Tamarindus indica L. Tamarind

Leguminosae (Caesalpinioideae) Legume family

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Tamarindus indica L. is a large, long-lived, usually evergreen tree native to the Old World Tropics. Commonly known as tamarind, this tree is widely planted and naturalized in tropical and subtropical regions, including the Caribbean, Central America, and northern South America *(26)*. Mature individuals, which commonly grow to heights of 25 m, with stem diameters of up to 150 cm, are characterized by a dense, spreading, rounded crown, a low-branching habit, paripinnate leaves, and thick, gray, deeply fissured bark *(30, 44)*. In the American Tropics, tamarind is cultivated chiefly for its fruits, as a source of fuelwood, and as an ornamental *(26)*.

HABITAT

Native Range

Tamarind is native to the dry savannas of tropical Africa (fig. 1), from Sudan, Ethiopia, Kenya, and Tanzania, westward through sub-Sahelian Africa to Senegal *(15, 16, 23, 30, 44)*. Senegal's capital city, Dakar, is named after the tree *(30)*. The tree was introduced to Egypt, the Middle East, and Asia by Arab traders in antiquity, and to the New World Tropics in more recent times, probably during the early years of the West African slave trade *(30)*. It is now cultivated pantropically, and has become naturalized in many locales, particularly in South Asia *(13, 19)*. In Puerto Rico, it is fairly common along roads, around houses, and on hillsides in dry, coastal regions *(26)*.

Climate

Tamarind is adapted to regions that have extended dry seasons *(30)*. In humid tropical regions with a constant rainfall pattern, trees tend to grow poorly and generally do not produce fruit *(1, 30)*. Seedlings are very sensitive to frost but can withstand drought *(44)*. The strong, supple branches are seldom affected by wind, and the tree is known to be hurricane resistant *(30)*.

Soils and Topography

Tamarind requires well-drained soils and grows best on deep, alluvial soils *(13)*. The species can flourish on a wide variety of soils, including coastal sands and rocky soils *(30)*, although poor growth has been reported on sites characterized by a shallow, calcareous hardpan *(14)*. Tamarind is often found growing along streambanks and riverbanks and, in its native range, on or beside anthills and termite mounds *(1, 16, 18, 23)*. It is well adapted to dry savannas and poor soils in lowland areas *(1)*. In northeast Thailand, tamarind has been reported to establish naturally in areas with recently salinized soils *(31)*. In East Africa, tamarind is reportedly found growing from near seal level to an altitude of 1,500 m *(7, 15)*.

Associated Forest Cover

In the Sahelian region of Africa, tamarind is commonly associated with baobab (*Adansonia digitata* Linn.) *(16)*, and in East Africa tamarind is commonly found growing in woodlands, wooded grasslands, and deciduous bushlands *(7)*. In the tropical dry riverine forests of south-central India, tamarind is occasionally found in association with *Terminalia arjuna* W. & A., *Anogeissus acuminata* Wall., *Pongamia glabra* Vent., *Barringtonia acutangula* Gaertn., and *Alangium lamarkii* Thw. *(12)*. In the dry deciduous forests of the Western Ghats (India), tamarind occurs as a canopy codominant in association with *Chloroxylon swietenia* DC., *Givotia rottleriformis, Gyrocarpus jacquini, Commiphora caudata, Moringa oleifera* Lam., and *Holoptelia integrifolia* Planch. *(39)*.

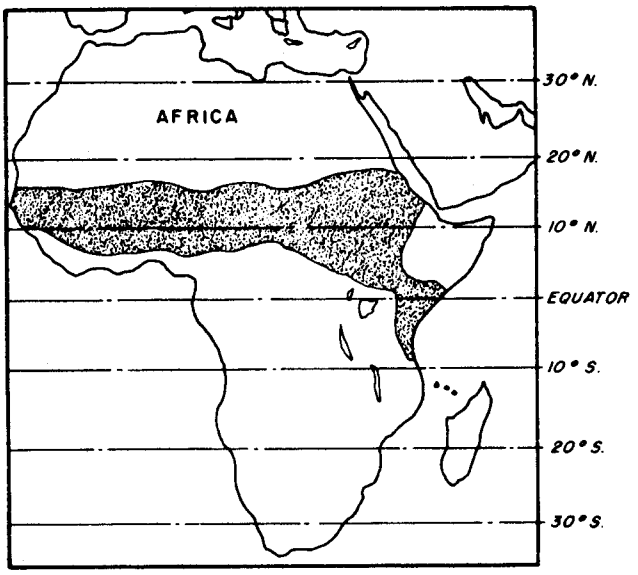

Figure 1.—*Shaded area represents approximate native range of tamarind,* Tamarindus indica *L., in Africa.*

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LIFE HISTORY

Reproduction and Early Growth

Flowering and Fruiting.—Flowering generally occurs in synchrony with new leaf growth, which in most areas is during the spring and summer *(4)*. In Sri Lanka, tamarind exhibits two flowering periods, one between March and April and the other in October *(47)*. The flowers are borne throughout the canopy in small, loose, showy clusters of pale-yellow, pink-veined blossoms *(30)*. Individual flowers, measuring approximately 2.5 cm in diameter, have three stamens and three unequal petals, one variegated yellow and red or orange, and the other two reduced to minute scales *(4, 15)*.

Tamarind usually starts bearing fruit at 7 to 10 years of age *(24, 30)*, with pod yields stabilizing at approximately 15 years *(24)*. Oblong in shape and roughly oval in cross section, the fruits are 8 to 15 cm long, 1.9 to 2.5 cm wide, 1.0 to 1.6 cm thick, curved and irregularly swollen, and brown in color (fig. 2, *26*). When ripe, pods are brown in color with a brittle epicarp, and contain several seeds (usually 3 to 10) set in a dark-brown, fibrous pulp *(4)*. The indehiscent pods ripen approximately 10 months after flowering and may remain on the tree until the following flowering period *(4, 13, 34)*.

Seed Production and Dissemination.—Seeds are obovate-orbicular, compressed, shiny brown in color, approximately 1.6 cm long, with roughly 850 to 1,000 seeds per kilogram *(13, 26, 46)*. Seeds are released from the fallen pods following partial decomposition and are sometimes dispersed by animals, which consume the pods. In South Asia, monkeys are among the chief dispersal agents *(44)*. The pedicles that hold the fruit to the tree are very strong and must be clipped rather than torn by hand to avoid damaging the fruit *(30)*.

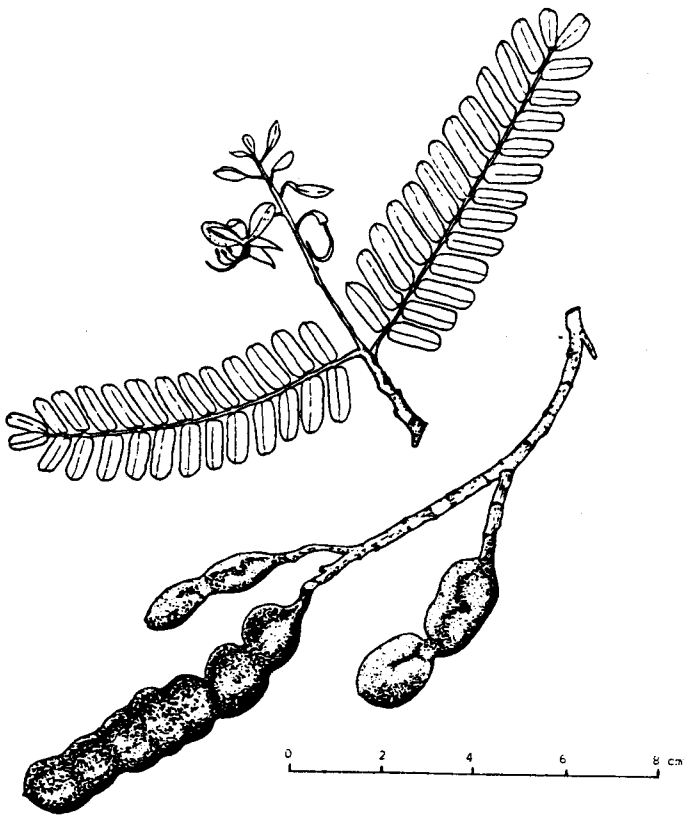

Figure 2.—*Foliage and fruit of tamarind,* Tamarindus indica *L. (adapted from* 26*).*

Seedling Development.—Germination in tamarind is epigeous *(44)*. Recommended seed treatments include soaking in cold or tepid water for 24 to 48 hours, with or without an initial soaking in hot water, although seeds may be sown without pretreatment *(44, 46)*. Seeds germinate 5 to 10 days after sowing, either in containers or in raised nursery beds containing light, porous soil *(44)*. Germination ranges from 30 to 70 percent. The natural regeneration is reported to be good *(43)*.

Seedlings produce a long taproot at an early age, which may reach 30 cm or more in length within 2 months of germination *(44)*. Under favorable conditions, seedlings grow 60 cm or more in height during each of the first two growing seasons *(44)*. Early growth is favored by weed control, porous soils, and light shade *(44)*. Seedlings in the nursery are reportedly tolerant of alkaline irrigation water (pH 8.4), with high concentrations of carbonate (12 mg/L) and bicarbonate (0.66 g/L) *(25)*.

Plantations may be established by direct sowing along cleared lines or by transplanting containerized seedlings *(13, 44)*. Containerized seedlings may be transplanted from 4 to 6 months after sowing; transplantings should be conducted during the rainy period in seasonally dry regions *(44)*. In India, seedlings ranging in size from 40 cm to 2 m in height are commonly planted *(24)*.

Transplanting of larger, older seedlings with entire root systems is more difficult; these are more effectively transplanted as stumped seedlings, with stems and taproots pruned to lengths of about 5 cm and 20 to 25 cm, respectively *(44)*.

Vegetative Reproduction.—Tamarind produces root suckers when damaged *(44)*. Girdling etiolated shoots reportedly stimulates air-layered root growth within 10 weeks, a process that can be accelerated by several weeks through the application of the growth regulator indolebutyric acid *(20)*. Successful grafting techniques have been reported in Peru *(35)*.

Sapling and Pole Stage to Maturity

Growth and Yield.—Tamarind's growth is slow, with annual height increments usually between 0.5 and 0.8 m *(11, 30, 43)*. Depending on site conditions, mature trees attain a maximum height of between 15 to 25 m *(1, 13, 24)*. A maximum trunk diameter at breast height (d.b.h.) of 4.1 m was recorded in Sri Lanka *(19)*. Trees are often very long lived; individuals with ages of up to 150 years in Hawaii and 200 years in Sri Lanka have been reported *(1)*.

Average annual fruit yields from a mature tree are approximately 150 to 200 kg per tree, or about 12 to 16 t/ha *(30)*, although yields as high as 500 kg per tree have been reported in India *(24)*. As pod yields start to decline, usually at an age of 50 years or more, trees are commonly harvested for fuelwood or charcoal *(24)*.

Rooting Habit.—Tamarind trees produce a stout taproot and an extensive lateral root system, except on sites characterized by poorly drained or compacted soils *(13, 14)*. While

tamarind had earlier been considered to be a non-nodulating species *(1)*, recent evidence suggests that it does in fact form a symbiotic association with *Rhizobium* spp. bacteria *(3)*, enabling the tree to fix atmospheric nitrogen under appropriate conditions *(17, 33)*. Root nodules collected from trees grown in plantations on acidic soils in Guangdong Province, China, described as elliptical or circular and light yellow in color, reportedly had a high nitrogenase activity *(33)*. Rhizobial isolates from tamarind in the Philippines have been described as gram negative, with short and long rods *(33)*.

Reaction to Competition.—Tamarind is shade intolerant and does not appear to regenerate beneath its own canopy. The deep shade cast by the tree's dense canopy and abundant leaf litter prevents most undergrowth. In India, tamarind plantations are generally established at relatively wide spacings, commonly 8 by 8 m, 8 by 12 m, and 12 by 12 m *(24)*. Because of the allelopathic effects often attributed to tamarind *(19, 48)*, mixed species plantations are not recommended.

Damaging Agents.—The most serious insect pests of tamarind in India are reported to be the scale insects *Aonidiella orientalis* (Newst.), *Aspidiotus destructor* Sign., and *Saissetia oleae* (Ol.); the mealybugs *Nipaecoccus viridis* (Newst.) and *Planococcus lilacinus* (Ckll.); and the borer *Pachymerus gonagra* Fabr. *(8, 13)*. Leaves are frequently eaten by the bruchid beetle *Caryoborus gonagra* Fabr. *(19)*. The lac insect *Kerria lacca* (Kerr) and the bagworm *Pteroma plagiophleps* Hampson have been reported as minor pests in India *(9, 29)*. In Brazil, the larvae of the beetle *Lochmaecles* sp. has been reported to cause some damage to tamarind branches *(10)*. In south India, tamarind is reported to be a host of the burrowing nematode *Radopholus similis*, a serious pest of coconut palm *(42)*. The termite *Cryptotermes hainanensis* (Isoptera, Kalotermitidae) has been reported on tamarind in Hainan, China *(32)*.

Several insects are known to attack the fruits and seeds of tamarind. In India, stored tamarind pods are reportedly susceptible to attack by *Paralipsa gularis* (Zell.) and *Corcyra cephalonia* (Stnt.) *(8)*. The larvae of the groundnut bruchid beetle *Caryedon serratus* (Olivier), considered a serious pest in India *(8, 27)*, has been recently reported in Colombia *(45)* and Puerto Rico *(2)*.

Tamarind is reportedly susceptible to a large number of diseases in India *(28)*. These include leaf spot caused by *Bartalinia robillardoides* Tassi *(38)*, *Exosporium tamarindi* Syd., *Hendersonia tamarindi* Syd., *Pestalotia poonensis* V.Rao, *Phyllosticta tamarindicola* V.Rao, *P. tamarindina* Chandra & Tandon, *Prathigada tamarindi* Muthappa, *Sphaceloma* sp., and *Stigmina tamarindii* (Syd.) Munjal & Kulshreshta; the powdery mildews *Erysiphe polygoni* DC and *Oidium* sp.; and the sooty mold *Meliola tamarindi* Syd. *(28, 41)*. *Fracchiaea indica* Talde has been reported as a stem disease, *Ganoderma lucidum* (Leyss.) Karst. as a cause of root and wood rot, *Hypoxylon nectrioides* Speg. as the cause of stem canker, *Lenzites palisoti* Fr. as a wood rot, *Myriangium tamarindii* Tendulkar as a bark parasite, *Pholiota gollani* P.Henn. as a stem rot, *Phytophthora nicotianae* var. *nicotianae* as a collar rot, and *Stereum nitidulum* Berk. as a trunk and root rot *(28, 40)* of tamarind trees.

SPECIAL USES

In its native and introduced range, the wood is highly valued, although most trees produce very little heartwood *(13)*. The sapwood is up to 200 mm wide, pale yellow, and sometimes red streaked; the heartwood is generally narrow, dark brown to purplish, and mottled with black in old trees *(6, 16, 18)*. The wood is very hard and heavy, with a specific gravity of 0.86 to 0.90 g/cm^3, tough and fibrous, difficult to work, and liable to crack in seasoning; however, the wood does polish well *(1, 6, 13, 16, 18)*. It is used for carpentry, furniture, boats, wheels, agricultural implements, sugar mills, mortars, and pestles *(13, 16, 34)*. The wood has been sold in North America as "Madeira mahogany" *(30)*. Tamarind wood is described as producing a superior charcoal *(13)*.

The pulp of the fruit, which comprises about half the pod weight and has a sweet-sour taste, contains sugars (30 to 40 percent by weight); organic acids such as citrus, acetic, tartaric, and ascorbic (vitamin C); pectin; vitamins; and minerals. It is also a rich source of calcium *(13, 30)*. The pulp is used extensively in south Indian cooking and for the preparation of refreshing drinks, confections, and ice cream throughout the species' native and introduced range *(16, 18, 26, 30)*. The leaves, flowers, and sometimes the seeds are also used in cooking *(4)*.

Tamarind products are used extensively in traditional Indian and African medicine. A decoction of the bark is used as an eye lotion and as an astringent in the treatment of diarrhea *(4, 16)*. Ash of the bark is used as a digestive aid in India *(34)*. In eastern Sudan, the bark is used as a tonic and antipyretic *(16)*. A poultice of the leaves is used to wash wounds and to reduce inflammation *(16, 34)*. The leaves are also used in the treatment of ulcers *(34)*, and the juice of the leaves, boiled with oil, is applied externally to treat rheumatism and external swellings *(34)*. A poultice of the flowers is given to relieve conjunctivitis, and boiled leaves are used externally to treat ophthalmia in India *(34)*.

The powdered seeds are astringent and are used to treat dysentery and boils in India *(34)*. Boiled, pounded seeds are reportedly used to treat ulcers and bladder stones, and powdered seed husks are used to treat diabetes *(34)*. The pulp of the fruit is often used as a dressing for wounds *(16)* or eaten as a laxative and carminative *(4, 13, 16, 18)*. The fruits were well known in Europe during the Middle Ages for their medicinal properties, having been introduced through Arab trade from India *(4)*.

The root is used in conjunction with other native medicines for the treatment of leprosy in northern Nigeria and is used elsewhere in Africa for the treatment of chest pains *(16)*. Root bark, powdered or in decoction, is taken as a remedy for diarrhea and dysentery in India *(34)*.

The ground seeds may be used as livestock feed and can be prepared for use in stabilizing processed foods and in jelling fruit juices *(30)*. Ground, boiled, and mixed with gum, the seeds produce a strong wood cement *(4, 34)*. Seeds are also used to produce an amber-colored oil for burning in lamps or for the preparation of paints and varnishes *(34)*.

The leaves yield a red dye, which is used to give a yellow tint to cloth previously dyed with indigo. The pulp of the fruit, sometimes mixed with sea salt, is used to polish silver, copper, and brass in India and elsewhere (*4, 18*). The fruits are reported to have antibacterial and antifungal properties (*21, 36*), and the seed husk has been found to be an effective fish poison (*37*). Both the leaves and bark are rich in tannins (*1, 6*), and an ink is made from the burned bark (*1*). Ashes of the wood are used in removing the hair from animal hides (*16, 23*), and tamarind wood ash, pods, bark, and plant galls collected from young branches are all used in leather and fabric dyeing in parts of Africa (*16, 23*).

Tamarind is not recommended as a shade tree, as it appears to have an allelopathic effect on understory vegetation (*19*). Tamarind leaf extracts have been reported to reduce mitotic activity and induce chromosomal aberrations in *Allium sativum* root meristems (*48*).

In Africa, tamarind is a host of one of the wild silkworm (*Hypsoides vuillitii* Joannis) (*16*). The flowers are reportedly a good source of honey (*30*).

GENETICS

There appears to be considerable genetic variation within tamarind's native African and introduced South and Southeast Asian ranges, as indicated by wide variations in commercial pulp quality (*7, 30*). A red-fruited variety common in India has been considered an infraspecific taxon, *Tamarindus indica* var. *rhodocarpa* (*5*). To date, however, no large-scale germplasm collections have been initiated. *Tamarindus indica* is the sole member of the genus *Tamarindus*. Botanical synonyms include *T. occidentalis* Gaertn. and *T. officinalis* Hook. (*22*). The name tamarind derives from the Arabic "tamar-u'l-Hind," meaning "date of India" (*30*).

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