m) and acid soils. It is fairly rapid in growth and may be a useful parent species for improving tree form.
- *Leucaena trichodes*—a large-leaf species that ranges from a small drought-hardy shrub to a tall tree (22 m) in southern Panama. This South America leucaena appears to be slower in growth and of interest primarily in hybridization.

9 Recommendations and Research Needs

This report has detailed leucaena's potential value as a source of feed, fuel, and wood and its promise for solving deforestation problems in some tropical regions. Experience with leucaena is increasing very rapidly. However, more detailed information on site adaptability and cultivation practices is still needed. Leucaena research presents an area worthy of financial support and should be supported by philanthropic institutions and international development agencies concerned with problems of food and resource shortages.

Specific recommendations follow.

Trial Plots

Small trials of a standard leucaena variety can indicate quickly whether leucaena is adaptable to an area. Where large-scale production is planned, such pilot trials and soil analyses are strongly recommended. Since leucaena is deep rooted, the properties of the subsoil (50–200 cm depth) must be assessed, especially the pH and the levels of exchangeable aluminum and calcium. If surface soil or subsoil pH values are less than 5.5, difficulties in growing leucaena can be expected and a different species of tree should be tried.*

Adaptability Trials

Extensive trial plantings are taking place in the Philippines, India, Indonesia, Malaysia, and other countries. Nevertheless, it is important to develop more precise guidelines as to where and how leucaena may

*Other trees worth considering include *Acacia mangium* and other tropical acacias, *Casuarina* species, and *Leucaena* species that are more tolerant of acid conditions. These trees are described in the previous chapter and in companion reports nos. 41 and 43. (To order, see page 97.)

be grown. Replicated trials and comparative observations of existing plantings are needed throughout the tropics to assess the growth and performance of what appear to be the best strains for given locations and the best cultivation regimes. Detailed site characteristics must be compared, so that predictions of leucaena's performance on other sites throughout the tropics can be made.

Sites 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 local decisions to cultivate large leucaena plantations can be made.

Extensive field trials exist in the Philippine wood energy program; there is a need for scientists to observe and document what has worked and what has not.

Agronomic Research Needs

This research should include:

- Improving growth in very acid soils (for example, oxisols) by breeding and selecting adapted varieties and studying effects of lime application and long-term soil changes under leucaena;
- Breeding and selecting varieties for best growth under other difficult conditions (including higher latitudes and higher elevations with some frost, waterlogged soil, and drought);
- Determining specific nutrient requirements through appropriate foliar analysis (assessing critical levels of phosphorus, sulfur, calcium, magnesium, potassium, molybdenum, zinc, and copper);
- Speeding up seedling growth (using seed treatment, weed control, inoculation, fertilization, varietal selection, seasonal timing, and land preparation);
- Determining the cheapest methods of seed-bed preparation, weed control, and planting and seed harvesting, handling, and storage, and establishing seed orchards;
- 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);
- Controlling insects (such as ants and various predators); and
- Controlling diseases (such as gummosis).

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

Forage Research Needs

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

It is important to continue work on breeding low-mimosine leucaena varieties to produce lines for use with pigs, poultry, and rabbits. Mimosine appears to be a metabolic by-product that is not crucial to leucaena, and crossing the plant with low-mimosine leucaena species could lower the mimosine content to half of normal. Australian work with crossing *L. pulverulenta* with leucaena (*L. leucocephala*) promises to produce very vigorous hybrids with reduced mimosine.

Research is also needed on:

- The DHP problem that exists in Fiji, Papua New Guinea, and Australia (in particular, the feasibility of transferring DHP-degrading bacteria into commercial herds, for which *in vitro* multiplication of the bacteria may be necessary);
- The effects of mimosine on nonruminant animals as well as on the people in Central America and Indonesia who now eat leucaena;
- Detoxifying mimosine by heat as well as by chemicals such as ferrous sulfate and aluminum sulfate, with studies on the suitability of the feed after treatment;
- Studying the effect of DHP (as opposed to mimosine) on nonruminants;
- Managing leucaena for grazing, small-farmer holdings, mechanized agriculture, or hedgerow production (determining optimum spacing, cultivation methods, harvest time, cutting heights, and rotations); and
- Incorporating leucaena in pasture combinations and maximizing animal production on such combinations.

Silviculture Research

Throughout the tropics, forestry research programs should include trials with giant leucaenas.

The present results, though highly promising, are inadequate to support establishment of large plantations and large-scale use of leucaena wood, except on sites where leucaena's successful growth has been established by direct trials. Much of the information still needed can come only from local trials. Comparison of experiences from pilot plantations will provide the foundation for decisions on how to establish and utilize large plantations locally 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 cheaper, more successful, and more widely applicable. Some particular research needs are:

- Analyzing experiences with leucaena revegetation in the Philippines, India, Indonesia, Guam, and Saipan;
- Developing management techniques to maximize the economics of wood production (determing optimum seed-handling methods, nursery practices, plantation spacing and management, and rotation time);
- Screening existing gernnplasm collections;
- Improving present leucaena varieties (using intervarietal and interspecific crosses to produce elite types that optimize growing time, shade tolerance, wood quality, and other 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, and silica) for making paper, pulp, fiberboard, particleboard, and other cellulose derivatives;
- Investigating methods for handling and processing leucaena wood (drying, preserving, sawmilling, and veneering);
- Breeding or selecting varieties suitable for reforestation at high elevations;
- Developing methods of vegetative reproduction that are reliable and cost-effective;
- Developing techniques that allow partial harvest of plants on erosion-prone slopes without reducing their soil-stabilizing benefits; and
- Testing belts of leucaena planted as fire protection around existing forest plantations.

Reforestation and Erosion Control

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, common leucaena has been successfully planted to revegetate lowland hill slopes in the Philippines and some western Pacific islands. Now, the less weedy giant types should be tested for this purpose in trials throughout the tropics.

Firewood Research

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

Other Leucaena Species

Only *Leucaena leucocephala* has been collected and evaluated extensively from its region of origin. Other leucaena species are in need of greatly expanded germplasm collections and evaluations. For instance, *L. diversifolia*, *L. esculenta*, and *L. pulverulenta* deserve evaluation in cooler highlands.

Research could open up a vast new wealth of leucaena hybrids with particular promise for sites that are now marginal for leucaena itself. Shown here is a hybrid between leucaena and *Leucaena diversifolia*, which performs well on acid soils (right), whereas leucaena is stunted and yellow (left). (E.M. Hutton)

Hybridization of other species with *L. leucocephala* and assessment of cold, acid, and drought tolerance of the hybrids and a search for low mimosine varieties are needed.

The research needed with other leucaena species is much the same as that outlined for *L. leucocephala*, with more emphasis on wood production, ornamentals, and marginal environments. Little attention is needed on their forage potential.

Other Research Needs

- Agroforestry. 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 and fuelwood tree with the production of food crops so that shifting is no longer required and sedentary agriculture is feasible.
- Fuelwood. Leucaena needs wider demonstration in farm forestry as a fuelwood resource.
- 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. A more widespread adoption is suggested.
- Windbreaks and ornamental plantings. Some species, for example, *L. esculenta*, have particularly attractive foliage and warrant greater recognition.

Appendix A

Selected Readings

General Leucaena Literature

A leucaena bibliography has been compiled by A. J. Oakes. This collection of 1,308 references, with an addendum of 692 references, covers the scientific literature on leucaena and is available from: Germplasm Resources Laboratory, U.S. Department of Agriculture, Beltsville, Maryland 20705, USA.

Leucaena Research Reports (formerly *Leucaena Newsletter*) is published annually by the Nitrogen Fixing Tree Association (NFTA) and the Council on Agricultural Planning and Development, Taipei, Taiwan (J. L. Brewbaker, R. Van Den Beldt, and Ta-Wei Hu, eds.). Copies are available from: NFTA, P.O. Box 680, Waimanalo, Hawaii 96795, USA. (NFTA was organized in 1981 as a result of the rising international interest in leucaena. Its purpose is to encourage international research and development, communication, and utilization of nitrogen-fixing trees to provide forests and improved fuel, fertilizer, forage, food, fiber, and other products for the benefit of mankind.)

Two books that complement this report by providing information on planting and management of leucaena are: Nitrogen Fixing Tree Association. In press. *Leucaena Forage Production and Use* and *Leucaena Wood Production and Use*. NFTA. These are available from: NFTA, P.O. Box 680, Waimanalo, Hawaii 96795, USA.

A report on handling leucaena seed and inoculum is: Halliday, J., and D. Billings. 1983. *Leucaena Seed Production Manual*. University of Hawaii NifTAL Project, Maui, Hawaii, USA.

A companion volume to this book, containing the papers presented at an international meeting of leucaena experts held in Singapore in 1982, is: International Development Research Centre. 1983. *Leucaena Research in the Asian-Pacific Region: Proceedings of a Workshop Held in Singapore, 23–26 November, 1982*. IDRC. 192 pp. (Available from IDRC, P.O. Box 8500, Ottawa, Ontario, Canada.)

A pamphlet on leucaena is available in either English or Spanish from: New Forests Project, Center for Development Policy, 418 Tenth Street S.E., Washington, D.C. 20003, USA.

A pamphlet *(Leucaena: Tree of a Thousand Uses)* and filmstrip *(Leucaena: The Miracle Tree)* are available from World Neighbors International Headquarters, 5116 North Portland Avenue, Oklahoma City, Oklahoma 73112, USA.

References

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Brewbaker, J. L. 1983. Systematics, self-incompatibility, breeding systems, and genetic improvement of *Leucaena* species. Pp. 17–22 in Leucaena Research in the Asian-Pacific Region: Proceedings of a Workshop Held in Singapore, 23–26 November, 1982. IDRC, Ottawa, Ontario, Canada. 192 pp.

Brewbaker, J. L. In press. Guide to the systematics of the genus Leucaena. Allertonia 3.

Brewbaker, J. L., and E. M. Hutton. 1979. Leucaena, versatile tropical tree legume. Pp. 207–257 in New Agricultural Crops, G. A. Ritchie, Editor. Westview Press, Boulder, Colorado.

Brewbaker, J. L., D. L. Plucknett, and V. Gonzalez. 1972. Varietal Variation and Yield Trials of *Leucaena leucocephala* (Koa Haole) in Hawaii. Hawaii Agricultural Experiment Station Research Bulletin No. 166. University of Hawaii, College of Tropical Agriculture, Honolulu. 29 pp.

Chagas, J. M. 1981. *Leucaena leucocephala* as a green manure for bean growing in cerrado soil. Pesquisa Agropecuaria 16(6):809–814. (Reprints available from the author at EMBRAPA, Centro Nacional Pesquisa Arroz e Teijao, Caixa Postal 179, BR-74000 Goiania, Goias, Brazil.)

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Appendix B
Researchers Working with Leucaena

Argentina

Universidad Nacional de Tucuman, Laboratorio de Genetica, Facultad de Agronomia, Ayacucho 482, San Miguel de Tucuman

Australia

Cunningham Laboratory, CSIRO, St. Lucia, Brisbane, Queensland 4067 (R. A. Bray, R. M. Jones, M. P. Hegarty)
Davies Laboratory, Division of Tropical Crops and Pastures, CSIRO, Private Mail Bag, P.O. Aitkenvale, Townsville, Queensland 4814 (R. J. Jones, R. G. Megarrity)
Department of Forestry, Division of Technical Service, GPO Box 944, Brisbane, Queensland 4001

Brazil

E. Mark Hutton, % CPAC-EMBRAPA, Km 18, BR-020 Caixa Postal 70/0023 CEP 73.300, Planaltina, D.F.

Colombia

Centro International de Agricultura Tropical, Apdo. Aereo 6713, Cali

Costa Rica

Programa de Recursos Naturales Renovables, Centro Agronomico Tropical de Investigacion y Enseñanza, Turrialba

Ethiopia

N. H. Ayodele Cole, Director, Environment Coordination Office, United National ECA, P.O. Box 3001, Addis Ababa

India

Bharatiya Agro-Industries Foundation, Kamdhenu, Senapati Bapat Marg, Pune 411016, Maharashtra (Narayan Hegde)
Indian Grassland and Fodder Research Institute, Jhansi, Uttar Pradesh 286003
Nimbkar Agricultural Research Institute, P.O. Box 23, Phaltan Maharashtra 425523
Regional Research Laboratory (CSIR), Canal Road, Jammu-Tawi 180001
Tamil Nadu Agricultural University, Department of Forestry, Coimbatore, Tamil Nadu
University of Agricultural Sciences, Hebbal, Bangalore, Karnataka 560024

Indonesia

Balai Penelitian Ternak, Center for Animal Research, P.O. Box 123, Gawi Bogor
Dinas Pertanian Rakyat, Kabupaten Sikka, Maumere-Flores

Kenya

International Council for Research on Agroforestry (ICRAF), P.O. Box 30677, Nairobi (Peter Huxley)

Malawi

Bunda College of Agriculture, P.O. Box 219, Lilongwe

Malaysia

Malaysian Agricultural Research and Development Institute (MARDI), Petisurat No. 2301, Pejabat Besar Pos, Kuala Lumpur 0102

Mauritius

School of Agriculture, University of Mauritius, Reduit
Azad M. Osman, Senior Lecturer, School of Agriculture, The University of Mauritius, Reduit

Mexico

Banco de Mexico, FIRA, Insurgentes Sur 2375, Piso 4, Mexico 20, D.F.
Instituto Nacional de Investigaciones Pecuarias, Forages Department, La Posta, Paso del Toro, Vera Cruz, Vera Cruz
Manuel Valdes Castillo, Patricio Sanz 1214, Colonia Del Valle, Mexico 12, D.F.

Nepal

Tribhuvan University, Institute of Forestry, Hetauda, Narayan Anchal

Nigeria

International Institute of Tropical Agriculture, Private Mail Bag 5320, Ibadan

Papua New Guinea

Office of Forestry, Division of Primary Industry, Department of Southern Highlands, Mendi, Southern Highlands Province

Philippines

Bureau of Animal Industry, Research Division, Santa Mesa, Metro Manila
Forest Research Institute, College, Laguna 3720
University of Philippines at Los Baños, College of Forestry, Los Baños, College, Laguna 3720

Sri Lanka

Department of Crop Science, University of Sri Lanka, Peradeniya

Taiwan

Division of Silviculture, Taiwan Forestry Research Institute, 53 Nan Hai Road, Taipei (Ta-Wei Hu)

Tanzania

Faculty of Agriculture, Forestry, and Veterinary Sciences, University of Dar es Salaam, P.O. Box 643, Morogoro

Thailand

Department of Agriculture, Khon Kaen University, Khon Kaen 40002
Thailand Institute of Science and Technological Research, 196 Phahonyothin Road, Bangkhen, Bangkok

United Kingdom

Commonwealth Forestry Institute, South Parks Road, Oxford OX1 3RB
Lee St. Lawrence, 288 London Road, Deal, Kent CT14 9PR

United States

Agronomy Department, University of Florida, Gainesville, Florida 32611
M. Benge, DS/FNR, Agency for International Development, Washington, D.C. 20523
P. Felker, Caesar Kleberg Wildlife Research Institute, Texas A & I University, P.O. Box 218, Kingsville, Texas 78363
NifTAL Project, P.O. Box 0, Paia, Maui, Hawaii 96779 (J. Halliday, J. Roskoski)
Nitrogen Fixing Tree Association (NFTA), P.O. Box 680, Waimanalo, Hawaii 96765
A. J. Oakes, Research Agronomist, Germplasm Resources Laboratory, USDA, ARS, Room 338, Building 001, BARC-West, Beltsville, Maryland 20705
University of Hawaii, Department of Horticulture, 3190 Maile Way, Honolulu, Hawaii 96822 (J. L. Brewbaker, R. J. Van Den Beldt)

West Indies

D. Minott, Enerplan, 6 Lockett Avenue, Kingston 4, Jamaica

Zaire

Claude Brasseur, Mission Belge de Cooperation, B.P. 148, Lubumbashi

Appendix C

Sources of Leucaena Seeds and Inoculum

Australia

R. A. Bray, Cunningham Laboratory, CSIRO, St. Lucia, Brisbane, Queensland 4067. (small quantities)
R. A. Date, Cunningham Laboratory, CSIRO, St. Lucia, Brisbane, Queensland 4067. (experimental quantities of inoculum)
Kingston Rural Management Pty., Ltd., P.O. Box 47, Maryborough 4650, Queensland. Varieties: K8
R. Reid, Davies Laboratory, CSIRO, Private Mail Bag, P.O. Aitkenvale, Townsville, Queensland 4814. (small quantities)
J. H. Williams & Sons Pty., Ltd., P.O. Box 102, Murwillumbah 2484. Varieties: not specified

Brazil

Nuno M. Sousa Costa, EPAMIG, Caixa Postal 295, CEP 35.700, Sete Lagoas, M.G. Varieties: K8, Peru (large amounts), 22 other accessions (small amounts)

India

Bharatiya Agro-Industries Foundation, Kamdhenu, Senapati Bapat Marg, Pune 411016, Maharashtra. Varieties: K8, Cunningham, Hawaiian
Indian Grassland and Fodder Research Institute, Jhansi, Uttar Pradesh 286003. Varieties: not specified
Pratap Nursery and Seed Stores, P.O. Box 91, Panditwari, P.O. Premnagar, Dehra Dun, Uttar Pradesh 248007. Varieties: not specified
Regional Research Laboratory (CSIR), Canal Road, Jammu Tawi 180001. Varieties: K8, K28, K29, K67, and Cunningham
UAS/KDDC Fodder Project, University of Agricultural Sciences, Hebbal, Bangalore 560024. Varieties: not specified

Malawi

General Manager, National Seed Co. of Malawi, Ltd., P.O. Box 30050, Lilongwe 3. Varieties: not specified

Mexico

Ing. Guillermo Sanchez Rodriguez, Banco de Mexico, S.A., Calle 58 #389, Merida, Yucatan. Varieties: K8, K28, Peru, Yucatan (and others for research purposes)

Philippines

Ms. Belen Abreu, Magasaysay Foundation, 1640 Roxas Blvd., Manila. Variety: "Giant"

Taiwan

Sheng Feng Leucaena Farm, Attn.: Li-Chung Yao (General Manager), 99-4, Tung-an Street, Taipei. Varieties: K8, K28, K29, K67, K72, Peru, and Cunningham
Yilin Co., Attn.: Fu-Hsiung Li, 24 Fu-jen 2nd Street, Hualien. Varieties: K8, K28, K29, K67, and K72

United Kingdom

Kins Plants, Ltd., Woodcote Grove, Ashley Road, Epsom, Surrey KT18 5BM, England. Variety: K67
Lee St. Lawrence, 288 London Road, Deal, Kent CT14 9PR

United States

J. Halliday, NifTAL Project, P.O. Box 0, Paia, Maui 96779. (rhizobium inoculant and/or cultures for leucaena and seed)
G. R. Lovell, Coordinator, Southern Regional Plant Introduction Station, USDA, Experiment, Georgia 30212. (seed)
Amorient, Inc., P.O. Box 131, Kahuku, Hawaii 96731. Varieties: K8, K28, K29, K67, K72, K132, and K341
Nitrogen Fixing Tree Association, P.O. Box 680, Waimanalo, Hawaii 96795
New Forests Project, Center for Development Policy, 418 Tenth Street S.E., Washington, D.C. 20003
Tree Seeds International, 2402 Esther Court, Silver Spring, Maryland 20910
G. A. White, USDA Gennplasm Resource Laboratory, AID/USDA Seed Project, Building 001, Room 322, Beltsville, Maryland 20705

West Indies

Caribbean Agricultural Research and Development Institute, Forage Legume Project, P.O. Box 1099, St. Johns, Antigua. Variety: Cunningham

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19. **Methane Generation from Human, Animal, and Agricultural Wastes.** 1977. 131 pp. Discusses means by which natural process of anaerobic fermentation can be controlled by man for his benefit and how the methane generated can be used as a fuel.

33. **Alcohol Fuels: Options for Developing Countries.** 1983. 128 pp. Examines the potential for the production and utilization of alcohol fuels in developing countries. Includes information on various tropical crops and their conversion to alcohols through both traditional and novel processes.

36. **Producer Gas: Another Fuel for Motor Transport.** 1983. 112 pp. During World War II Europe and Asia used wood, charcoal, and coal to fuel over a million gasoline and diesel vehicles. However, the technology has since been virtually forgotten. This report reviews producer gas and its modern potential.

39. **Proceedings, International Workshop on Energy Survey Methodologies for Developing Countries.** 1980. 220 pp. Report of a 1980 workshop organized to examine past and ongoing energy survey efforts in developing countries. Includes reports from rural, urban, industry, and transportation working groups, excerpts from 12 background papers, and a directory of energy surveys for developing countries.

Technology Options for Developing Countries

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

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

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

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

34. **Priorities in Biotechnology Research for International Development: Proceedings of a Workshop.** 1982. 261 pp. Report of a 1982 workshop organized to examine opportunities for biotechnology research in developing countries. Includes general background papers and specific recommendations in six areas: 1) vaccines, 2) animal production, 3) monoclonal antibodies, 4) energy, 5) biological nitrogen fixation, and 6) plant cell and tissue culture.

Plants

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

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

37. **The Winged Bean: A High Protein Crop for the Tropics.** (Second Edition). 1981. 59 pp. An update of BOSTID's 1975 report of this neglected tropical legume. Describes current knowledge of winged bean and its promise.

47. **Amaranth: Modern Prospects for an Ancient Crop.** 1984. 90 pp. Before the time of Cortez grain amaranths were staple foods of the Aztec and Inca. Today this extremely nutritious food has a bright future. The report also discusses vegetable amaranths.

53. **Jojoba: New Crop for Arid Lands.** 1984. Describes *Simmondsia chinensis*, a North American desert shrub whose seeds are rich in a unique vegetable oil with considerable potential as an industrial raw material.

Innovations in Tropical Reforestation

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

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

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

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

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

43. **Casuarinas: Nitrogen-Fixing Trees for Adverse Sites.** 1983. 118 pp. These robust nitrogen-fixing Australasian trees could become valuable resources for planting on harsh, eroding land to provide fuel and other products. Eighteen species for tropical lowlands and highlands, temperate zones, and semiarid regions are highlighted.

52. **Leucaena: Promising Forage and Tree Crop for the Tropics.** (Second Edition). 1984. 110 pp. Describes a multipurpose tree crop of potential value for much of the humid lowland tropics. Leucaena is one of the fastest growing and most useful trees for the tropics.

Managing Tropical Animal Resources

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

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

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

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

General

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

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

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