Gliricidia sepium (Jacq.) Walp. — Gliricidia, Mother of cocoa

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Leguminosae (Papilionoideae) — Legume family

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Gliricidia sepium (Jacq.) Walp., commonly known as gliricidia, mother of cocoa, madre de cacao, mata-ratón, and madero negro, is a small- to medium-sized, thornless, deciduous tree with a short trunk and irregular, spreading crown (fig. 1). Native to Mexico and Central America, gliricidia has been extensively planted in tropical and subtropical regions outside of its native range for use as a living fence; for the production of small timber, fuelwood, and fodder; and as a shade tree and living post for vine crops in agroforestry systems *(22, 25)*.

HABITAT

Native and Introduced Ranges

The best available information suggests that gliricidia is native to Mexico and Central America over a range of 18° latitude, from 25°30′ N. in northwestern Mexico to 7°30′ N. in Panama *(22)* (fig. 2). It has also been described as native to northern South America as far south as Venezuela and the Guianas *(26, 35)*.

Since pre-Columbian times it has been cultivated and widely introduced well beyond its native range. It has been naturalized in the West Indies from Cuba and Jamaica to the Lesser Antilles, Trinidad, and Curaçao *(32)*, and in Hawaii, West Africa, southern Africa, India, Sri Lanka, Thailand, the Philippines, Indonesia, and Australia *(22, 26)*. In Puerto Rico planted trees are common along roads, in fencerows, and as an ornamental in the moist and dry coastal regions, in the moist limestone regions, and in the lower mountain regions *(26)*.

Climate

Most of gliricidia's native range is characterized by a subhumid climate, with mean annual rainfall between 900 and 1500 mm and a 5-month dry period from December to April. The driest areas of its native range receive 600 to 700 mm annual rainfall with a 7- to 8-month dry season. The wettest areas of its native range receive up to 3500 mm of annual rainfall with a distinct, though shorter, dry season *(22)*. Gliricidia has been cultivated in wetter climates with no marked dry season. Best growth occurs in areas receiving between 1500 and 2300 mm of annual rainfall *(25)*. In Puerto Rico, gliricidia grows in areas receiving between 1000 and 1900 mm annual rainfall.

The species is reported to be drought-hardy and intolerant of frost *(22, 25)*. Mean annual temperatures of 22 to 28 °C are characteristic of the species' native and introduced ranges, with mean maximum temperatures of 34 to 41 °C during the hottest months and mean minimum temperatures of 14 to 20 °C during the coldest months *(51)*.

Soils and Topography

In its native range, gliricidia grows on a wide variety of soil types, from pure sands to unstratified rocky regasols to deep black vertisols, and is cultivated on soils from clays to sandy loams *(22)*. Soils are predominantly well drained, highly disturbed as a result of either vegetation removal or erosion, and often very shallow, stony regasols of recent volcanic origin *(22, 35)*. Extensive stands are sometimes found

Figure 1.—*Two-year-old gliricidia* (Gliricidia sepium) *growing at a coastal plantation site in Puerto Rico.*

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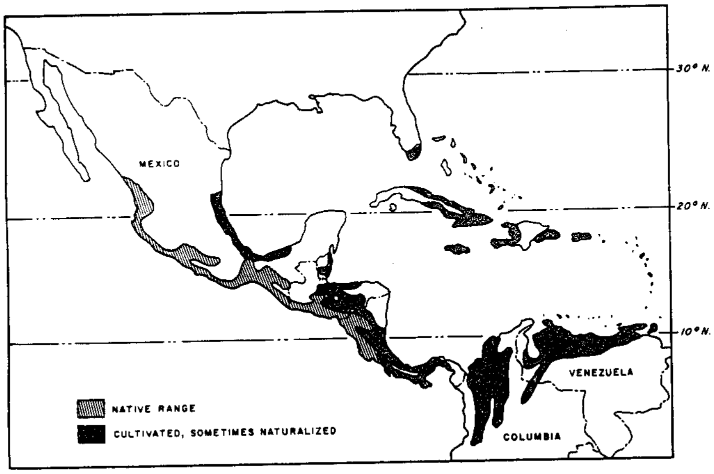

Figure 2.—*Native and introduced ranges of gliricidia* (Gliricidia sepium) *in tropical America.*

in slightly saline coastal sand dunes with a dry season water table as deep as 10 m *(22)*. The species is intolerant of waterlogging or soil compaction on strongly basic, black vertisols *(22)*. Soil pH in most of gliricidia's native range is 5.5 to 7.0 *(22)*.

In Puerto Rico, gliricidia is planted as an ornamental in the moist and dry coastal limestone and central mountain regions on a variety of soils *(26)*. Good early growth has been observed at a coastal plantation site in Puerto Rico characterized by slightly saline, alkaline (pH 7.5 to 8.5) sands (author, personal observation).

Within its native range, gliricidia occurs in most topographical positions from sea level to an altitude of 1,200 m, and has been cultivated at 1,600 m in Guatemala and Costa Rica *(22, 25)*. In Puerto Rico, this exotic species grows between sea level and 600 m, and in the Philippines, between sea level and 900 m *(36)*.

Associated Forest Cover

In Mexico and Central America, gliricidia either forms pure stands or dominates mixed secondary forest vegetation on heavily disturbed sites such as coastal sand dunes, riverbanks, flood plains, and abandoned shifting cultivation sites *(22)*. Published data on associated forest species within gliricidia's native range are not presently available. In calcareous saline wastelands in Barbados, gliricidia is associated with *Tabebuia heterophylla* (DC.) Britton, *Cordia obliqua* Willd., *Ricinus communis* L., and *Albizia lebbeck* (L.) Benth. *(18)*.

LIFE HISTORY

Reproduction and Early Growth

Flowering and Fruiting.—Gliricidia commonly flowers during the dry season when trees are partially or totally leafless. Although the time of flowering varies both within and between sites, it usually occurs between January and March in the species' native range and between December and May in Puerto Rico and elsewhere in the Caribbean *(18, 26)*. The showy, pink, pea-shaped flowers are borne on unbranched, numerous racemes 5 to 12 cm long that are opposite the leaves along old branches (fig. 3). Individual flowers, measuring about 2 cm long, grow on slender stalks and consist of a five-toothed bell-shaped calyx, light green tinged with red, and a pea-shaped corolla of five whitish-pink or purplish-tinged petals, with a broad standard, yellowish near its base, two oblong curved wings, and two united petals. There are 10 whitish stamens; 9 are united in a tube and 1 is separate. The pistil has a stalked, narrow, red ovary and a whitish, bent style *(25)*.

Trees flower and set fruit as early as the second growing season (author, personal observation), usually within the first 5 years *(22)*. The duration of the flowering may show considerable year-to-year variation. In Sierra Leone, for example, the average flowering period for a group of 20 trees in a seed orchard was 31, 42, and 88 days over 3 successive years *(6)*. The fruits are flat pods, 10 to 15 cm long and 12 to 15 mm wide, and are yellow green when immature, turning dark brown to black at maturity. A pod contains three to eight seeds *(6, 25)*. The period between flowering and pod ripening is short, generally between 40 and 55 days *(22)*. In

Figure 3.—*Foliage and fruit of gliricidia* (Gliricidia sepium) *(26)*.

Central America, peak ripening time ranges from late February to late May at different sites and is strongly related to altitude; ripening occurs later at higher elevations *(22)*.

Seed Production and Dissemination.—Gliricidia seeds are beanlike, elliptical, shiny, light to dark brown in color, and 10 mm in length *(25)* (fig. 3). There are approximately 4,700 to 11,000 seeds per kilogram, with considerable variation in seed weight among provenances *(22, 51)*. In its native range, gliricidia produces seeds in most years at highly predictable times. This does not appear to be the case where the species is cultivated, possibly because of genetic factors and the lack of insect pollinators *(22)*. Seed production in an 18-month-old seed orchard in Nigeria averaged 37 kg/ha *(46)*. The dehiscent pods curl and explosively release their seeds, which may be dispersed up to 25 m from even small trees *(22)*.

Seedling Development.—Germination in gliricidia is epigeal. Seeds germinate readily with no pretreatment, although some authors recommend soaking seeds in hot water, then cooling them for approximately 12 hours before sowing *(51)*. Germination in fresh seeds is usually between 90 and 100 percent and takes place between 3 and 15 days after sowing *(22, 28, 39, 51)*.

Seeds appear to remain viable for up to 12 months in storage *(51)*, although tests conducted in Puerto Rico showed a decline in germination from 99 percent for fresh seeds to 68 and 30 percent for seeds stored at 26 °C for 3 and 6 months, respectively *(28)*. Fresh, viable seeds tend to be light brown in color, but they become a darker brown and lose their viability in storage.[1] Seed germination is not affected by storage temperatures between 20 and 32 °C, but germination declines to zero when seeds are stored between 32 and 40 °C *(52)*.

Seeds are normally planted in light-textured, well-drained soils in the nursery. Nursery-grown seedlings usually reach plantable size in 2 to 3 months *(51;* author personal observation). Plantations are commonly established using containerized seedlings or branch cuttings *(51)*. In areas receiving erratic rainfall, cuttings measuring 1.2 m were preferable to 0.5-m cuttings *(55)*. In nursery trials conducted in Costa Rica involving 10 Central American provenances, average seedling heights for all provenances were 4.9 cm at 15 days and 42.2 cm at 60 days, with an average root collar diameter of 6.3 mm at 60 days *(39)*. In trials conducted in Puerto Rico, direct seeding resulted in good survival and growth during the first 3 months after sowing, but during the subsequent 15 months, only 7.5 percent of the seedlings survived, and the mean seedling height was 1.3 m.[1]

Abundant seed production, rapid germination, and early seedling growth make gliricidia an aggressive colonizer in disturbed habitats such as roadsides and deforested areas in its native range of Mexico and Central America *(22)*. Natural regeneration of gliricidia tends to be very poor where planted in Puerto Rico and in Nigeria *(6)*.

Vegetative Reproduction.—Gliricidia is easily propagated by cuttings with or without auxin treatment, provided cuttings are of sufficient age and size *(13)*. Good results are usually obtained using stem cuttings that are 6 months old or older, with a minimal length of 50 cm, and by planting the cuttings in moist soil to a minimum depth of 10 cm *(53)*. Stem cuttings may be as large as fenceposts *(25)*. Experiments were conducted with 20-cm-long softwood cuttings (6 months old) and mature wood (6 to 12 months old) under different watering regimes, hormone applications, and bark stripping treatments (removal of bark from base of cutting). The results indicated that short softwood cuttings do not root regardless of treatment *(15)*. The same study reported that both commercial hormone rooting powder and bark stripping increased the survival rate of mature cuttings 35 days after establishment. The most successful treatment (86-percent survival) for mature cuttings was bark stripping and mist watering for 3.5 minutes at 12-hour intervals. Tissue culture plantlets have been produced using pollen *(2)*.

Gliricidia readily resprouts after cutting and is commonly managed through coppicing or pollarding. Rapid vegetative regrowth occurs even after severe fires have killed the upper parts of the trees *(22)*. Similarly, seedlings whose aerial portions were destroyed by hurricane-force winds recovered quickly by producing numerous basal sprouts *(33)*.

Sapling and Pole Stage to Maturity

Growth and Yield.—Mature trees are characterized by short trunks that are often twisted. The trees may have a d.b.h. of up to 30 cm, with a gray or light-brown, smooth or slightly fissured bark, and irregular, spreading crowns. Average height at maturity ranges from 5 to 15 m. Leaves are alternate, pinnately compound, 15 to 40 cm long, with slender, yellow-green axes covered with fine hairs. Each pinnae is composed of 7 to 17 leaflet pairs and a terminal leaflet. Leaflets are elliptical or lance-shaped, 3 to 6 cm long and 1.5 to 3.0 cm wide. The smooth-edged leaflets are short- to long-pointed at the tip, rounded or short-pointed at the base, with thin, dull-green and hairless upper surfaces; slightly hairy, gray-green lower surfaces; and hairy leaflet stalks 5 mm long *(25)* (fig. 3).

When managed as a hedgerow crop or living fence, gliricidia is planted at spacings of 30 to 45 cm or greater. In such plantations, leaf biomass production is optimized by harvesting once or twice a year during the first 2 years and every 3 months thereafter *(53)*. In Central America, gliricidia in natural forests are typically cut for fuelwood on rotations of 6 to 8 years. Fuelwood plantations in this region are commonly established at densities ranging from 1,000 to 5,000 trees per hectare and coppiced every 5 years *(21)*. In tropical Asia, woodlot plantations are generally established at 1- by 1-m to 2.5- by 2.5-m spacings, and coppiced every 1 or 2 years after trees are well established *(53)*. Trees are usually cut near the ground in woodlots and in intercropped hedgerow agroforestry systems, or at a height of 1 to 2 m for shade trees or living fences *(53)*.

[1] On file with the Institute of Tropical Forestry, USDA Forest Service, Southern Forest Experiment Station, Río Piedras, PR.

Growth rates as well as foliage and wood yields for gliricidia are highly variable and depend largely on site conditions and management. During the first 2 years, reported annual height increments range from 0.4 to 4.3 m per year *(5, 10, 14, 17, 33, 53)*, and annual stem diameter increments range from 1.9 to 3.5 cm per year *(5, 10, 33)*.

In the early 1980's, a comprehensive study of gliricidia was initiated in experimental fuelwood plantations across a wide range of site conditions in Guatemala, Honduras, El Salvador, Nicaragua, Costa Rica, and Panama. This study provided a wealth of growth and yield data. Based on this study, site index curves for dominant height, basal area, and total wood production have been developed for stands between 12 and 60 months old at an initial stocking of 2,500 trees per hectare *(21)*. On intermediate quality sites, the current annual increment for fuelwood culminated at 2 years at approximately 4.5 kg per tree; mean annual fuelwood increment culminated between 3 and 4 years at approximately 3.5 to 4.0 kg per tree *(21)*. The following regressions were developed for site index, mean tree height, basal area, and fuelwood dry mass *(21)*:

Site index (SI): $\ln(SI) = 2.5055 + (age^{0.4551}/5.823)(\ln H_d - 2.5055)$

where

H_d = dominant height in meters; age is in months

$r^2 = 0.80$; $n = 477$

Mean height (m): $\ln H = 0.1671 - 14.684/age + 0.9538 \ln(SI)$

$r^2 = 0.85$; $n = 472$

Basal area (m^2/ha): $BA = 12.249\,(1 - e^{-0.005948\,SI*age})^{2.0981}$

$r^2 = 0.62$; $n = 310$

Fuelwood dry weight (kg/tree):

$\ln(FDW) = -1.229 + 0.94 \ln ba$

where

ba = basal area per tree in cm^2

$r^2 = 0.87$; $n = 86$.

In the Philippines, where gliricidia woodlots are generally coppiced once a year for fuelwood production, annual yields (stacked volume) range from approximately 23 m^3/ha on sloping lands with shallow soils to 40 m^3/ha on deeper soils *(53)*. At a degraded site in Java, total aboveground biomass in 6-year-old stands were reported to be 47.3 to 53.2 t/ha at a spacing of 2 by 1 m, and 38 t/ha at a spacing of 4 by 1 m *(53)*.

Rooting Habit.—Gliricidia tends to form an extensive lateral root system and is reportedly more shallow-rooted than species such as *Leucaena leucocephala* (Lam.) de Wit, *Gmelina arborea* Roxb., and *Flemingia congesta* Roxb. *(19)*. Unlike those grown from seeds, plants propagated from cuttings do not develop significant taproot systems *(10)*. Two-year-old trees grown from seed on coastal sands in Puerto Rico showed very poor taproot development but extensive, shallow lateral root development (author, personal observation). The fine roots are nodulated with nitrogen-fixing bacteria of the Rhizobiaceae. Nodulation of cuttings normally occurs within 3 months of planting *(53)*. Annual rates of nitrogen fixation by gliricidia have been estimated at 13 kg/ha *(38)*.

Reaction to Competition.—Seedlings are susceptible to competition from grasses during the first year or so of growth. Once established, however, gliricidia is an aggressive competitor. For this reason, gliricidia has been cultivated in West Africa and Indonesia to reclaim grasslands dominated by spear grass, *Imperata cylindrica* (L.) Beauv. *(3, 53)*.

Damaging Agents.—A number of insect pests cause minor damage to gliricidia in Trinidad *(40)*, including the scale insect *Orthezia praelonga* Douglass, the mealy bug *Puto barberi*, and the aphid *Aphis liburni (26)*. The species is a host of the weevil, *Ceutorhynchus asperulus*, which in southern India is a pest of pigeon pea, *Cajanus cajan* (L.) Millsp., *(45)* and of the polyphagous mites *Oligonychus biharensis* Hirst *(12)* and *Eutetranychus orientalis* Klein in the State of Karnataka, India *(9)*. Gliricidia is an alternate food plant for the lepidopteran pests *Orgyia postica* (Wlk.) and *Dasychira mendosa* (Hb.) *(37)* and for the groundnut aphid *Aphis crassivora* (Koch.) in India *(34)*. In Puerto Rico, leaf spot caused by *Cercospora gliricidiae* Syd. and thread blight caused by *Pellicularia koleroga* Cke. have been reported *(48)*. *Colletotrichum gloeosporioides* Penz. and *Cercosporidium gliricidiasis* have been identified as the causes of leaf spot on gliricidia in Nigeria *(23)*. A species of *Cladosporium* has been found to cause severe defoliation of young trees in Costa Rica *(17)*. The root fungus *Sphaerostilbe repens* Berk. & Br. infects gliricidia in Trinidad *(40)*. The stems of young plants and branches of older trees are brittle and break fairly easily, making gliricidia susceptible to damage by high winds and livestock.

SPECIAL USES

Gliricidia is often cultivated as a living fence, with shoots cut at frequent intervals for use as green manure *(27, 55)*, cattle fodder *(42)*, and fuelwood. As a fodder source for large and small ruminants, leaves of gliricidia have a mean crude protein content, lignin content, and *in vitro* dry matter digestibility of 19 to 30 percent *(13, 53)*, 9.14 percent, and 48 to 75 percent, respectively *(1, 43, 53)*. Gliricidia leaf meal has been found to be a useful additive in rations for laying hens *(31)*. Its use as fodder for livestock is debatable; although it has high nutritional value, palatability and toxicity problems have been reported *(13)*.

Gliricidia is also used in firebreaks and windbreaks and for reforestation of denuded watersheds *(25, 53)*. It is widely cultivated in agroforestry systems *(7, 8, 20)* as a shade tree for coffee, tea *(41)*, and cacao; as a support for vanilla *(4)* and pepper vines; and as an understory crop in coconut plantations *(27)*. Its use as a shade tree for cacao appears to have originated among the Aztecs in Mexico, by whom the tree was known as "cacahuanantl," or mother of cocoa *(26)*.

In the Philippines, branches of gliricidia are spread in rice fields, where they help to repel rice pests such as caseworm *(Nymphula* sp.) and whorl maggot *(Hydrellia* sp.) *(24)*. Using gliricidia as green manure in flooded, DDT-contaminated soils has been reported to accelerate reductive dechlorination of the pesticide without encouraging the formation of toxic byproducts *(30)*.

The sapwood is light brown and the heartwood is dark brown. The wood turns reddish on exposure; it is hard, heavy, strong, coarse-textured, and has an irregular grain. The wood seasons well, and, although not easy to work, it takes a good polish and is resistant to termites and decay. It is a useful source of fuelwood, and has a specific gravity of 0.47 to 0.75 g/cm^3 *(39, 53)* and a calorific value of 4.91 kcal/g *(51)*. Gliricidia is sometimes used for charcoal production, although no specific data on this use are available *(53)*. The wood is widely used for posts, railway ties, and heavy construction and locally for furniture, farm implements, tool handles, and small articles *(25)*. Although gliricidia is sometimes considered unsuitable for pulp and paper production *(56)*, when it is used for these purposes it is usually mixed with wood of other species *(53)*.

The toxic seeds, bark, leaves, and roots are used to poison rats and other rodents *(25, 44, 49)*. Despite their reported toxicity to humans when consumed raw, flowers are sometimes eaten fried or boiled. Leaves hasten the ripening of bananas. The flowers are a source of pollen and nectar and have considerable potential value in apiculture *(50)*. Freshly crushed leaves are used as poultices in home remedies in some locales *(11, 25)*. In the Mexican state of Yucatán, various components of gliricidia are used medicinally for their possible antihistaminic, antipyretic, and diuretic properties *(29)*.

GENETICS

There is considerable variation in seed color and weight and in the morphology of pods, flowers, and leaves. Variations in seedling growth rates were reported among provenances from several locations in Guatemala and Costa Rica. Seed weight clearly increases with increasing altitude *(39, 47)*. Significant variations also have been reported among provenances and site characteristics with respect to early growth *(16)*.

The genus *Gliricidia* contains three or perhaps four species *(22)*. Although *G. maculata* (H.B.K.) Steud. has been considered a botanical synonym of *G. sepium*, it appears instead to be a separate taxon native to the Yucatán peninsula, northern Guatemala, and Belize, occurring at low densities in semideciduous forests. *Gliricidia maculata* is distinguished from *G. sepium* by its white flowers, smaller pods and seeds, distinctive leaflets, and its isolated distribution. *Gliricidia guatemalensis* M. Micheli, a highland species found between altitudes of 1,500 and 2,000 m, is native to southern Mexico, Guatemala, El Salvador, Honduras, and possibly Nicaragua. It is a small tree or woody shrub with smaller leaves, flowers, and pods than *G. sepium* *(22)*.

In the past, *G. sepium* has been placed in the genera *Robinia* and *Lonchocarpus* *(22)*. Botanical synonyms in addition to *Gliricidia maculata* include *G. lambii* Fernald, *Robinia sepium* Jacq., *R. maculata* H.B.K., *R. variegata* Schlecht., and *Lonchocarpus maculatus* DC. *(32)*. The Latin generic name, meaning "mouse-killer," and the specific meaning, "of hedges," indicated the species' uses.

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