Tamarindus indica (Tamarindo)

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Agricultural science 2024-2025
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Introduction:

Besides the ecological and biological importance of Tamarind, the Tamarind tree has a lot of history in human use. The Tamarind pulp has lots of vitamins, minerals, and antioxidants, which makes it very popular in Asia, Africa, and Latin America, and it is used as an ingredient in cuisine. Because of its sour flavor, you can see this fruit, especially in candies or drinks. Tamarind is used not only in food but also in medicine. They use it to help with inflammation and digestion. In many traditional medicinal systems, tamarind preparations are believed to aid in treating ailments such as fever, sore throat, and digestive discomfort. The versatility of tamarind in both culinary and medicinal contexts highlights its importance across different cultures.

1 Ecology

Table of affinities

Domain	**Eukaryota**
Kingdom	**Plantae**
Phylum	**Spermatophyta**
Subphylum	**Angiospermae**
Class	**Dicotyledonae**
Order	**Fabales**
Family	**Fabaceae**
Subfamily	**Faboideae**
Genus	***Tamarindus***
Species	***T. Indica***

1.1 Affinities:

Tamarindus indica (Tamarind) belongs to the family of Fabaceae, It is classified in the domain Eukaryota because its cells have distinct nuclei and membrane-bound organelles, typical features of other multicellular organisms like flowering plants, animals, and fungi. The tamarind belongs to the Kingdom Plantae, which makes it an autotroph. Autotrophs are organisms that manufacture their food through the process of photosynthesis, which involves the conversion of sunlight, water, and carbon dioxide into sugars and oxygen. (Smithsonian Science Education Center.) Tamarind is a plant that reproduces through its seed and “it belongs into the Phylum Spermatophyta as it reproduces” as it reproduces. Tamarind belongs to the class Dicotyledonae,

known as Dicots. Dicots are plants whose seeds contain two cotyledons, the leaves that first appear when a seed has sprouted. (*Cotyledon*. May 22, 2025)

It is classified by a few characteristics: flower parts typically numbering multiples of four or five, and veins that form a net-like pattern in their leaves. Besides, in tamarinds and other dicots, there is a taproot system with a large primary root running deep into the soil, which helps the plant draw water and nutrients in arid environments.(Moore & Bradley, 2022)

The order Fabales is one wherein tamarinds are grouped, primarily being legumes. This is an order quite remarkable for plants, which generally have symbiotic associations with nitrogen-fixing bacteria in their nodules, which act to enrich the soil. Of tropical and subtropical origin, this plant does well in extremely hot climates with seasonal rainfall, hence being quite adaptable to regions like Africa, South Asia, and Latin America.

While the common characteristics by which these pod-bearing plants may be recognized include fruits that grow from a solitary ovary, they usually consist of one or more seeds. The genus *Tamarindus* comprises only one species, *Tamarindus indica,* which indicates that it is a distinctive member of its genus. The species epithet, indica, reveals evidence of its historical importance and range in the Indian subcontinent; currently, this plant is widely cultivated in the tropics of both hemispheres. They have lived for a long time, they are in sturdy trees that can reach up to 20 to 30 meters, and some leaves that protect them from the hot climate. The fruit is brown and sticky, and it has a sour-sweet pulp highly valued for culinary, medicinal, and traditional uses. (Morton, J. (1987).

1.2 Environmental factors affecting its growth:

The tamarind uses, for the most part, the more common C3 photosynthetic pathway (The most common pathway for carbon fixation in plants. Under optimal conditions, photosynthesis of C3 plants occurs during the day when the stomata-one of the small pores in leaves that allow carbon dioxide to enter for sugar production, open. Tamarind uses several strategies to survive in drier climates than CAM species, though it may not be as water-conservative as C3. Its deep taproot system allows it to retrieve water stored deep beneath the ground surface, and its leaves are structured to significantly reduce the rate of transpiration through water loss. This will be important during dry seasons when most of the leaves fall to conserve water, and thus it can survive even in extremely unfavorable conditions of the environment.

1.3 Fossil record:

The fossil record of tamarind (*Tamarindus indica*) is not very complete, but if they were tamarind fossils, they would be found in places where they could be preserved.

Tamarind originally comes from tropical Africa, and there's evidence it has been around for thousands of years, spreading to other tropical areas like South Asia. Its history is still a bit unclear. Plants in drier or cooler places are more likely to leave fossils behind. There is some indirect proof of tamarind being grown a long time ago, such as ancient burned seeds found at archaeological sites in Africa and India. This suggests tamarind was used in early farming. Even

though we don't have a lot of tamarind fossils, its long history is supported by these archaeological finds and where it grows today.

(Duke & Duke, 2011)

1.4 Centre of origin:

Tamarind is one of the major tree species. Native to Madagascar, it is now grown in India, Thailand, Mexico, the Middle East, Africa, Southeast Asia, the Caribbean, Bangladesh, Myanmar, Malaysia, Sri Lanka, Central Africa, Australia, and Central and South America. It is one of the most common trees in most parts of India and the source of one of the most commonly used spices in the Indian kitchen. Tamarind grows well in areas above 1500m in elevation

(Azad, 2018).

1.5 Present distribution

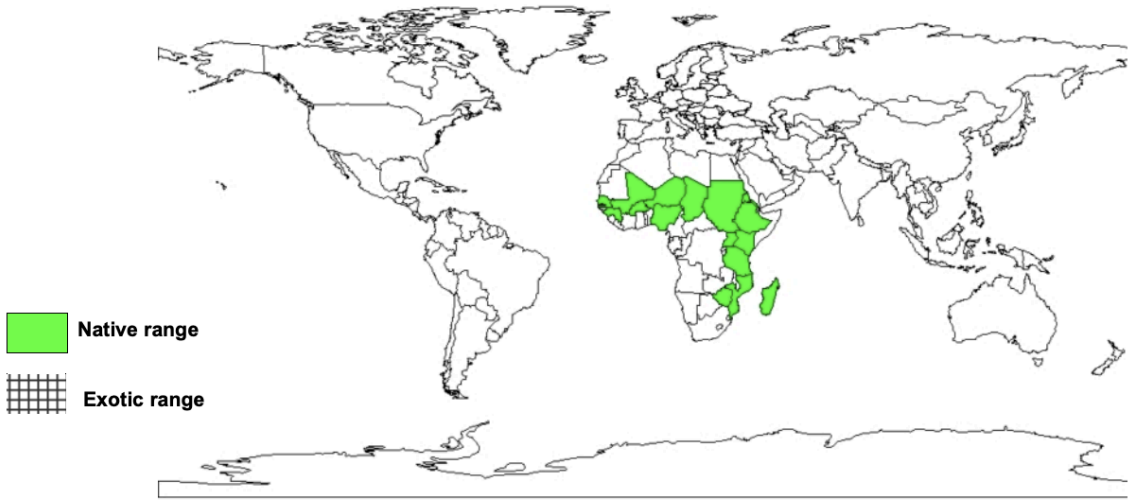


Photo of tamarindus native range and exotic range (Growables., n.d.).

Tamarind fruits were widely traded in ancient times, and even records from the eastern Mediterranean show that Tamarind had already been grown in the area in the fourth century B.C. Tamarind was introduced to India and Asia because of human transportation thousands of years B.C., and it extended the history of cultivation in the Indian subcontinent, which is sometimes reported to be indigenous. The species later spread throughout India to Persia and Arabia. Of tropical and subtropical origin, this plant does well in extremely hot climates with seasonal rainfall, hence being quite adaptable to regions like Africa, South Asia, and Latin America.

(Growables., n.d.).

1.6 Elevation

Tamarind thrives in a tropical and subtropical climate, typically ranging from sea level to roughly 1,500 meters. It thrives in warm, sunny climates below 800 meters. The ideal temperature range is 20°C to 35°C (68°F to 95°F). Tamarind dislikes frost; if it gets too cold, around 1°C (30°F), young trees may be harmed. Although it can grow in a variety of soil types, the tree favors rich, well-drained soil. Tamarinds require a dry season to yield quality fruit, but they can withstand both low and high rainfall (between 300 and 4,500 mm annually). Temperature and precipitation, which are essential for tamarind growth and fruiting, are impacted by elevation. (Rojas-Sandoval, J, 2022).

1.7 Climate

Tamarind trees grow best in warm places, and their temperature is between 15°C and 40°C (59°F and 104°F). This climate is the best for them because it is where they grow strong and produce a lot of fruit. (Greg., n.d.)

1.8 Geology and soils

Tamarindus can grow in many different types of soils and environments. It prefers deep, well-drained soils that are a little acidic, but can also grow in soils with a pH from 4.5 to 8.7. The tree grows from sea level up to 1500 meters, it's also found often near rivers and flat areas that might flood. Its strong roots help it stay upright during strong winds, storms, and salty air, allowing it to grow in many tropical areas. (Dalla Rosa, K. R, 1993, July)

1.9 Pests and Diseases

Tamarind trees (*Tamarindus indica*) are generally hardy but can be affected by certain pests and diseases. Common pests include scale insects, mealybugs, and seed beetles, which can damage leaves and fruits. Diseases such as leaf spot, powdery mildew, and sooty mold may also occur, particularly in humid climates. Regular monitoring and proper cultural practices can help manage these issues. (Prithviraj, U. (2024)

2 Biology

2.1 Chromosome complement:

Tamarindus Indica is a diploid species with a chromosome number of 2n=24. This means that each somatic (body) cell contains 24 chromosomes, arranged in 12 homologous pairs (n=12 in gametes). The diploid nature suggests that it follows normal Mendelian inheritance patterns.

(Rojas-Sandoval, J, 2022)

2.2 Life cycle and phenology

The *Tamarindus indica* life cycle begins when seeds germinate in 7 to 14 days. The seed coat is hard and typically must be scratched or soaked to facilitate growth. Following this, the seeding phase occurs, during which the young plant develops seed leaves and its first true leaves, gradually developing a vigorous main root system. In the juvenile phase, which takes place in 5 to 10 years, the tree grows steadily but slowly, developing compound leaves and a woody stem. It starts flowering at around 7 to 10 years, producing tiny, yellowfish flowers that are pollinated by bees and wind. After fertilization, it develops long, brown, curved pods that will take 6 to 9 months to mature. Pods have sticky, sour pulp covering hard seeds inside. See, dispersal occurs naturally when the pods fall or are consumed by animals, so the cycle can be repeated. *Tamarindus indica* is a long-lived tree, sometimes exceeding 100 years, and can regenerate from seeds, suckers, or cuttings, so it is an extremely hardy and productive tree.

(Growables, n.d.).

Tamarindo seeds.

The phenology of *Tamarindus indica* follows a seasonal pattern influenced by climate, primarily governed by factors such as temperature, rainfall, and overall weather conditions.It is a semi-evergreen tree and retains most of its leaves throughout the year, however, it also loses some of them during dry seasons, and new leafing starts with the onset of the rainy season. Flowering normally starts between 7-10 years old, once annually at the close of the dry season or commencement of the rainy season, in pale yellow, insect-pollinated flowers in small clusters. After pollination, 6-9 months are needed for the development of the fruit, from green pods to mature brown, woody shells containing a sweet-sour pulp. Ripening of the fruits occurs between December and June, based on local conditions, and is followed by seed dispersal through animals like monkeys and birds. The seeds, which are covered by a hard coat, remain dormant until the rainy season when natural scarification enhances germination, typically within 7-14 days. Tamarind is a slow-growing tree during its initial years but reaches 20-30 meters at maturity, fruiting annually for over a hundred years, and hence is a highly productive and ecologically significant species in the tropics.

(Rojas-Sandoval, J, 2022)

2.3 Root system

The tamarind tree has a strong root system with one big main root, called a taproot, that grows deep into the ground. It also has many side roots that spread out widely. This helps the tree find water and nutrients from deep in the soil and stay steady during strong winds or dry weather. This type of root system is very useful in hot, dry places where water is hard to find. (El-Siddig et al., 2006).

2.4 Reproductive Biology

2.4.1 Pollen

The pollen of tamarind is relatively small and sticky, which helps pollinators such as bees and butterflies transfer it. Pollen viability and dispersal play a significant role in the plant's reproductive success. This tamarind flower is small, with yellow petals marked by thin red streaks. In the center, it has delicate stamens covered in fine yellow pollen. These flowers normally grow in small, hanging clusters. When in bloom, they show a mix of colors and details that stand out and attract pollinators, for example, Bees. (Gilman, E. F, 2018)

2.5 Pollination and potential

Entomophily is the process by which insects primarily pollinate Tamarind. (Figure (Sauer, W, 1998) . Pollinators are drawn to the flowers because of their bright yellow petals with red streaks and nectar production. Insects brush against the stamens and gather nectar or pollen. Some of that pollen is transferred to the stigma as they travel to another flower, facilitating fertilization. Although butterflies, ants, and solitary bees are the most frequent pollinators. Since the flowers are not suited for the wind and the pollen is rather heavy and sticky, the wind does not significantly affect tamarind pollination.

2.6 Fruit development and seed set

In tamarindus fruit development starts when the ovary turns into a pod and the fertilized ovules become seeds following successful pollination and fertilization. As an indeterminate pod, the fruit develops slowly and usually reaches 10 to 20 cm. It begins soft and green, but it creates a brown, brittle shell with a dark, sticky pulp inside as it ages. Depending on the tree's health and pollination's effectiveness, each pod typically contains three to twelve hard, glossy brown seeds. Cross-pollination, climate, tree age, and soil nutrients are some variables that affect seed set. Fruiting typically happens once a year, usually during the dry season, and the entire development process from pollination to mature fruit takes roughly eight to ten months.
(World Agroforestry Centre, n.d.)

2.7 Sexuality and reproduction

Tamarind reproduces sexually througout hermaphrodite flowers that allow both self-pollination and cross-pollination, despite the species' strong preference for outcrossing. Its reproductive system is mostly entomophilous since it relies on insects for pollination. Open pollination usually produces only 1% to 2% of natural fruit despite this dual ability, indicating poor self-fertilization success. Tamarind pollen does not reproduce by apomixis (asexual seed formation), and it has low sterility and dimorphism, wich is beneficial for controlled breeding. These reproductive characteristics suggest that successful propagation in cultivation often requires insect pollinators and human assisted pollinator methods.

(Nagarajan et al., 1997)

3. Propagation and Management

3.1 Natural regeneration

Animals and gravity play a major role in the natural seed dispersal that allows Tamarindus indica to regenerate. Under the right circumstances, the seeds inside fallen fruits can sprout, particularly in sandy loam soils that drain well. However, the hard seed coat that restricts water uptake often slows natural regeneration, and weed competition can further complicate seedling establishment.

3.2 Nursery Propagation

3.2.1 Pre-preparation and Implications for Germination

Tamarind seeds need to be pre-treated to break dormancy and improve germination. Common techniques include mechanically scarifying the seed coat or soaking seeds in warm water for 24 to 48 hours. These treatments help accelerate germination and increase the rate of water absorption. (Khaled et al., 2023, p. 33)

3.3 Sowing and Germination Process

Before being sown 1.5 cm deep in well-draining soil at 24 to 29°, Tamarind seeds should be mechanically scarified or soaked in hot water to soften the hard seed coat. They should germinate in 10 to 15 days under ideal conditions. (Gardenisto, Greg App).

3.4 Propagation from seed

When propagating Tamarind from seed, rip pod seeds are immersed in warm water for a full day to soften the coat and improve germination. The seeds are then planted an inch deep in well draining soil and kept in a warm, sunny place at 75°F (24°C). Germination usually occurs in one to two weeks if the soil stays moist. Once about four inches tall, seedlings can be transferred to larger pots or placed outdoors in areas that don't get cold. Trees grown from seeds can produce fruit in three to four years instead of six to eight years if they are grafted or cut. (Everglades Farm, n.d.).

Process of propagating a *Tamarind* seed ((Gardenisto, 2014)

3.5 Storage

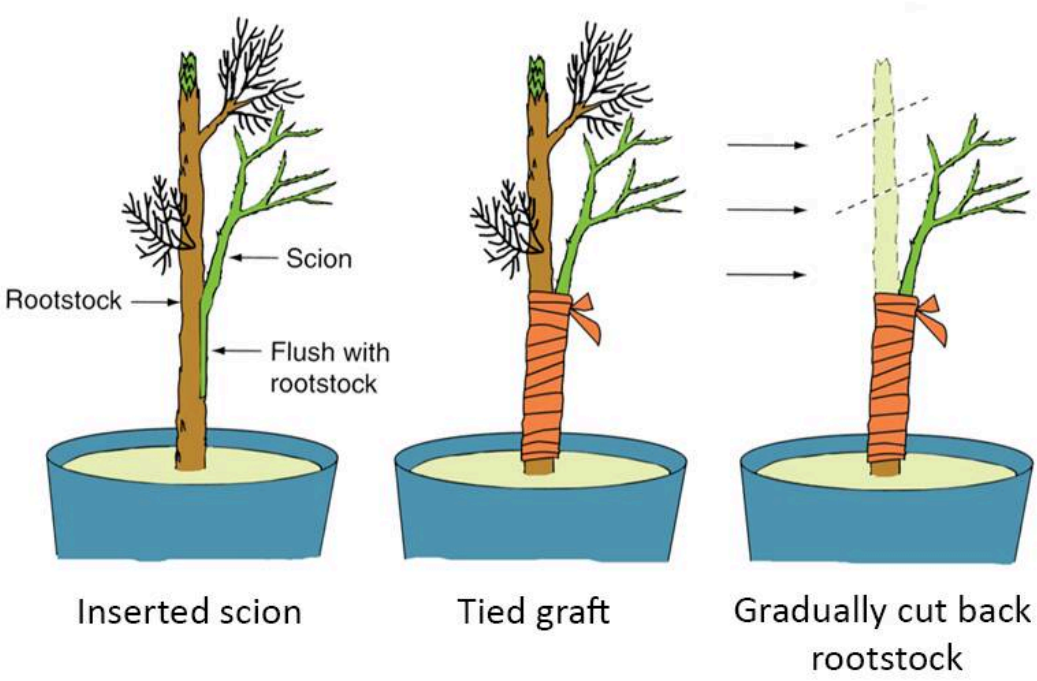
Tamarind must be stored properly to maintain it's flavor and increase it's shelf life. Tamarind paste can be kept for several weeks in the refrigerator if it is kept in a clean, airtight container. For even longer preservation, it can be frozen in small portions, for example ice cubes. This helps maintain the Tamarinds signature sweat-sour flavor over time.

(Love is in my Tummy, 2016)

3.6 Vegetative propagation

Vegetative propagation of Tamarind offers a reliable method of producing true-to-type plans, especially for cultivants with desire traits. Common techniques include veneer grafting, and air layering. Softwood grafting involves attaching a young scion to a rootstock, typically in the warmer months, to promote a successful union. Veneer grafting, wich also targets young scions, is effective in similar situations. Air layering is the process of making a branch grow roots while it is still attached to the parent plant, resulting in a new plant that can be separated once rooted. These methods are particularly helpful for ensuring consistent fruit production and preserving genetic traits.

(Gardenisto, 2014)



Example of how veneer grafting occurs ((University of Florida IFAS, 2023)

3.7 MANAGEMENT

Tamarind plays a vital role in the Wester Sahel (Africa), where it is used across seven categories, including various food forms and both human and veterinary medicine. Communities manage Tamarind thorough a mix of cultivation and reliance on wild trees, depending on local practices and availability. These diverse uses underline the species' cultural and nutrional significance. Sustainable management approaches are recommended to preserve Tamarind populations and ensure long-term access to it's benefits. (Tandfonline, 2020)

3.8 Fruiting

As Tamarind matures, its greenish interior turns brown, becoming sticky and pasty, with the seeds transioting from whitish to brown. In Mexico, Tamarind is cultivated i states like Jalisco, Guerrero, Colima, Chiapas and veracruz. The fruit is widley used to flavor various foods, candies and beverages.

(Kenyon, 2021)

4. COMMERCIAL IMPORTANCE

4.1 Exporting and importing of the product

Tamarind holds significant economic anc cultural value in India, serving as a key ingredient in various culinary and medical applications. India is the worlds largest producer of Tamarind, with an annual production exceeding 162,000 metric tons, primarily from the southern states of Tami Nadu, Karnataka, and Kerala. The country exports Tamarind in multiple forms, including raw pods, desseded pulp, paste, and processed products, to over 100 countries. Major export destinations include the United Arab Emirates, the United States, the United Kingdom, Malaysia, and Saudi Arabia. This extensive export network underscores Tamarind's importance in India's agricultural economy and its growing demand in international markets.

4.2 IMPORTANCE IN THE ECONOMY

Globally, Tamarind contributes significantly to the agricultural economies of tropical countries, especially in Asia and Africa. Its demand in food, pharma ceuticals, and cosmetic industries drives international trade, with India leading global exports. Countries like Thailand, Indonesia and several African nations also benefit economically from its cultivation and export. Tamarinds versatility and shelf stability makes it a valuable commodity in global markets, supporting income generation and rural employment.

(Seair Exim Solutions, n.d.)

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