CHAPTER 12

TAMARIND
Tamarindus indica L.

H.P.M. Gunasena
Department of Crop Science, Faculty of Agriculture,
University of Peradeniya, Peradeniya, Sri Lanka

D.K.N.G. Pushpakumara
ICRAF-Country Liaison Scientist to Sri Lanka,
Department of Crop Science, Faculty of Agriculture,
University of Peradeniya, Peradeniya, Sri Lanka

INTRODUCTION

Tamarind (*Tamarindus indica* L.) is a multipurpose tropical fruit tree used primarily for its fruits, which are eaten fresh or processed, as a seasoning or spice, or the fruits and seeds are processed for non-food uses. It is widely grown as a subsistence crop for meeting local demands. It is also grown commercially. Numerous national programmes have recognized Tamarind as an underutilized crop with wider potential since the demand for products is substantial and the species can be incorporated into agroforestry systems. There are also well established international trade channels. The importance, distribution and popularity of Tamarind in ancient Sri Lanka is explained by its uses in toponomy (e.g. Siyambalanduwa, Siyabalagastenna etc.). Further exploitation of Tamarind can therefore provide added incomes for rural communities and thereby improve their well-being.

TAXONOMY

Tamarindus is a monotypic genus containing the only species *T. indicus*. It is thought that Linnaeus gave the specific epithet *indicus* because the name Tamarind itself was derived from Arabic which combined Tamar meaning 'date' with the Hindi meaning 'of India'. The full Arabic name was Tamar-u'l-Hind and the word 'date' was included because of the brown appearance of Tamarind pulp. No systematic cytogenetic studies have been carried out for Tamarind although diploid chromosome number (2n) has been reported as 24 (x=12) (Purseglove, 1987).

The nomenclature of Tamarind is as follows:

Kingdom:	Plantae (plants)
Sub kingdom:	Tracheobionta (vascular plants)
Super division:	Spermatophyta (seed plants)
Division:	Magnoliophyta (flowering plants)
Class:	Magnoliopsida (dicotyledanae)
Sub class:	Rosidae
Order:	Fabales
Family:	Fabaceae
Genus:	*Tamarindus*.
Species	*Tamarindus indica* L.

Source: http://plants.usda.gov/; Rudd (1991).

Common/Vernacular Names

Tamarind is known by a variety of common/vernacular names that vary both within and from country to country (Table 12.1), mainly because of its importance, distribution, multiple uses and popularity among the people.

BOTANICAL DESCRIPTION

Tamarind tree has been described extensively by many researchers i.e. Chapman (1984); Coronel (1991); El-Siddig *et al.* (2006), FAO (1988); Gunasena and Hughes (2000); Jayaweera (1981); Nagarajan et al. (1977); Rudd (1991).

Plant: Tamarind is a long-lived, large, evergreen or semi-evergreen tree, 20-30 m tall with a thick trunk that can reach 1.5-2 m diameter. The trunk is sometimes multi-stemmed with widely spreading branches. The bark is brownish-grey, rough and scaly. Young twigs are slender and puberulent. A dark red gum exudes from the trunk and branches when they are damaged. Tamarind produces a deep taproot and an extensive lateral root system.

Table 12.1: Common/Vernacular Names of Tamarind.

Country/ Language	Common / Vernacular Name
Assamese	Tetili
Bengali	Tintiri, Tintul, Tetul
Burmese	Magyi, Magyee majee pen
Cambodian	Am pul, Ampil, Khoua me
China	Khaam, Mak kham
Dutch/German	Tamarinde
English	Tamarind, Indian date, Maderia mahogony
Ethiopia	Hemor, homor, humar, komar, tommar, arabeb, b/roka, racahu, dereho, dindie, ghroma, Gainko, Omar
French	Tamarin, Tamarainer, Tamarindier
Gondi	Chita, Hitta, Sitti
Gujarati	Amali, Ambali
Hindi	Ambli, Amli, Imli
Indonesian	Asam jawa, Assam, Tambaring
Italian	Tamarindizio
Kenya	Mkwaju, Ol-masamburai, Eopduran, Roka, Chwa waa, Muthithi, Oran
Laos	Kham
Malawi	Ukwaju, Bwemba, Mkwesu, Nkwesu
Malayasia	Asam jawa
Marathi	Chinch, Chitz, Amli, Chis, Hunchi
Nepalese	Ttri, Imli, Titis, Paun
Nigeria	Tsamiya
Philippines	Sampalok, Kalamagi, Solomagi
Portuguese	Tamarindo
Sanskrit	Amaliki
Sinhala	Siyambala, Maha siyambala
Sino-Tibetian	Khaam, Mak-kham
Somalia	Hamar
South Africa	Tamarinde
Spanish	Tamarin, Tamarindo
Sudan	Aradeib, tamarihindi, Shekere, Kuashi, Danufi
Tamil	Puli
Tanzania	Ukwaju
Telugu	Chinta
Thailand	Makham, Bakham, Somkham
Uganda	Esukuru, Esuguguru, Apedura, Iti, Chwa, Pitei, Mukoge
Uriya	Koya, Tentuli
Vietnamese	Me, Trai me
Zambia	Mushishi, Mwemba, Musika

Sources: Jayaweera (1981); Morton (1987); Rudd (1991); Simon *et al.* (2005).

Leaves: Leaves are alternate and even pinnate, in length 5-15 cm, shortly petiolated (up to 1.5 cm long) and petiole glabrous or puberulent as is the leaf rachis. Laminae are glabrous or puberulent, glaucous underneath and darker green above. Venation is reticultate and the midrib of each leaflet is conspicuous above and below. Leaflets are in 6-20 pairs/leaf, each narrowly oblong, rounded at the apex and slightly notched and asymmetric with a tuff of yellow hairs; at the base obliquely obtuse or sub truncate. At the leaf base is a pulvinus and two small stipules 0.5-1.0 cm long which are caduceus early on; stipules are falcate, acuminate and pubescent (Figure 12.1). A permanent scar is seen after leaf fall. Leaflets fold after dark due to the presence of lupeol synthesized when light and degraded in the dark (Ali *et al.,* 1998).

Flowers and flowering phenology: Tamarind flowers are borne in axillary or terminal drooping racemes. The racemes are 4-5 cm long and produce 8-18 flowers per raceme. Flowers are white, yellow or red in colour although a single tree bears only one colour of flowers. Flower initiation and development is sequential. Flowers are bisexual, helically arranged, small approximately 1.5 cm long and 2-2.5 cm in diameter (Figures 12.1 and 12.2 and Plate 12.1). Tamarind flowers are zygomorphic. Pedicels are about 5 mm long, nodose and jointed at the apex. The flowers have similar colored paired caducous bracts and bracteoles, the latter ovate-oblong and valvate. The hypanthium is narrowly turbinate, the calyx tube four-parted, the sepal lobes imbricate and membranous, the adaxial sepal lobe of which is broad and double.

The corolla has five free petals, of which the upper, more adaxial three are equally long (11-13 mm) and the lower are minute (1-2 mm long). The median adaxial petal is overlapped by the laterals. The nine stamens include 3 (5) large functional stamens, with filaments connate to half their length and dorsifixed introse anthers dehiscing longitudinally, and six minute staminodia lining the rim of the hypanthium. There is a stipitate superior ovary, the stipe adnate adaxially to the elongate hypanthium, which is lined with a disk. The style is elongated, the stigma truncate, narrow, and subcapitate; ovules are 8-10 or more. Ovary base has numerous uniseriate hairs with copious nectar (Coronel, 1991; Jayaweera, 1981; Nagarajan *et al.*, 1997; Rudd, 1991; Tucker, 2000).

Observations carried out in Sri Lanka revealed that anthesis starts at 16.30 to 21.00 hrs and flowers completely open by 04.00 hrs. Anther dehiscence occurs from 7.00 to 11.00 hrs. Stigmas are receptive almost for two days. In India, anthesis starts at about 16.00 to 20.00 hrs and flowers are completely open by 02.00 hrs. Anther dehiscence occurs from 08.00 to 10.00 hrs in the morning (Nagarajan *et al.*, 1997; Thimmaraju *et al.*, 1977). Tamarind stigmas are receptive nearly for 48 hrs with peak receptivity on the day of anthesis (Nagarajan *et al.*, 1997; Thimmaraju *et al.*, 1977). Based on the timing of stigmas receptivity and anther dehiencence, Tamarind is classified as a protogynous species. Tamarind flowers show herkogamous adaptation where androecium and gynocium are placed in different angles and heights. It is also observed that the style and ovary length varied between clones.

In Tamarind, terminal vegetative shoots are produced annually which bears flowers only in the next and immediate flowering season. Two types of terminal shoots have been observed in Tamarind by Nagarajan *et al.* (1997), shorter (erect habit) and long shoot (drooping habit). This has been identified as a character to evaluate clones, since terminal shoot length and foliage production are found to be highly correlated. In an inflorescence, flowers open only on alternative days.

Flowering and fruiting varies from country to country and region to region depending on the latitude and altitude. It is reported that production of flowers varies considerably with the clones in India. Clones with longer vegetative terminal shoots produce more flowers. In general, flowering and fruiting of takes place in the dry season. An extended spell of dry weather may be essential for fruit development, and trees, which grow in the humid tropics without this dry spell they do not often bear fruit. In India early, mid and late flowering types of Tamarind have been identified and those with delayed flowering habit are reported to be high yielders (Usha and Singh, 1994). Mass flowering is common in Tamarind during the flowering season. However, in some trees, flowers can be seen any time during the year. This may be due to genotype environmental interactions (Coronel, 1992; Jayaweera, 1981; Nagarajan *et al.*, 1997).

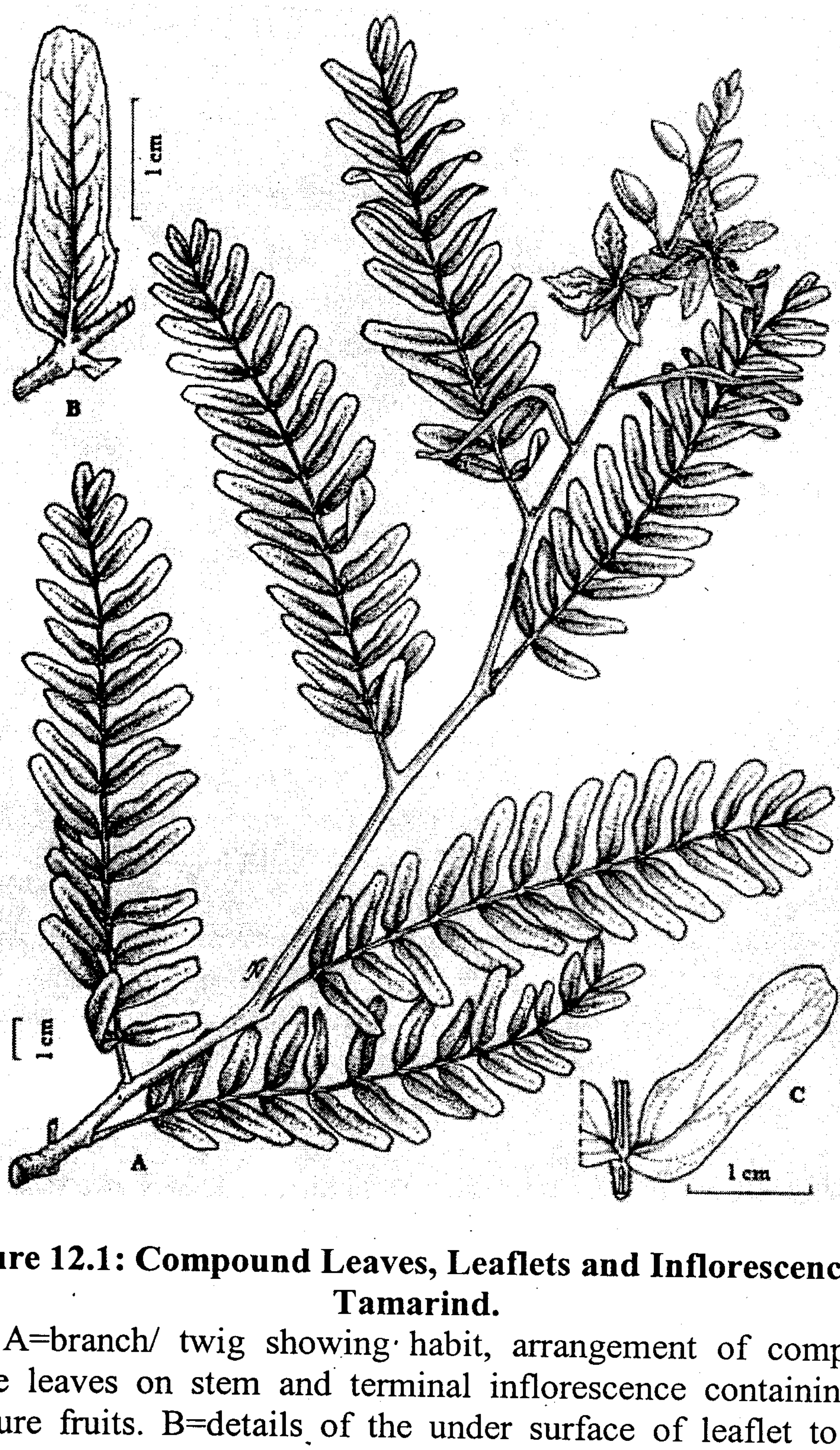

Figure 12.1: Compound Leaves, Leaflets and Inflorescence of Tamarind.

Note: A=branch/ twig showing habit, arrangement of compound/ pinnate leaves on stem and terminal inflorescence containing two immature fruits. B=details of the under surface of leaflet to show venation. C=details of the upper surface of leaflet to show groove in leaf/ rachis (Illustrations by Ms. N. Simpson).

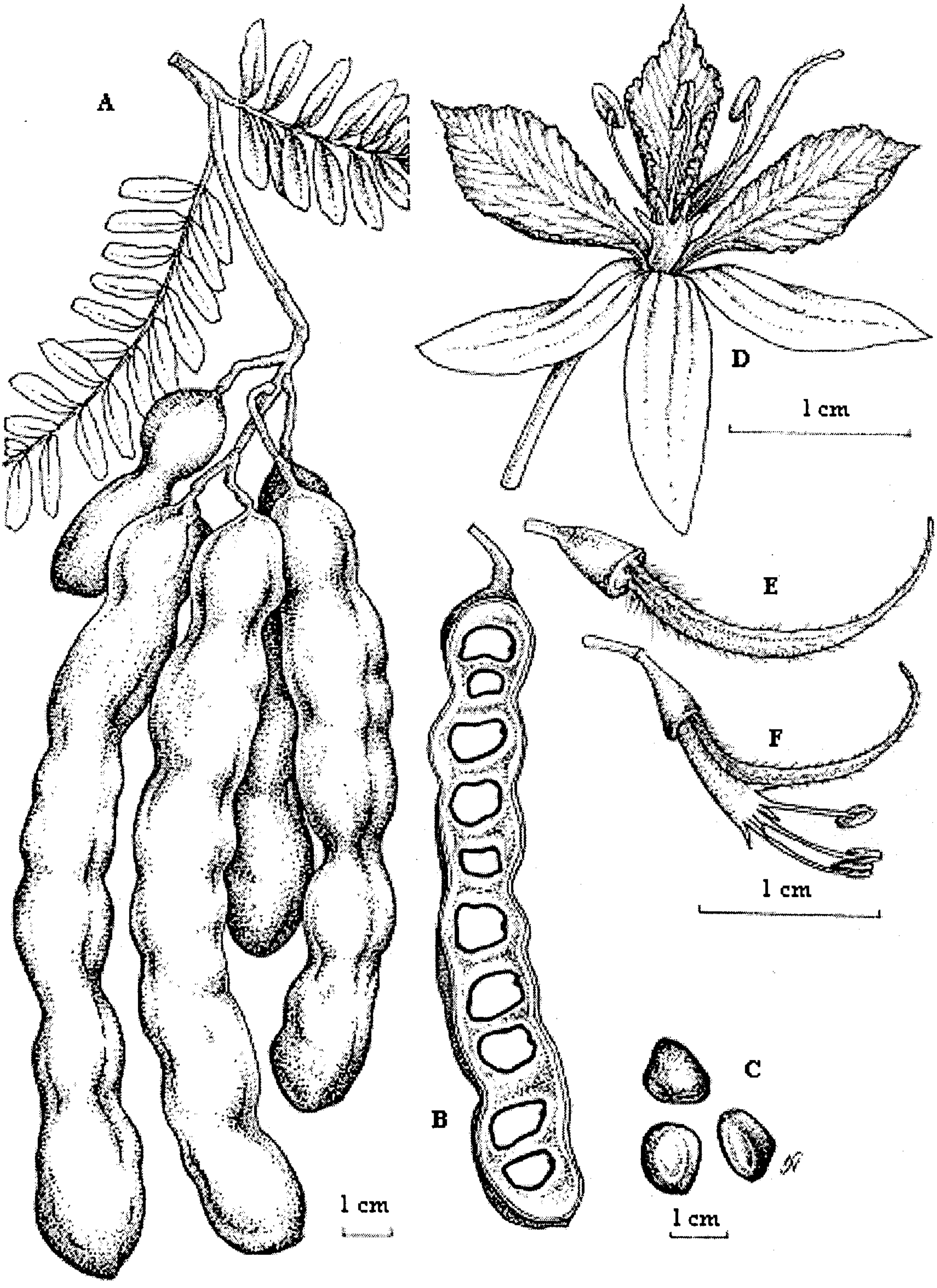

Figure 12.2: Flower and Pods of Tamarind Showing Pistil, Stamens and Seed.

Note: A=cluster of mature fruits, B=vertical section through a single pod/ fruit to show seed arrangement, C=deeds, D=flower, E=details of pistil and stigma, F=details of corolla tube, pistil and stamens (Illustrations by Ms. N. Simpson).

Plate 12.1: Mass Flowering of Tamarind in Sri Lanka.

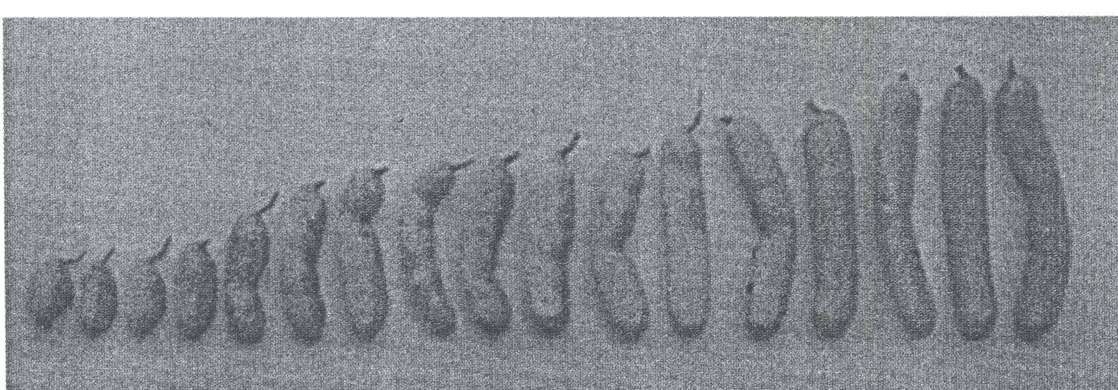

Plate 12.2: Variation in Tamarind pod size.

Pollen and pollination: Pollen grains of Tamarind are dimorphic with two distinct size variation 40-42 μm and 22-25 μm pollen size, radially symmetrical, tricolporate, oblate-spheroidal in shape and sticky (Nagarajan *et al.*, 1997; Perveen and Qaiser, 1998). This size variation was attributed to resources limitation towards the latter part of the flowing season. Pollen sterility was very low in Tamarind (less than 2%). Under ambient condition (37-40 ^{0}C) pollen viability was

88% until 3 days, while pollen stored in 4 ^{0}C remained 97% viable up to 100 days.

Sticky pollens are not effective for wind pollination. Honey bees (*Apis* spp.) are common visitors to Tamarind flowers from 8.00 to 11.00 hrs and 16.00 to 18.00 hrs. Observations of honey bee activities on flowers and their visitation pattern also suggested that they are effective pollinators (El-Siddig *et al.*, 2006). Prasad (1963) also suggested that Tamarind is insect pollinated due to floral characters and the presence of copious levels of nectar. Similar observations were also made in India by Nagarajan *et al.* (1997) and Thimmaraju *et al.* (1977).

Fruit set, breeding and mating system: In spite of profuse flowering, fruit set in Tamarind is very low under open pollination. Studies carried out in Sri Lanka revealed that about 10-15% of flowers developed as fruits (El-Siddig *et al.*, 2006) although Nagarajan *et al.* (1997) observed only 1-2% of flowers developed as fruits. This may be due to the short-lived nature of flowers (about 48 hours) and also due to pollinator limitation, thus many flowers appear not to be pollinated during their short stigmatic receptive period. All unpollinated flowers drop within two days. In contrast, in controlled cross pollination fruit set was more than 75% whilst controlled self-pollination resulted 2-6% fruit set (Nagarajan *et al.*, 1997; Usha and Singh, 1996).

Tamarind is a predominatly outcrossing (with outcrossing rate of 0.67-0.68) species with some level of selfing (Shanthi, 2003). Herkogamous floral adaptation, protogyny and self-incompatibility observed in Tamarind may promote outcrossing under natural conditions. However, it is suggested that the fruit set is influenced by environmental factors, age and size of shoots, carbon:nitrogen ratio and the hormonal balance under which the trees are grown. Hence, high seasonal and annual yield variations could be expected.

Fruits and seeds: The fruits are pods, 5-16 cm long x 2 cm broad, oblong, curved or straight, with rounded ends, somewhat compressed and indehiscent although brittle. The pod has an outer epicarp which is light grey or brown and scaly. Within is firm but the soft pulp is thick and blackish brown. The pulp is traversed by formed seed cavities, which contain the seeds. The outer surface of the pulp has three though branched fibres from the base to the apex.

Each pod contains 1-12 seeds which are flattened, glossy, orbicular to rhomboid, each 3-10x1.3 cm and the centre of each flat side of the seed is marked with a large central depression. Seeds are hard, red to purple brown, non arillate and exalbuminous. Seed chambers are lined with a parchment like membrane. Cotyledons are thick (von Hong *et al.*, 1996; El-Siddig *et al.*, 2000). Pods ripen about 10 months after flowering and can remain on the tree until the next flowering period, unless harvested (Rama Rao, 1975; Chaturvedi, 1985).

Fruit development and ripening: In most of the Tamarind producing countries the fruits are harvested from February to March/April, but sometimes the harvesting period may extend to June (Coronel, 1992). In India, fruits are harvested between April-May although in Kerala and other parts of South India fruit collections may be over by the end of February. In Sri Lanka, fruits ripen from January to February and June (Macmillan, 1943; El-Siddig *et al.*, 2006). Generally fruit development in Tamarind takes three distinct stages, growth, maturation and ripening. The fruits begin to dehydrate 203 days after fruit set and continues to 245 days when it reaches full ripeness with up to half the original water content lost.

ORIGIN AND GEOGRAPHICAL DISTRIBUTION

Various geographical areas have been proposed for the origin of Tamarind: India (Morton, 1987) or the far east or Africa but the consensus is that it is Africa, placed it in Ethiopia, but others considered it indigenous to the drier savannahs of tropical Africa, from Sudan, Ethiopia, Kenya and Tanzania, Westward through sub-Sahelian Africa to Senegal (El-Siddig *et al.*, 2006; NAS, 1979). It is thought to have been introduced to south and southeast Asia a very long time ago (Brenan, 1967; NAS, 1979) and naturalized in many areas where it was introduced (Purseglove, 1987; Coronel, 1991).

According to Simons *et al.* (2005) the native distribution of Tamarind is as follows: Burkina Faso, Cameroon, Central African Republic, Chad, Ethiopia, Gambia, Guinea, Guinea-Bissau, Kenya, Madagascar, Mali, Niger, Nigeria, Senegal, Sudan, Tanzania, Uganda, Cape Verde.

PROPERTIES OF THE SPECIES

Tamarind is a nutritious fruit with a variety of uses. The properties of this species have been extensively studied, particularly with reference to the components of the seed. Tamarind has many valuable properties and virtually every part of the tree has been utilized by both rural and urban dwellers.

Table12.2: Proximate Composition of Dried Pulp of Tamarind Fruit per 100 g.

Constituent	Amount
Moisture (%)	15-30
Proteins (%)	2-9.10
Fat/oil/Lipid, crude (%)	0.5-3.1
Carbohydrates, total (%)	56.7-82.6
Fibre, crude (%)	2.2-18.3
Tartaric acid, total (%)	8-18
Reducing sugars (%)	25-45
Total ash (%)	2.1-3.3
Pectin (%)	2-4
Cellutosic residue (%)	19.4
Albuminoids (%)	3-4
Total available carbohydrates (%)	41.77
Alcohol insoluble sugars (%)	22.7
Water insoluble sugars (%)	20.5
Non-reducing sugars (%)	16.52
Total sugars (%)	41.2-58.7
Starch (%)	5.7
Tanning, (mg)	600
Ascorbic acid, (mg)	3-9
ß-carotene equivalent (µg)	10-60
Thiamine(mg)	0.18-0.22
Riboflavin (mg)	0.07-0.09
Niacin (mg)	0.6

Sources: Ishola *et al.* (1990); Coronel (1991); Feungchan *et al.* (1996a; 1996b).

The most valuable and commonly used part of the Tamarind tree is the fruit. The pulp constitute 30-50% of the ripe fruit (Purseglove, 1987), the shell and fibre account for 11-30% and the seed about 25-

40% (Chapman, 1984). The fruit composition of Tamarind depends on locality. Average composition of the Tamarind fruit is given in Table 12.2 whilst some pysico-chemical properties of the lipid extracted pulp and seed is given in Table 12.3.

Table 12.3. Physico-chemical Properties of the Lipid Extracted from the Pulp and Seed of Tamarind.

Character	Pulp	Seed
Saponification value (mg KOH/g)	301.3	266.6
Iodine value	120.6	78.1
Unsafonified matter (g/kg)	139.0	31.3
Acid value (g/kg)	896.0	292.6
Free fatty acid (g/kg)	448.0	46.3
Peroxidase value (m Eq/kg)	123.3	98.9

Source: Ishola *et al.* (1990).

The major volatile constituents of Tamarind pulp include furan derivatives (44.4%) and carboxylic acids (38.2%), the component of which are furfural (38.2%), palmitic acid (14.8%), oleic acid (8.1%) and phenyl acetaldehyde (7.5%) (Wong *et al.*, 1998). According to Lee *et al.* (1975), the most abundant volatile constituent of Tamarind is 2-acetyl-furan, coupled with traces of furfural and 5- methyl furfural, which form the total aroma. In total content of volatile components listed above there may be up to 81 different volatile substances (Pino *et al.*, 2004). The fruit contains a variety of pigments. The red colour is due to water soluble red-rose anthocyanine pigment, while in the common types of pulp leuco-cyanidin is present (Bhattacharyya, 1974). Lectins have been shown to be present and these could be of medicinal interest (Coutino-Rodriguez *et al.*, 2001).

The most outstanding characteristics of Tamarind is its sweet acidic taste, the acid due mostly to tartaric acid (2, 3- dihdroxybutanedoic acid, $C_4H_6O_6$, a dihydroxydicarboxylic acid), ranging from 12.2-23.8%, and uncommon in other plant tissues. It is an unusual plant acid, which is formed from the primary carbohydrate products of photosynthesis, and once formed; it cannot be further used in the plant due to the absence of the necessary enzymes. Although tartaric acid occurs in other sour fruits, such as Grapes, Grapefruit and Raspberries, it is not present in such high proportions as in Tamarind.

The tartaric acid is synthesized in the leaves in the light and translocated to the flowers and fruits (Patnaik, 1974). It is high in young leaves and decreases with age and has been reported to show seasonal variations (Bueso, 1980). The content of tartaric acid, however, does not decrease during fruit ripening, indicating that it is not utilized in fruit development; but during this time, reducing sugars increase to 30-40% giving the sour fruit a sweeter taste. As the acidity does not disappear with ripening, more or less matches with increasing sugar levels, Tamarind is known to be simultaneously the most acidic and sweetest fruit (Coronel, 1991).

USES AND PRODUCTS

Tamarind is a versatile tree and can be used for many purposes. Virtually every part of the tree (wood, root, leaves, bark and fruits) has some value and a number of commercial applications are well known. The major product is the fruit pulp which has a unique sweet/sour flavour and is popular in cooking and flavouring.

Land use and agroforestry: Tamarind is used in agroforestry systems in many parts of the tropics due to its multiple uses. Tamarind is also an important tree in homegardens in south and southeast Asia. Tamarind has been intercropped with annual and perennial crops. Intercropping of Tamarind with annual crops can enhance farm income and improve the well being of rural populations, by providing a constant income to the farming community. Once the Tamarind tree has passed its juvenile stage and comes into bearing, it will provide a constant supply of fruit, in addition to the produce from the annual crop species.

Tamarind trees are widely used in India and Sri Lanka as ornamentals and shade trees, planted along avenues, roadsides, in park and along river banks. Tamarind has become popular in the United States as a tree for indoor ornamentations (NAS, 1979). Tamarind trees have been used as windbreaks due to their resistance to storms.

Food uses:

Pulp: Tamarind is valued mostly for its fruit especially the pulp, which is used for a wide variety of domestic and industrial purposes (Kulkarni *et al.,* 1993). Tamarind is not generally a dessert fruit, although sweet Tamarind flesh is often eaten directly from the pod. Fully grown but still unripe fruits are also eaten, they are roasted in coal, the skin is then peeled back and the sizzling pulp is dipped in wood ash and eaten (Morton, 1987). The pulp is usually removed from the pod and used to prepare juice, jam, syrup and candy. The immature green pods are often eaten by children and adults dipped in salt as a snack.

More commonly, the acidic pulp is used as a favourite ingredient in culinary preparations such as curries, chutneys, sauces, ice cream and sherbet. In Sri Lanka, Tamarind is widely used in cuisine as an alternative to lime and also in pickles and chutneys (Jayaweera, 1981). It is also used in India, to make 'Tamarind fish', and sea-food pickle, which are considered a great delicacy. Immature tender pods are used as a seasoning agent for cooked rice, meat and fish and delicious sauces for duck, waterfowl and geese are also prepared.

Tamarind pulp is often made into a juice, infusion or brine. In India the juice is used to preserve fish, which can be preserved up to six months. Tamarind is used in this way in Sri Lanka and many other Asian countries (Macmillan 1943). The juice is also an ingredient of Worcestershire and other barbecue sauces, commonly used in European and North American countries (NAS, 1979).

Tamarind drink is popular in many countries around the world, though there are many different recipes. In the Philippines, Sri Lanka and Thailand, fibres are removed from the fruit pulp, which is mixed with sugar, wrapped in paper and sold as toffees. The pulp is also used to make sweetmeats mixed with a sugar called 'Tamarind balls' (Purseglove, 1987).

Seed: The presence of tannins and other colouring matter in the testa make the whole seed unsuitable for human consumption. Therefore, the testa has to be separated from the kernels by boiling or roasting. Otherwise, such side effects as depression, constipation and gastro-intestinal disorders may result (Anonymous, 1976). In some African countries and India seeds are pounded and eaten in times of famine. The seeds are also eaten after removal of the testa after roasting or boiling. The roasted seeds are claimed to be superior to peanuts in flavour and are also used as a substitute or adulterant with coffee. Sometimes they are made into flour for bread, Indian chapattis and cake making (Purseglove, 1987).

Leaves and flowers: The leaves, flowers and immature pods of Tamarind are used to make curries, salads, stews and soups in many countries, especially in times of food scarcity (Benthall, 1933). Young leaves of the Tamarind are used as a seasoning vegetable in some Thai food recipes because of their sourness and specific aroma (Coronel, 1991). Tamarind leaves are used for fodder and are relished by cattle and goats, and wild animals.

Wood: Tamarind heartwood is considered to be a very durable and has many uses including making furniture, wheels, mallets, rice ponders, mortars, pestles, ploughs, well construction, tent pegs, canoes, side planks for boats, cart shafts and axels, and naves of wheels, toys, oil presses, sugar presses, printing blocks, tools and tool handles, turnery, etc. Sometimes due to its hardness it is difficult to work and liable to crack during seasoning (Chathurvedi, 1985). The wood is also good fuelwood with a calorific value of 4850 kcal/kg, producing a great heat. Tamarind wood density is high (850 kg/m^3). The wood ash is used to remove hair from animal hides (Simons *et al.*, 2005) and can be mixed with fruit pulp for cleansing and brightening brass and copper vessels.

Medicinal uses: The laxative properties of the pulp and the diuretic properties of the leaf sap have been confirmed by modern medical science (Bueso, 1980). Tamarind fruits were well known in Europe for their medicinal properties, having been introduced by Arab traders from India (Rama Rao, 1975). Tamarind products, leaves, fruits and seeds have been extensively used in traditional Indian and African medicine (Jayaweera, 1981; Parrotta, 1990).

In former times, the fruit pulp was used as a gentle laxative under the name 'Pulpa Tamarindourum'. It is available commercially in tablet from in Thailand for the reduction of excess weight. Tamarind pulp alone or in combination with lime juice, honey, milk, dates, spices or camphor is used as a digestive and a carminative, even for elephants, and as a remedy for biliousness and bile disorders and febrile conditions. It is said to improve the loss of apatite.

Tamarind is also said to aid in the cure of malarial fever (Timyan, 1996).

The seed is usually powdered and often made into a paste for the treatment of most external ailments. In Cambodia and India, powdered seeds have been used to treat boils and dysentery (Rama Rao, 1975; Jayaweera, 1981). Seed powder has also been externally applied on eye disease and ulcers. Boiled, pounded seeds are reported to treat ulcers and bladder stones and powdered seed husks to treat diabetes (Rama Rao, 1975). Osawa *et al.* (1994) found that an ethanol extract prepared from the seed coat exhibited antioxidative activity. Ethel acetate extracts prepared from the seed coat have strong antioxidant activity. This suggests that Tamarind seed coat could be used as a safe and low-cost source of antioxidants (Ramos *et al.*, 2003).

Tamarind leaves mixed with salt and water, are used to treat throat infections, coughs, fever, intestinal worms, urinary troubles and liver aliments. Internally, leaves and pulp act as a cholagogue, laxative and are often used in treating 'congestion' of the liver, habitual constipation and haemorrhoids. Leaf extracts also exhibit anti-oxidant activity in the liver. Also taken internally, the leaves are used in cardiac and blood sugar controlling medicines. The poultice of flowers is used in the treatment of eye diseases and conjunctivitis in the Philippines. The flowers are also used internally as a remedy for jaundice and bleeding piles. In the northwest of Coimbatore, Tamil Nadu, India, the root bark is ground into a powder and mixed with hot water and administered three days before abortion and for prevention of pregnancies (Lakshmanan and Naranayan, 1994).

Industrial uses: Tamarind pulp is used as a raw material for the manufacture of several industrial products, such as Tamarind Juice Concentrate (TJC), Tamarind Pulp Powder (TPP), tartaric acid, pectin, tartarates and alcohol (Anonymous, 1982a).

Tamarind Kernel Powder (TKP): The major industrial use of the seeds is in the manufacture of Tamarind Kernel Powder (TKP). The general characteristic of a good Tamarind seed powder is that it should have the characteristic flavouring when dissolved in water and be free of any burnt or other undesirable flavours; it should have good keeping quality and be free from any insect pests, fungal growth or extraneous materials. The TKP, when boiled in water containing boric acid and phenol as preservatives, makes a very good paper adhesive (Anonymous, 1976). In India, TKP is used as a source of carbohydrate for the adhesive or binding agent in paper and textile sizing, and weaving and jute products (Anonymous, 1976) as well as textile printing. The sizing property of TKP is due to the presence of up to 60% of the polysacchaide.

Pectins: Polysaccharides obtained from Tamarind seed kernels form mucilaginous dispersion with water and possess the characteristic property of forming gels with sugar concentrates, like fruit pectins. However, unlike fruit pectin Tamarind polysaccharide can form gels over a wide pH range, including neutral and basic conditions. Tamarind polysaccharides are also not affected by boiling in neutral aqueous solutions, even if boiled for long periods. Fruit pectins undergo degradation on boiling and fall to one-third of their original value in one hour of boiling. Therefore Tamarind polysaccharide can be useful as a gel formation agent, and may be substituted for fruit pectins. Tamarind polysaccharide does not contain galacturonic acid and methyluronate and is therefore not regarded as a true pectin; it is termed 'jellose' (Rao, 1995).

Tamarind Juice Concentrate (TJC): The extraction and processing techniques of the pulp for the preparation of canned Tamarind syrup, clarified Tamarind juice and other soft drinks have been reported by Bueso (1980). The industrial method used in India for the manufacture of Tamarind juice concentrate is by extraction of all the soluble from the fruit pulp in boiling water (Nagaraja *et al.*, 1975).

Tamarind pickle: Pulp is used commercially to prepare Tamarind pickle. The pickles are commonly used in Asia as an accompaniment to curries or other main meals. Pickles are hot, spicy and have a salty-sour taste, and can be preserved for several months. Preservations of pickles are simple and can be done at a household level.

Other uses: The seed is also used as a filter for adhesives in the plywood industry and a stabilizer for bricks, as a binder for sawdust briquettes and a thickener for some explosives. Ground, boiled and mixed with gum, the seeds produce strong wood cement (Benthall, 1933; Rama Rao, 1975). A composite material of Tamarind seed gum and the cellulose rich sisal plant fibre was prepared by a process of humidification and compression to increase its strength. This material is suitable for construction applications such as false roofing and room partitioning.

ECOLOGICAL REQUIREMENTS

Climate: Tamarind grows well with an evenly distributed mean annual rainfall of 50-1,500 mm (FAO, 1988). The minimum rainfall requirement is 250 mm. The maximum annual rainfall which Tamarind can tolerate is up to 4,000 mm, provided that the soil is well-drained. Dry weather is important for flower initiation and if heavy rains occur during flowering Tamarind does not bear fruit. Thus, in the wet tropics, the trees grow well but do not produce any fruit (Morton, 1987). Tamarind thrives under a maximum annual temperature ranging from 33-37 ^{0}C to a minimum of 9.5-20 ^{0}C. Tamarind has been reported to grow from altitudes of 0-2,000 m. The lack of Tamarind growing at higher altitude is associated more with the decrease in temperature than the altitude itself.

Tamarind is a light demanding tree that grows very slowly. It is very resistant to strong winds, and can tolerate violent typhoons and cyclones. Often known as the hurricane-resistant tree (NAS, 1979), it has strong and pliant branches and a deep and extensive root system, which solidly anchors it to the ground (Coronel, 1986).

Soil requirement: The Tamarind tree can grow in a wide range of soils. However, Tamarind thrives best in loamy, deep, well drained alluvial soils, which favors the development of a long tap root. The tree does not tolerate water-logging. The optimum pH for Tamarind is 5.5-6.8, which is slightly acidic (FAO, 1988), though it also grows well in alkaline soils.

AGRONOMY

Propagation

Tamarind is traditionally grown from seed, although vegetative and tissue culture propagation methods have been developed to capture the attributes of specific genotypes.

Seed Propagation: Propagation by seed is the least expensive and can be used to produce a large number of new plants. In addition, seed propagation is necessary in order to produce seedlings to be used as rootstocks onto which selected cultivars can be grafted.

Seed collection for propagation involves selection of vigorous, disease-free mother trees of superior phenotypes. The pods should either be dried in the sun and the seed removed from the pulp by hand-kneading, or by soaking in water for several hours, which makes it easier to remove the seeds by rubbing the pulp through a screen. Washed seeds are then dried in shade and stored in well-ventilated gunny bags, or paper bags, in a cool place. Seed dressing with fungicides have been recommended for control of seed borne fungi.

Seeds may be germinated in nursery beds, seed boxes, pots or plastic bags. When grown in nursery beds, the recommended spacing is 20-25 cm both ways. The best germination results if the seeds are covered by 1.5 cm of loose sandy loam or a mixture of loam and sand. If the seeds are planted too deep seedling emergence is delayed and there may be some rotting due to poor aeration. Sowing seeds in an upright position with the micropylar end positioned upwards significantly improved germination and seedling vigour.

Although no seed pre-treatment is essential, various pre-treatment can accelerate the speed of germination. Chemical (through concentrated sulphuric acid) and mechanical scarification proved to be highly effective in hastening germination of Tamarind seed. Tamarind seeds begin to germinate about 13 days after sowing but may take a month to complete. The germination capacity of fresh or well stored Tamarind seed is reported to vary from 65-75%. Germination of the Tamarind seed is epigeal.

Vegetative Propagation

Tamarind can be propagated by root and stem cuttings or air and stem-layering (Anonymous, 1976, von Maydell 1986), Morton, 1987) or by budding and grafting.

Cuttings: The easiest and the cheapest method of vegetative propagation of Tamarind is by stem cuttings. A technique using soft wood terminal cuttings has been developed, and the protocol standardized, by the Forest Research Station at Maddimadugu, Andra Pradesh, India (Srivasuki *et al.*, 1990). The use of the growth regulator IBA increased the rooting of cuttings to over 94% compared to the control, which recorded only 25%. Furthermore, the time taken to initiate rooting was only 10-15 days with IBA, while the control took 40-50 days. Terminal cuttings have an advantage over mid stem cuttings because there is only one cut end thus reducing the possibility of infection by disease causing organisms during or after the rooting phase.

Budding and grafting: Vegetative propagation by shield and patch budding, cleft grafting, whip grafting and approach grafting are reliable methods, although they are expensive and time consuming. Root stock selection for vegetative propagation of Tamarind is important as it controls the vigour and the equilibrium between yield and quality. Dwarfing rootstocks are considered best because they result in short trees, which are easy to manipulate for management practices, have increased fruit production, and require less land and labour inputs.

Layering: Layering is a widely practiced easy propagation method for Tamarind. In ground layering, a flexible branch is bent down and pegged to the ground, and the point of contact covered with soil. A small cut is made in the lower side of the stem where it touches the ground to impede sap circulation and encourage rooting. After 3-6 weeks roots form at the point of contact with the soil and a new plant can be obtained by severing the branch above the place of rooting.

Micro propagation: Tamarind may be propagated by tissue culture techniques; however, reports on in vitro morphogenesis in this species are limited. Although micro-propagation techniques have shown promise, none of them has reached the stage of commercialization (Prabakaran *et al.*, 2003).

Field Establishment

Tamarind may be grown as an orchard crop in a pure stand, as an agroforestry species in mixed cropping systems including home gardens, or as hedgerow trees. In each of these systems, there are several methods available for establishing the tree.

Direct seedling: Tamarind can be established in the field by directly sowing the seed. On suitable sites, direct seeding of Tamarind may be a more economical method of establishment, as it eliminates the cost of growing seedlings in the nursery and is less time-consuming than planting seedlings. The primary advantage of seed planting versus seedlings planting is that the germinating seedlings have an undisturbed root system and does not suffer from transplant shock.

Transplanting: Transplanting nursery grown plants into the field can have advantages over direct seeding as the plants are already established. However, most newly planted trees are subject to 'transplant shock', which may result increase vulnerability to drought, insects, diseases and other problems. The chances of survival can be significantly improved by using practices which favour the development of the root system. Thus, regular care during the first 2-3 years following transplanting is thus very important.

Planting should be done in 1x1x1m pits filled with well rotted organic manure at the time of planting. A nursery produced plant can be transplanted in the field at about 12-14 months, by which time they are about 80 cm tall. Under optimum growing conditions they may achieve this height in 4-6 months (Jambulingam and Fernandes, 1986).

Field spacing: The spacing between plants may range from 5-13 m apart. Spacing may be even wider on fertile soils where the trees grow larger. When establishing a pure stand plantation, the final spacing should be at least 13x13 m square or on the triangle. There can be an advantage in planting at higher density (4x4 m or 5x5 m), followed by thinning two or three times to the appropriate final spacing of 8-15x8-15 m. This allows some further selection in the field and reduces the weeding costs in the early years. In parts of India, Tamarind is established at 8x8 m, 8x12 m or 12x12 m (Jambulingam and Fernandes, 1986). The final spacing can be closer when vegetatively propagated plants are used, as they do not attain the height or spread of seed propagated trees, and their management is easier.

Time of planting: In seasonally dry regions, the best time for field planting is at the beginning of the rainy season, as soon as there is sufficient moisture in the soil. If irrigation is available, field establishment may be undertaken at any time of the year, even in the dry season. However, it is advisable to provide partial shade to the newly established plants if planting is carried out during the dry periods.

Pruning and Training

Initial training and pruning of young plants during the first years is essential for the development of well-formed trees. Tamarind is a compact tree and produces symmetrical branches. Young trees should be pruned to allow 3-5 well spaced branches to develop into the main scaffold structure of the tree. Bearing trees require very little pruning other than maintenance pruning to remove dead, weak and diseased branches and water sprouts (Samons *et al.*, 2005).

Intercropping

Tamarind allows intercropping with a variety of annual crops. Vegetables and legumes can be grown during the rainy season in the interspaces in the first three to six years to augment farm income and improve soil fertility. The intercropping period is usually limited to four years for vegetatively propagated trees. In Thailand's central delta, intensive cropping is practiced in the plantations of the sweet cultivars, which are always vegetatively propagated and transplanted. Intercropping can be extended up to even 8-10 years for the slower maturing seedling propagated plantations.

Irrigation

Irrigation is not normally practiced in Tamarind cultivation, but promotes better growth during establishment and the early stages of growth, especially during the dry seasons. Where irrigation facilities are available watering should be done and repeated as the need arises in the early stages of growth. In latter years as the deep tap root system develops, the need for watering becomes less,. Flowering and fruiting is promoted by irrigation. In dry areas the use of water harvesting techniques during the rainy season should be considered as it encourages subsequent growth and fruiting (Chundawat, 1990). Mulching during the dry season will also help to reduce water losses from evaporation. Mulches around the trees help in weed control and water conservation.

Diseases and pests

Diseases: Several diseases have been reported to infect Tamarind in India, including various tree rots and bacterial leaf spots. The major diseases reported are leaf spots (*Bartalinia robilardoides* Tassi., *Exosporium tamarindi* Syd., *Hendersonia tamarindi* Syd., *Pestalotia poonensis* V Rao., *Phyllosticta tamarindicola* V Rao., *P. Tamarindina* Chandra and Tandon., *Rathigoda tamarindi* Muthappa, *Xanthomonas tamarindi* Cook, *Sphaceloma spp.* and *Stigmina tamarindi* (Syd.) Munjal and Kulshreshta, powdery mildew (*Erysiphe polygoni* DC. and *Oidium* spp.), a sooty mould (*Meliola tamarindi* Syd.), stem disease (*Fracchiaea indica* Talde.), white rot and wood rot (*Ganoderma indicum* (Leyss) Karst and Lenzites palisoti Fr.), stem rot (*Pholiota gollani* P. Henn), trunk and root rot (*Stereum nitidulum* Berk.), collar rot (*Phytophthora nicotianae* var. *Nicotianae*), stem canker (*Hypoxlon nectriodes* Speg) and a bark parasite (*Myriangium tamarindi* Tendulkar) (Morton, 1987; Parrotta, 1990). In Karnataka State, India, stony fruit disease caused by the fungal pathogen *Pestalotia macrotricha* Syd. makes the fruits hard and stony with fibrous structures. In general, sap rot and white rot, which might be caused by several diverse fungi, are the major diseases.

A mildew caused by *Oidium sp.* is a common occurrence in nursery seedlings. The disease causes defoliation and early growth is severally retarded. In Uttar Pradesh, India, Tamarind has been attacked by *Cercospora* leaf disease resulting in severe defoliation. The causal agent is a form of *C. tamarindi*. A seedling blight disease caused by *Macropomina phaseolina* and *Rhizoctonia solani* is also important during the nursery stage.

Pests: Tamarind trees are liable to be attacked by a large number of insect pests although in general it is not harmed by many of them except in plantations. In India alone, over 50 insect pests have been recorded as attacking Tamarind, causing severe economic losses. The major pests which attack Tamarind include shot hole borers, toy beetles, leaf feeding caterpillars, bagworms, mealy bugs and scale insects (Coronel, 1991). Among the worst are the sapsuckers, which affect the tender shoots and fresh foliage. The most destructive among these are white files, thrips, coccids and apids. The defoliators, which include caterpillars and the chafer beetles, can also cause considerable damage. Some of these insects attack the flower buds and the developing fruits and seeds, while others damage the fruits during storage.

Nematodes are also reported to attack Tamarind. The major nematodes are: *Radapholus similes*, the burowing nematode, and *Meloidogyne incognita*, the common root knot nematode. In south India in particular the burrowing nematode is reported to be a serious pest of both Tamarind and the coconut palm.

HARVEST, POST HARVEST AND PROCESSING

Fruits are harvested at two stages, based on developmental stages, green pods for flavouring and ripe pods for processing. Harvesting of Tamarind fruits commences when the pods feel brittle by pressing. Trees grown from seed may take more than seven years to start bearing and up to 10 or 12 years before an appreciable crop is produced. Grafted trees will however come into bearing several years before. The sweet cultivars planted in Thailand bear in about 3-4 years. These differences in the onset of bearing may be associated with genetic or ecological factors.

Mature fruits have brown shells, while immature once are green. Tapping them with the finger can help to identify the mature fruits. A hollow, loose sound will be produced as the pulp shrinks with maturity and the shell becomes brittle. At this stage the fruits are mature and ready for harvesting. However, it is not always easy to determine whether the fruits are ready for harvesting, as the testa colour only changes slowly as the pods mature. Individual fruits on the same tree also mature at different times making it necessary for the harvesting to be done selectively. The pods are gathered when ripe and the hard pod shell is removed. The pulp is preserved by placing it in casks and covering it with boiling syrup or packing it carefully in stone jars with alternate layers of sugar. The seeds, when used as a food, are roasted and soaked in water until the hard seed coat split and comes off. The cotyledons are then boiled and eaten.

Yield

The yield of Tamarind varies considerably in different countries, depending on genetic and environmental factors. Feungchan *et al.*, (1996a) reported that the fruit yields are influenced by environmental and genetic factors.

A young tree yields 20-30 kg fruits per year, while full grown trees of 20 years of age are known to yield 150-200 kg/tree/year or 12-16 t/ha (NAS, 1979; Chapman, 1984). A full-grown tree is reported to yield about 180-225 kg of fruits per season (FAO, 1988). In India, the average production of Tamarind pods per tree is 175 kg and of processed pulp is 70 kg/tree (Kulkarni *et al.*, 1993). Yields up to 170 kg/tree/yr of prepared pulp have been reported in India and Sri Lanka (Coronel, 1991). Rao (1995) reported that Periyakulam 1 (PKM1), an improved cultivar in Tamil Nadu, yields about 263 kg/tree, 59% more than unselected cultivars. In India, Jumbulingam and Fernandes (1986) reported very high yields of 500 kg/tree/year. Based on this yield, 100 trees per ha will yield about 8-9 mt of prepared pulp (Coronel, 1991). Under average conditions the pod yield ranges from 80 to 90 kg/tree/year. As pod yield starts to decrease after about 50 years, older trees are sometimes harvested for charcoal or fuelwood (Jumbulingam and Fernandes, 1986).

Storage

Fresh fruit are often dried using small-scale dehydrators, however in most countries rural households dry pods in the sun. The shells, fibres and seeds are then removed and the pulp stored in plastic bags or earthenware pots. After separating the pulp from the fibres, seed and shells, it is then compressed and packed in palm leaf mats, baskets, cornhusks, jute bags or plastic bags for storage and marketing. In Thailand, the pulp is mixed with salt and compressed and packed in plastic bags to exclude air for storage.

In Sri Lanka, the harvested pods are dried in the sun for 5-7 days to bring all fruit including the half-mature fruit to the fully ripe stage. The pods are than cracked to separate the pulp. The pulp with the seed is spread on thick polythene sheets and dried in the sun for 3-4 days to remove excess moisture and prevent the growth of moulds. The dried pulp is mixed with salt and packed in clay pots for storage. These pots are usually kept in a dry place, preferably in the kitchen. Through this process Tamarind can be stored for about a year, after which the colour changes to dark brown or black and changes in flavor occur. Although the pulp is stored with the seeds intact in rural households, seedless pulp is stored in plastic bags in retail shops (Gunasena and Hughes, 2000).

Production Areas

Precise data on production and acreage of Tamarind are quite difficult to obtain, often because most of the fruit is collected from the wild by rural people or harvested from small isolated areas. It is only grown on a major plantation scale in few countries, e.g. India and Thailand. Thus, information on area and quantity of production are mostly estimates. India is the world's largest producer of Tamarind products. More recently, Thailand has become a major producer of Tamarind, with sweet and sour cultivars in production. Thailand is particularly prominent due to the availability of the sweet Tamarind types grown there.

At present Tamarind is cultivated in 54 countries of the world: 18 in its native range and 36 other countries where it has been introduced. The major areas of production are in the Asian and American continents. In most countries, Tamarind is a subsistence tree crop used to meet local requirements, although some of it is also exported. Consequently, production and export data are not available.

GENETIC RESOURCES AND IMPROVEMENT

Tamarind shows extensive variation in characters such as foliage and flower production, flower colour, length of pod, pod weight, pod colour, seed number and shape and pulp quality (sweetness of pulp), pulp yield and wood quality (Table 12.4). The composition of pulp also varies widely and the pulp is usually better developed in Indian than that in African Tamarinds (Purseglove, 1987). Recent evidence also indicates the existence of variation of characters of fruit pulp in different countries, some with less acid or sweet fruits. The variations have also been reported for tolerance to drought, wind, poor soils, water logging, high and low pH and grazing.

Phenological diversity also exists in Tamarind and tree to tree variations are common in flowering and in maturing fruits (Mahadevan, 1991), which may reflect either genetic variation or genotype x environmental interactions and /or both. Feungchan *et al.* (1996a), Jambulingam and Fernandes (1986) and NAS (1979) reported the considerable variation in fruit yield (from 150-200 kg/tree/year) of Tamarind in different countries showing the potential for improvement of fruit production. Brenan (1967) and NAS (1979) suggested that genetic diversity of Tamarind is high in native African savannahs than in those introduced to the south and southeast Asian regions, as indicated by the wide variations in the commercial pulp quality.

Table 12.4: Variation in Characters of Tamarind.

Character	Variation
Terminal shoot length	Short-long
Flowering behaviour	Early-mid-late
Number of primary branches	5-8
Number of secondary branches	30-63
Number of tertiary branches	45-91
Number of inflorescence/branch	531-990
Number of flowers/branch	5697-15587
Number of fruits/branch	748-1595
Pod length (cm)	4-30
Pod width (cm)	1.9-4.0
Pod weight (g)	4.5-60.0
Amount of pulp in ripened fruit (%)	30-50
Single seed weight (g)	0.8-1.2
Number of seeds/pod	4-10
Seed weight (g)	1.6-10.0
Sweetness of pulp	Sweet-sour
Fibre content	Low-high
Pod yield per plant (kg/tree)	20-500

Sources: Bennet et al. (1977); El-Siddig *et al.* (2006).

Wide phenotypic variation in Tamarind germplasm has been attributed to geographic isolation and gene mutation (Feungchan *et al.,* 1996a). The origin of sweet Tamarind has been attributed to a point mutation. It is also assumed that the sweetness in Tamarind is a rare trait, which may be governed by recessive genes (Fuengchan *et al.,* 1996a). Occasionally, isolated branches on a tree may bear sweet fruits, while the other branches have the normal sour type. Grafted plants from these trees are maintained to serve as sources of bud sticks for large-scale propagation and distribution. Budspots are also commonly found in the Philippines. These are isolated branches bearing sweet fruits from normally sour Tamarind trees. These Budspots will provide ample opportunities for genetic improvement of Tamarind. From such diverse germplasm, plants with sweeter;

more juicy pulp and other desirable characteristics could be selected for tree improvement programmes. Some of the potential characters that could be used in evaluation are listed in Table 12.5.

Table 12.5: Potential Characters Useful to Distinguish Tamarind Cultivars.

Plant part	Character
Shoot	Terminal shoot length
Flower	Colour of petals (dark pink to whitish cream), Number of inflorescence per branch, Number of flowers per inflorescence, Flowering pattern (early - late)
Pod	Pod form, length, breadth, curvature, shape, pod size, pod weight, colour of shell
Pulp	Pulp colour, (red/whitish), Pulp: shell ratio, Real pulp value, Pulp yield, Pulp recovery percentage, Fibre content, Ease of pulp extraction, Colour, Weight of pulp
Seeds	Number of seeds per pod, Seed: pulp ratio
Yield	Total yield of pods Alternate/ regular bearing habit
Biochemical	Sweetness of pulp (ratio of tartaric acid: sugar), Protein, mineral and amino acid composition
Others	Resistance to salinity, drought, degraded soils, water logging, high pH, low pH, grazing Diseases and pests; Tree form

Source: El-Siddig *et al.* (2006).

The apparent high phenotypic variability within and between populations indicates that economic benefits may be obtained by selecting superior trees within provenances. Some of the major Tamarind growing countries have selected improved cultivars from among the natural populations as shown in Table 12.6.

In spite of wide recognition, use of germplasm collections for tree improvement is limited in Tamarind and the opportunity is not fully exploited (Gill, 1984; 1985). Presently attempts are being made in different countries to collect germplasm to improve Tamarind to meet the commercial needs of the world.

Table 12.6: Selected Tamarind Cultivars Grown in Some Countries.

Country	Cultivar
Thailand	Sweet Tamarind: Muen Chong, Sri Tong, Nam Pleung, Jac Hom, Kun Sun, Kru Sen, Nazi Zad, Sri Chompoo
Philippines	Sweet Tamarind: Cavite, Batangas, Bulacan, and Laguna
India	Prathisthan, Periyakulam (PKM 1), Urigam

Sources: Webster (1921); Feungchan *et al.* (1996b).

RESEARCH AND TECHNOLOGY NEEDS

Very little is known about the genetic variation of Tamarind. Due to its out breeding nature and exceedingly wide distribution in the wild or naturalized state no concerted effort has been made to strategically sample populations and analyze patterns of variation. Because of the long-lived nature of the trees molecular and biochemical techniques of analysis should be combined with biometrical measurements and other assessments of traits of value in characterizing any stocks to be put into working collections for potential use in genetic improvement. Additionally research is needed on the effective size of breeding populations.

The genetic improvement goals are based on the available material. They are: faster growth and higher yielding lines for selection for different uses. Since normal crossing is not an option, more trait specific work is needed so that provenance trials can lead to selections which combine the desirable characters, and then to cultivars developed from them. These should be developed to fit the different land-use systems of agroforestry, orchards/ plantations, as well as certain stress conditions inherent in a number of wastelands which need to be rehabilitated.

Tamarind is so widespread that little attention has been paid to genetic conservation. Any needs for this will become much more apparent as soon as enhanced research on pattern of variation is carried out. Existing *ex situ* collections are is no way conservation collections since they relate to working collections for selection or adoption for test of introduced materials. As genetic improvement is enhanced the landmark genetic lines will need to be conserved.

Once cultivars are selected, propagation methods are necessary to produce young plants and make them available to growers. Vegetative propagation techniques should be standardized, simple and easily performed by farmers.

One area of research which needs much more emphasis is on flowering, fruit set and fruit production. The development of standardized relatively low-cost spays to enhance fruit production is an urgent research need since growers will have to factor this cost into their cost-benefit analyses. More attention needs to be paid to harvesting, currently a laborious time consuming operation. Rather than harvesting from a diverse age and size range of trees, the future is likely to relate to efficient harvesting techniques applicable to small-scale plantations.

Shelling by hand is common practice in many countries. It requires eight man-hours to shell 45 kg of fruits. Further work on the development of small-scale shellers would be required to improve the efficiency of processing. Processing technology at the producer level is lacking and heavy losses are reported, hence simple methods for processing, storage and value addition should be developed. Although a number of processing technologies are available these are not widely disseminated among growers. This emphasizes the need for extension programs.

The brown-red colour of the pulp starts to deteriorate in storage and becomes black within a year. Improved methods for processing and storage need to be developed and standardized. Destruction of the pulp by insects and fungi during storage is also a problem and this needs attention. There is need to develop technologies for manufacturing Tamarind products to make better use of the pulp and seed which are produced in large quantities in most Tamarind-growing countries. Value addition through product diversification is another area that deserves research attention.

Whereas some data exist on marketing, most marketing systems are traditional and at the farm-gate prices received by growers and collectors are low. It will be essential to organize marketing channels, such as village level co-operatives, fair price shops or similar marketing institutions, so that the primary producers are not forced to dispose of their produce at lower prices. Local market surveys will be useful to identify potential markets for various products of Tamarind. There is a total lack of socio- economic research at all levels along the production to consumptions chain where women, men and children are all involved. Benefits can be quantified as on-farm and off-farm incomes and these measured in purchasing powers, credit, education opportunities etc.

It is noted that international trade, albeit small, is well established. This would be strengthened by the adoption of quality control standards but this requires research and policy changes by authorities.

CONCLUSIONS AND FUTURE IMPACTS

The wide variety of uses for Tamarind in many of the countries has not been exploited, although in the future the area and extent of production are likely to increase as Tamarind assumes greater recognition and importance.

There exists a considerable land area where Tamarind growing could be expanded in its native and naturalized range, but due to low priority allocation, many countries have not identified areas that could be used for expansion. Potential production areas for Tamarind depend on the demand for Tamarind products. Areas many range from scattered trees for personal use by producers to plantations for market production. The initial spread of plantations is likely to occur around the current production centers where technology, skill and marketing channels are already in place. Application of standards for products could increase competition. Cultivation is likely to spread to arid and semi-arid areas, resource-poor areas and wastelands where other crops cannot grow, because such land usage is receiving increased attention.

There exist good business prospects for Tamarind in many tropical and subtropical countries. The potential to develop a commercial Tamarind industry is excellent provided that such development is targeted to an industry based on reliable production, post-harvest processing and marketing. Export oriented plantations of Tamarind will also require technology inputs by producers to the production, post-harvest processing and marketing systems. The development of interest in organic production by consumers will also enhance opportunities for export.

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