CHAPTER 6

SAPODILLA
Manilkara zapota L. van Royen

K.H.S. Peiris

Fruit Crops Research and Development Centre
Horana, Sri Lanka

INTRODUCTION

Sapodilla (*Manilkara zapota* L. van Royen) is an economically important species of the Sapotaceae family native to tropical America. As a rainforest tree known as the "chickle tree", it has a long history of human use (Simpson and Ogorzaly, 1995). It has been used for many purposes including latex, fruit and timber. The name Sapodilla is derived from the Spanish word *zapotilla*, meaning "small sapote." It is a popular fruit crop presently and widely cultivated in most tropical countries across the globe. Today Sapodilla is cultivated almost exclusively for commercial fruit production in other countries. The ripe Sapodilla, unchilled or preferably chilled, is consumed as a dessert fruit. A number of processed food items such as dessert, Sapodilla pie, and canned slices are made from the ripe fruit. Ripe Sapodillas have also been successfully dried by osmotic dehydration. It is an important adjunct in ice cream and milk shakes in its fresh form. Fruit can also be used for preparing liquor and alcohol because of its richness in sugar. For many years latex of Sapodilla has been employed as the chief ingredient in chewing gum. As a fairly slow-growing, medium sized (15-30 m), long-lived evergreen tree, Sapodilla is also valued as an ornamental tree and used in tropical landscapes due to their rounded crowns and glossy leaves. It is an underutilized species in Sri Lanka.

TAXONOMY

Sapotaceae family is a diverse and ecologically important family of 700 species and 35 or 40 poorly defined genera (Takhtajan, 1997; Shultes and Raffouf, 1990). These shrubs and trees are widely distributed pantropically (Shultes and Raffouf, 1990). This family is easily recognized by the combination of milky latex and alternate (spiral) leathery leaves with parallel secondary and tertiary veins (Gentry, 1993).

The genus *Manilkara* includes 30 New World and 32 Old World species, several of which are economically important as sources of latex, fruit and timber (Gentry, 1993). Sapodilla is also sometimes known as Sapote, are about the most confusing of all the fruits. The name is derived from the Aztec "tzapotl", which means soft, and gives rise to a seemingly inexhaustible realm of terms for sapote fruits, as well as for those not even remotely related. A fruit sometimes called "mamey sapote" (*Pouteria sapota*) is a sapote fruit and not related to another fruit also called "mamey". The 'white sapote' (*Casimiroa edulis*) is not related, and neither is 'chupa chupa' (*Quararibea cordata* of the family Bombacaceae), which grows in Peru and Colombia. Black sapote (*Diospyros ebenaster*) is another name that is sometimes used for the black persimmon. Some varieties that are related to Sapodilla are the sapote (*Calocarpum mamosum*), which has a large central seed similar to the avocado, the green sapote (*Calocarpum viride*), and the star apple (*Chrysophyllum cainito)*. However, the species, Sapodilla has the best claim to the name.

The nomenclature of Sapodilla 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:	Dilleniidae
Order:	Ebenales
Family:	Sapotaceae
Genus:	*Manilkara* Adans. (manilkara)
Species	*Manilkara zapota* (L.) van Royen

Source: http://plants.usda.gov

Diploid chromosome number of Sapodilla is 2n=2x=26 (Schlegel, undated)

Synonyms

There are a large number of synonyms used in literature as follows:

Achras sapota L.
Achras zapota L. var. zapotilla Jacq.
Achras zapotilla Nutt.
Achras mammosa L.
Manilkara achras (Miller) Fosberg
Manilkara zapotilla (Jacq.) Gilly
Sapota zapotilla (Jacq.) Coville
Sapota achras Miller
Sapota zapotilla (Coville)

Both *Manilkara* and *Achras* are commonly used as generic names and there appears to be no agreement among botanists or horticulturists as to the proper term. *Sapota* (*zapota*) or *sapote* (*zapote*) is commonly used as the species name, although this too is variable among regions and authors. Gilly (1943) addressed this problem of confused nomenclature. It seems the generic name *Achras*, given by Linnaeus, was based upon a plate and description by the botanist Plumier. Unfortunately, the plant described by Plumier is not Sapodilla, leading, to the misnaming. Gilly suggests that *Manilkara zapotilla* (Jacq.) Gillys's is the only proper name since *Manilkara* is the earliest recorded name of the group to which Sapodilla belongs and *zapotilla* was specifically applied to Sapodilla at the time of its publication.

Vernacular names

Sapodilla is known by a number of vernacular/common names (Table 6.1). The profusion of such an array of names for the fruit is probably due to the many small, isolated growing areas it occupies, where names are often derived from local words.

Table 6.1: Common/Vernacular Names of Sapodilla.

Country/ Language	Common / Vernacular Name
Brazil	Sapoti, Sapotilha
Bahamas	Dilly
Cuba	Sapota, Sapote
Puerto Rico	Nispero
Thailand	Lamoot, Lamut, Lamut-farang
English	Sapodilla
Indonesia	Sawu
India	Chikoo, Chicku, Chiku
El Salvador	Muyozapot
Mexico	Chicopote, Chicozapote
West Indies	Nasebery
Dutch West Indies	Sapatija, Sapodilla plum, Sapodille
French West Indies	Sapotille, Sapotillier
Singapore	Ciku
Malaysia	Chikoo
Surinam	Mispu, Mispel, Mispelboon
Sinhala	Sapodilla, Rata mee
Virgin Island	Mespel

Source: Morton (1987).

BOTANICAL DESCRIPTION

Tree: Sapodilla is a medium to large tree with a pyramidal to rounded canopy with many branches. It produces a dense crown and a characteristic branching system (sympodial), in which the young branches are arranged horizontally. These long-lived trees grow slowly but after many years, may reach 20-30 m in height. Branches are horizontal or drooping. A milky latex known as "chicle" exudes from all tree parts.

Leaves: The leaves are highly ornamental, 7.5-11.25 cm long and 2.5-3.75 cm wide. They are medium green, glossy, alternate and spirally clustered at the tip of forked twigs. The foliage is evergreen. Leaves spirally arranged and clustered at the shoot tips, simple, elliptic or oblong, apex obtuse to shortly acuminate; coriaceous, shining, glabrous when mature. Secondary veins make a wide angle with the midrib. Leaves are oblong to narrowly oblong-obovate, 8 to 13 cm in length, pointed at both ends and clustered at the ends of shoots. The leaves are pinkish brown when newly emerged and light green to dark green at maturity. Leaves contain a bitter principle alkaloid and fixed oil.

Flowers: The flowers are distinctive due to a two-whorled calyx of three sepals each, the outer valvate, and the open corolla having lobes three-parted to near the base, sometimes the lateral lobes divided again to give up to 30 segments (Gentry, 1993). Flowers greenish, solitary, cyathiform or campanulate, with a brown pubescent peduncle; 6 sepals, 6 corolla lobes. Flowers are hairy outside, 8 mm long and 6-parted. Flowers are borne singly or in clusters in leaf axils near the tips of branches. Flowers are small, bisexual, off-white, bell-shaped, and measure about 10 mm in diameter. There are several flushes of flowers throughout the year.

Roots: Sapodilla is a shallow-rooted tree, with more than 80% of the roots located within the top 75 cm of soil, concentrated within an area half the width of the canopy (Bhuva *et al*., 1991). About 66% of the moisture extracted from the soil is in the first 75 cm. This root morphology suggests that irrigation may be economically feasible in areas of low rainfall.

Fruit: The fruit, a berry may be nearly round, oblate, oval, ellipsoidal, or conical; varies from 5-10 cm in width. When immature it is hard, gummy and very astringent. Though smooth-skinned it is coated with a sandy brown scurf until fully ripe. The flesh ranges in color from yellowish to light- or dark-brown or sometimes reddish-brown; may be coarse and somewhat grainy or smooth; becomes soft and very juicy, sweet to very sweet (19-24^{o} Brix), pleasant flavor resembling that of a pear. When fruit reaches maximum size, it may be picked and allowed to ripen off the tree. From experience, one can judge maturity of fruit of a particular variety or selection by its size and appearance. Fruit growth follows a sigmoid pattern (Lakshminarayana and Subramanyam, 1966).

Seeds: Some fruits are seedless, but normally there may be from 3 to 12 seeds (frequently 5) which are easily removed as they are loosely held in a whorl of slots in the center of the fruit. They are brown or black, with one white margin; hard, glossy; long-oval, flat, with usually a distinct curved hook on one margin. The seeds contain sapotin, saponin, achras saponin, an alkaloid, fixed-oil (16-23%), and the bitter principle sapotinine (0.08%). They also contain hydrocyanic acid and should be removed before eating the fruit.

Reproductive biology: Sapodilla is an out-breeding, self-incompatible species (Coronel, 1983; Mickelbart, 1996). Honeybees collect nectar from the flowers and may contribute to the pollination. Isolated Sapodilla trees may not be productive because some Sapodilla cultivars are self-incompatible. In self-incompatible cultivars the flowers require cross-pollination by another Sapodilla variety in order to produce fruit. Other varieties may not require cross-pollination but produce more fruits when cross-pollinated.

Flowers are bisexual; the stigma extends beyond the corolla. The tree flowers and fruits throughout the year; fruit take about 4 months to mature. Seedlings may take 5-8 years to bear fruit, while grafted varieties take only 2-3 years from planting.

Pollination: Sapodilla is an insect pollinated species. Pollinators include *Hermitia* spp.,, *Oecophylla smaragdina*, thrips (*Thrips hawaiiensis* and *Haplothrips tenuipennis*) (Coronel, 1983; Mickelbart, 1996). Honey bees also visit Sapodilla flowers and may be involved in pollination.

ORIGIN AND GEOGRAPHICAL DISTRIBUTION

Sapodilla is a tree native to tropical America. It is believed to be native to Yucatan and possibly other nearby parts of southern Mexico, as well as northern Belize and northeastern Guatemala. It is found in the wild from southern Mexico to Nicaragua. The tree was cultivated in the region long before the arrival of the Spaniards, who introduced it to the Philippines. From there, it spread through southeast Asia and to India and is now found growing throughout the warmest regions of the world.

The Spanish explorers recorded Sapodilla being referred to as ‘chikle’ by the Aztecs. The Mayan Indians of Mexico and Central America traditionally have chewed the raw chicle latex. Furthermore, Aztec prostitutes loudly snapped their chewing gum to advertise their trade during the height of pre-Columbian Aztec civilization (Plotkin, 1993).

Presently, Sapodilla is cultivated because the fruits are so tasty. It is grown on a commercial scale in India, Thailand, Philippines, Malaysia, Mexico, Venezuela, Vietnam, Guatemala, and some other Central American countries. In fact, India is one of the largest producers of Sapodilla.

The species is found in forests throughout Central America where it has apparently been cultivated since ancient times. It was introduced long ago throughout tropical America and the West Indies, the Bahamas, Bermuda, the Florida Keys and the southern part of the Florida mainland. In Asia, it was first introduced to the Philippines by the Spanish and later spread to other Asian countries. It reached Sri Lanka in 1802 (Morton, 1987). As a native tree species Sapodilla is found in Brazil, Costa Rica, Cuba, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama and Venezuela.

Sapodilla introduced to India in 1898 was first planted in the village Gholwad in Maharashtra. Thereafter it flourished under the patronage of Maharashtra farmers and now the crop has attained the status of a major fruit industry of India (Singh, 2004). Sapodilla has long been grown in Sri Lanka mostly as a home garden fruit crop and as a landscaping tree in gardens and parks. The true commercial potential of this important tree fruit crop has not yet been fully exploited and it has not yet even regarded as a mainstream fruit. The available literature on Sapodilla is very limited. In Sri Lanka, it is found in home gardens, parks and in fruit farms as a minor fruit crop in wet, intermediate and dry agro-ecological zones. Cultivation extents, production figures and price information are not available since it is not cultivated as a commercial fruit in the country.

PROPERTIES OF THE SPECIES

Sapodillas are nutritious and mostly eaten as fresh fruits (Table 6.2). Its total acid ranges from 0.09 to 0.15%; pH, 5.0 to 5.3; total soluble solids, 17.4º to 23.7º Brix; as for carbohydrates, glucose ranged from 5.84 to 9.23%, fructose, 4.47 to 7.13%, sucrose, 1.48 to 8.75%, total sugars, 11.14 to 20.43%, starch, 2.98 to 6.40%. Tannin content, because of the skins, varies from 3.16 to 6.45%. The fruit also contains sapotin (Morton, 1987).

Table 6.2: Average Composition of Sapodilla Fruit.

Constituents	**Amount (per 100 g)**
Water (g)	73.7
Energy (k cal)	98
Protein (g)	0.4-0.7
Fat (g)	1.1
Carbohydrate (g)	21.4
Calcium (mg)	28
Phosphorus (mg)	27
Iron (mg)	2
Thiamin (µg / 100g)	20
Riboflavin (µg / 100g)	30
Niacin (mg / 100g)	0.2
Vitamin C (mg / 100g)	6
Vitamin A (µg / 100g)	48

Sources: Department of Agriculture (2004); Morton (1987).

Analyses of 9 selections of Sapodillas from southern Mexico showed great variation in total soluble solids, sugars and ascorbic acid content. Unfortunately, the fruits were not peeled and therefore the results show abnormal amounts of tannin contributed by the skin (Morton, 1987).

The wood is strong, durable, homogenous, deep red, very hard, strong, tough, dense, resistant and durable. It is suitable for heavy construction, furniture, joinery and tool handles. Sapwood is pale pinkish, merging gradually into the red or reddish-brown heartwood. Luster low. Grain mostly straight. Texture moderately fine. Bole 8-l0 m long, symmetrical. Timber is very hard and heavy, tough and strong. A difficult material to dry because of its marked tendency to distort, split and checks. Not very easy to work, but with proper care stock planes to a good surface. Finishes well and drills cleanly. Material cannot be nailed unless pre-bored. Turns quite well. Timber has very high strength values, especially in bending, compression and shock resistance. Reported to be very resistant to insect attack and fairly resistant to marine borers (Berni *et al*., 1979).

USES AND PRODUCTS

Food : Sapodilla is highly prized and considered as one of the best fruits in Central America. Generally, the ripe Sapodilla, unchilled or preferably chilled, is cut in half and the flesh is eaten with a spoon. It is an ideal dessert fruit as the skin, which is not eaten, remains firm enough to serve as a "shell". Care must be taken not to swallow a seed, as the protruding hook might cause lodging in the throat. The flesh could be scooped out and added to fruit cups or salads, sherbets, milk shakes and ice cream can be made from fresh pulp. A dessert sauce is made by peeling and seeding ripe Sapodillas, pressing the flesh through a colander, adding orange juice, and topping with whipped cream. Sapodilla flesh may also be blended into an egg custard mix before baking.

It was long proclaimed that the fruit could not be cooked or preserved in any way, but it is sometimes fried in Indonesia and, in Malaya, it is stewed with lime juice or ginger. Bahamians often crush the ripe fruits, strain, boil and preserve the juice as syrup. They also add mashed Sapodilla pulp to pancake batter and to ordinary bread mix before baking. A fine jam could be made by peeling and stewing cut-up ripe fruits in water and skimming off a green scum that rises to the surface and appears to be dissolved latex, then adding sugar to improve texture and sour orange juice and a strip of peel to offset the increased sweetness. Skimming until all latex scum is gone is the only way to avoid gumminess. Cooking with sugar changes the brown color of the flesh to a pleasing red.

In India, it has been shown that ripe fruits can be peeled and sliced, packed in metal cans, heated for 10 minutes at 70º C, then treated for 6 minutes at a vacuum of 28 in Hg, vacuum double-seamed, and irradiated with a total dose of 4 x 10^5 rads at room temperature. This process provides an acceptable canned product. Thailand also export canned Sapodilla slices in syrup (Plate 6.3)

Ripe Sapodillas have been successfully dried by pretreatment with a 60% sugar solution and osmotic dehydration for 5 hours, and the product has retained acceptable quality for 2 months.

Young leafy shoots are eaten raw or steamed with rice in Indonesia, after washing to eliminate the sticky sap. The fruit is also popularly used in the aging of the coconut liquor, in the Philippines. The juice may be boiled into syrup or fermented into vinegar.

Chicle: Sapodilla is primarily a source of the latex called chicle. The prevalence of this species in rainforests in the Yucatan and Guatemala that were once Mayan agricultural areas may reflect ancient encouragement, if not cultivation, of chicle (Mabberley, 1992). The dried latex was chewed by the Mayas and was introduced into the United States by General Antonio Lopez de Santa Ana about 1866 while he was on Staten Island awaiting clearance to enter US. He had a supply in his pocket for chewing and gave a piece to the son of Thomas Adams. The latter at first considered the possibility of using it to make dentures, then decided it was useful only as a masticatory. He found that it could be easily incorporated in flavoring and soon launched the chicle-based chewing-gum industry. In 1930, at the peak of production, nearly 6, 363,636 kg (14,000,000 lbs) of chicle were imported. Chicle remained the main base for the immensely popular chewing gum until 1944-1945 when it was replaced by petroleum-derived synthetics (Schwartz, 1990). During the intervening 75 years, U.S. manufacturers monopolized the product by financing chicle tapping in Mexico and Central America. By 1930 these companies were importing 15 million pounds of chicle a year, and their products were sold worldwide (Schwartz, 1990).

Chicle is the coagulated latex obtained from Sapodilla, which is produced on a commercial scale in Mexico and certain parts of Central

America. Sapodilla is indigenous to Central America and grows best in the Yucatan peninsula, which forms the principal chicle-producing area. Chicle is to be distinguished from sapote gum, the hard, gummy material that forms slowly over the wound made in a tree to obtain latex, once the latter has ceased to flow. Sapote gum was once used in Peru as a sizing agent for cloth, and as a glue, but it does not enter world trade. Chicle's economic importance has arisen from its use in the manufacture of chewing gum, where it imparts the "chewing" properties to the product. At one time, chewing gum base consisted almost entirely of natural "gums", of which the principal one was chicle. Nowadays, with the advent of cheaper, synthetic resins with suitable properties, demand for natural gums for use in chewing gum has declined.

Chicle is tasteless and harmless and is obtained by repeated tapping of wild and cultivated trees in Yucatan, Belize and Guatemala. It is coagulated by stirring over low fires, then poured into molds to form blocks for export. Processing consists of drying, melting, elimination of foreign matter, combining with other gums and resins, sweeteners and flavoring, then rolling into sheets and cutting into desired units.

Efforts have been made to extract chicle from the leaves and unripe fruit but the yield was insufficient. It has been estimated that 3,200 leaves would be needed to produce one pound (0.4535 kg) of gum.

Medicinal Uses: Sapodilla is also used for many indigenous medicines. Because of the tannin content, young fruits are boiled and the decoction taken to stop diarrhea. An infusion of the young fruits and the flowers is drunk to relieve pulmonary complaints. A decoction of old, yellowed leaves is drunk as a remedy for coughs, colds and diarrhea. A "tea" of the bark is regarded as a febrifuge and is said to halt diarrhea and dysentery. The crushed seeds have a diuretic action and are claimed to expel bladder and kidney stones. A fluid extract of the crushed seeds is employed in Yucatan as a sedative and soporific. A combined decoction of Sapodilla and chayote leaves is sweetened and taken daily to lower blood pressure. A paste of the seeds is applied on stings and bites from venomous animals. The latex is used in the tropics as a crude filling for tooth cavities. Fruit soaked in melted butter overnight, is thought to be preventive for biliousness and fevers.

Seeds are antipyretic, and when ground with water they act as a diuretic. The plant is a source of sapotin, a glucoside used in medicine as a febrifuge. In Indonesia, the flowers are used as one of the ingredients of a powder that is rubbed on the body of a woman after childbirth. In Cambodia, tannin from the bark is used to cure diarrhea and fever.

The tannin content of the unripe fruits is said to help stomach problems. The old and yellowed leaves are said to cure colds and coughs. The crushed seeds are used for treating stones in the kidney. A paste of the seeds is used to treat animal bites.

Other Miscellaneous Uses: The latex is employed as birdlime, as an adhesive in mending small articles in India; it has been utilized in dental surgery, and as a substitute for gutta percha, or Percha Rubber derived from the latex of *Palaquium gutta* . The Aztecs used it for modeling figurines. Gum chicle is also used for transmission belts.

Timber: Sapodilla wood is strong and durable and timbers which formed lintels and supporting beams in Mayan temples have been found intact in the ruins. It has also been used for railway crossties, flooring, native carts, tool handles, shuttles and rulers. The red heartwood is valued for archer's bows, furniture, banisters, and cabinet work but the sawdust irritates the nostrils. Felling of the tree is prohibited in Yucatan because of its value as a source of chicle.

Bark: The tannin-rich bark is used by the Philippine fishermen to tint their sails and fishing lines.

Apiculture: Honeybees are known to collect nectar from the flowers.

ECOLOGICAL REQUIREMENTS

Sapodilla is a species of the lowland rainforest. Trees grow well in a wide range of climatic conditions from wet tropics to dry cool subtropical areas. They prefer a moist hot climate similar to that found at medium to low elevations in tropical areas, such as in coastal regions.

Rainfall: It prefers a hot humid climate with a mean annual rainfall of 1250-2500 mm. Fruiting is not adversely affected by heavy rainfall.

Temperature: A temperature range of 10-38°C is suitable for Sapodilla cultivation. Young Sapodilla trees may be severely damaged or killed at -1 to 0°C or below but mature trees may withstand down to about -3°C for a few hours without major damage. High temperatures exceeding 43°C leads to flower drop with adverse effects on fruiting.

Altitude: Sapota is found growing in locations from sea level up to 2800 m in altitude. It grows from sea level to 457 m in the Philippines, 1,220 m in India, 1,200 m in Venezuela, and is common around Quito, Ecuador at 2,800 m (Morton, 1987). In Sri Lanka, it is grown up to an elevation of 1000-1200 m above sea level.

Soil: Sapodilla grows naturally in the calcareous marl and disintegrated limestone of its homeland but it is well adapted to many other types of soil. It is grown in well drained medium, sandy loam and lateritic soils. Soils can be slightly alkaline, medium-textured loams; however, it can tolerate a wide range of soil types from drier sands through to heavy clays.

Drainage: Good drainage is very essential, for the growth of Sapodilla trees. Sapodilla has been observed to be moderately tolerant of excessively wet or flooded soil conditions. However, prolonged excessively wet or flooded soil conditions may reduce tree growth and crop yields. It does not do well in poorly drained, waterlogged and ill drained soils (Balerdi *et al.*, 1996).

Wind: Sapodilla trees are tolerant of harsh windy conditions although young trees generally do not have a problem with establishment on windy sites. Mature trees should be limited to 3.7-4.6 m in height to help reduce the chances of toppling due to hurricane force winds.

Drought resistance: It is highly drought resistant**.** Young Sapodilla trees have been observed to defoliate or decline due to lack of water;

therefore young trees should be watered periodically during dry periods. Mature Sapodilla trees are tolerant of dry soil conditions. However, for optimum fruit production and quality, periodic irrigation during long dry periods is needed from flowering through harvest. In the home gardens, well established Sapodilla trees generally do not require regular watering to produce satisfactorily.

Salt tolerance: Sapodillas grow well near the seashore, indicating good tolerance to sea salt sprays. It approaches the date palm in its tolerance of soil salinity, rated as EC of 14.20.

Light and shade: Trees prefer full sunshine. Sapodilla is also thrives in the tropical rainforests and is highly tolerant to shaded climate.

AGRONOMY

Prpopagation

Seed propagation: Seeds remain viable for several years if kept dry. The best seeds are large ones collected from well grown fruits. They germinate readily in 4-6 weeks without any treatment and up to 80% success exhibiting an epigeal type of germination. Growth is slow and the trees take 5 to 8 years to bear. There is also great variation in the form, quality and yield of fruits from seedling trees, therefore, vegetative propagation has long been considered desirable. Seeds germinate after about 30 days. The seeds for rootstock are sown in a sandy seed beds about 2 cm apart and at a depth of about 1 cm. After a few months, the seedlings are transplanted into polybags. They grow very slowly; even with nitrogen application rootstocks are not ready for grafting for 2-3 years.

Vegetative propagation: Sapodilla is vegetatively propagated using several methods such as grafting, inarching, ground-layering and air-layering. Vegetatively propagated trees may begin to bear 2-4 years after planting. After 10 years, a good cultivar may bear 45-180 kg of fruits per year. This yield may keep increasing until about the 12th to 15th year after planting depending on plant size and cultural practices.

Air layering is the most common means of propagation in India and there has been a fair amount of research regarding optimal treatment of air-layered plants. Using recently-produced branches, along with etiolation and application of a growth regulators such as IBA or NAA results in optimal growth of air-layered plants (Chadha,1992). In the Philippines, terminal shoots are completely defoliated 2 to 3 weeks before grafting onto rootstock which has been kept in partial shade for 2 months. However, inarching is considered superior to grafting, giving a greater percentage of success. Nurseryman often find air-layering easier and more successful than grafting, and air-layered trees begin bearing within 2 years after planting.

Veneer grafting resulted in the highest percent survival and moderate root growth in a study comparing various propagation techniques including side grafting, side inarching, tongue grafting, whip grafting, and saddle grafting (Hussain and Bukhari, 1977). Tongue grafting resulted in the lowest percent survival, although the plants produced had significantly larger root systems than those produced by the other methods. Malo (1967) describes a successful method for veneer grafting of Sapodilla plants designed to propagate large numbers of propagules.

Softwood grafting was successful (80% survival) in a study conducted in India (Kulwal *et al.*, 1985). The greatest success was obtained when scion wood was defoliated 8 days prior to removal and when grafting was done during the summer months.

In Florida, shield-budding, cleft-grafting and side-grafting were moderately successful but too slow for large-scale production. An improved method of side-grafting was developed using year-old seedlings with stems 6 mm thick. The scion (young terminal shoot) was prepared 6 weeks to several months in advance by girdling and defoliating. Just before grafting the rootstock was scored just above the grafting site and the latex "bled" for several minutes. After the stock was notched and the scion set in, it was bound with rubber and given a protective coating of wax or asphalt. The scion started growing in 30 days and the rootstock was then beheaded. Further experiments showed that better results were obtained by omitting the pre-conditioning of the scion and the bleeding of the latex. The operator must work fast and clean his knife frequently. The scions are veneer-grafted and then completely covered with plastic, allowing free gas exchange while preventing dehydration. Success is most dependent on the season: the 2 or 3 months of late summer and early fall.

Rootstocks: While Sapodilla seedlings are often used as rootstocks for grafted plants, some other species may be suitable and contribute to the management of orchards. Wild dilly [*Manilkara emarginata* (Bakar) Lam. and Meeuse] (Ogden and Campbell 1980) and *Manilkara hexandra* (Roxb.) (Chandler 1958) have been proposed as possible dwarfing rootstocks for Sapodilla. *Bassia latifolia, B. longifolia, Sideroxylon dulcificum* and *Mimusops hexandra* have also been used, and successful as the grafts grow vigorously and fruits heavily. *Manilkara kauki, Madhuka latifolia* are also used as rootstocks in India (Singh, 2003). In Sri Lanka, mee (*Bassia longifolia*) is commonly used as a rootstock for Sapodilla (Plate 6.4).

Plate 6.1: Fruit and Flower Bearing Branch of Sapodilla.

Plate 6.2. Immature Sapodilla Fruit with Brown Scurf on the Surface of Skin.

Plate 6.3. Fresh Fruit and Canned Sapodilla in Syrup.

Plate 6.4. ***Bassia longifolia*** **an Alternative Rootstock for Sapodilla.**

Plate 6.5. Sapodilla Variety with Round and Elongated Fruits.

Site Selection and Planting

Site selection: Sapodilla trees need full sun light for best growth and fruiting. Drainage of the site is very important as ill drained or excessively wet conditions will hamper the growth and production of fruits.

Spacing: Although Sapodillas grow slowly, trees that are not pruned eventually need a lot of space because they will develop a large canopy. Trees are spaced 7-12 m apart, depending on the growth habit of the cultivar.

Planting: Proper planting of Sapodilla propagules is one of the most important steps in successfully growing a strong, productive tree. The first step is to choose a healthy nursery propagule. Large trees in smaller containers should be avoided as the root system may be "root bound". Root bound plants may not grow properly once planted. Those with insect pests and diseases and wounds and constrictions should be discarded. Select healthy seedlings and water it regularly in preparation for planting in the ground. If necessary, young plants should be initially staked. It is always better to mix several cultivars in commercial plantings to overcome problems associated with self-incompatibility.

Management of Sapodilla Trees

Fertilizer application: Sapodilla is not demanding in its fertilizer requirements although fertilizer application improves fruit yield (Bhuva *et al*., 1990). Fertilizer application also improves total solids and pulp:seed ratio (Durrani *et al*., 1982). Newly planted trees need small and frequent feedings to become established. Fertilizers that contain 6-8% nitrogen, 2-4% available phosphoric acid and 6-8% potash give satisfactory results. First year applications should be made every two to three months beginning with 100g and gradually increasing to 450 g per plant. Thereafter, two to three applications per year are sufficient, in amounts proportionate to the increasing size of the tree.

In Florida, after planting, when new growth begins, application of 113 g mixture tree fertilizer such as a 6-6-6-2 with minor elements is recommended, with 20 to 30% of the nitrogen from organic sources.

This application is repeated every 6-8 weeks in the first year, and then gradually increased to 227 g, 341 g, 454 g as the tree grows. Use 4 to 6 minor element foliar sprays per year is also recommended. For mature trees, application of 2 to 3 times of 1.2-2.2 kg of fertilizer per year is recommended.

Sapodilla trees generally do not develop iron deficiency, even when grown in the rocky, calcareous, high pH soils. If iron deficiency symptoms appear (chlorotic leaves with green veins), iron should be applied. For trees in acid to neutral soils apply dry iron sulfate at 0.25 to 1 oz per tree to the soil 2 to 4 times per year and water the iron into the ground. In alkaline soils with a high pH, drench the soil adjacent to the tree trunk with iron chelate 1 to 2 times per year is advocated.

In India, application of up to 55 kg of FYM per tree per year is recommended. The amounts of NPK range from 45-900 g N, 20-640 g P_2O_5 and 25-1200 g K_2O per tree per year depending on growing area and age of trees (Singh, 2004). Phosphate fertilizer improves fruit size (Singh, 2003).

Irrigation: Newly planted Sapodilla trees should be watered at planting and every other day for the first week or so and then 1 to 2 times a week for the first couple of months. During prolonged dry periods (e.g., 5 or more days of little to no rainfall) newly planted and young trees (first 3 years) should be watered once a week. Once the rainy season arrives, irrigation frequency may be reduced or stopped. After 4 or more years, watering will be beneficial for plant growth and crop yields only during very prolonged dry periods. Mature trees do not need frequent watering and over watering may cause trees to decline. This is because too much water, too often applied causes root rot.

Weeds: Weeds compete for water and nutrients. Weeds may be controlled by herbicide applications, hand weeding, and mulching. Mulching Sapodilla trees helps retain soil moisture, reduces weed problems adjacent to the tree trunk, and improves the soil near the surface. Mulch with a 5-15 cm layer of paddy husk, straw, coir dust, wood chips, or similar material is beneficial. The mulch should be 20-30 cm away from the trunk to avoid termite attack.

Training and pruning: The development of a strong framework is important to allow Sapodilla trees to carry large crops of fruit without breakage. If the tree is leggy and lacks lower branches, remove part of the top to induce lateral bud break on the lower trunk. In addition, shoot tip removal of new shoots of about 1 m in length, once or twice will force more branching and make the tree more compact. Any branches that have a narrow crotch angle should be receded because these may break under heavy fruit loads.

As trees mature, most of the pruning is done to control tree height and width and to remove damaged or dead wood. Trees should be kept at a maximum of about 3.7-4.6 m. If the canopy becomes too dense, removing some inner branches will help in air circulation and light penetration. Another pruning objective is the removal of dead, damaged or diseased branches. Low branches should not be cut, unless they touch the soil. Cultural practices e.g., picking, spraying, and pruning are easier on small trees.

Topworking: Top working undesirable mature Sapodilla trees may be accomplished by cutting trees back to a 1m stump, white washing the entire stump and then veneer-grafting several new shoots when they reach 13 mm in diameter or larger. In India, 50% success has been realized in top-working 20-year-old trees--cutting back to 1 m from the ground and inserting scions of superior cultivars.

Pest and Diseases

Sapodilla tree remains healthy with little or no care. However, a number of insect pests and diseases have been reported from various growing areas.

Pests: Insects usually don't cause sufficient damage to necessitate control measures (Morton, 1987). In India, the trees are sometimes attacked by a bark-borer, *Indarbela (Arbela) tetraonis.* Mealy bugs may infest tender shoots and deface the fruits. A galechid caterpillar *(Anarsia)* causes flower buds and flowers to dry up and fall. In Indonesia, caterpillars of *Tarsolepis remicauda* may completely defoliate the tree. A caterpillar, *Nephopteryx engraphella,* feeds on the leaves, flower buds and young fruits in some areas of India (Kute and

Shete, 1995). The ripening and overripe fruits are favorite hosts of the Mediterranean (*Anastrapa ludens* Loew.), Caribbean, Mexican (*Ceratitis capitata* Wied) and other fruit flies. Various scales, including *Howardia biclavis, Pulvinaria* (or *Chloropulvinaria) psidii, Rastrococcus iceryoides,* and pustule scale, *Asterolecanium pustulans* Ckll., may lead to black sooty mold caused by the fungus *Capnodium sp.* on stems, foliage and fruits. The moth of a leaf miner *(Acrocercops gemoniella)* is active on young leaves.

Diseases: Leaf spot *(Septoria* sp.), leaf rust (*Uredo sapotae*), dry rot (*Fusarium solani*), septoria leaf spot (*Septoria* sp.), fruit rot (*Phytophthora palmivora*), phyllosticta leaf spot (*Phyllosticta sapoticola*), pestalotia leaf spot (*Pestalotia scirrofaciens*), anthracnose (*Colletotrichum gloeosporioides*), scab (*Elsinoe lepagei*), and phomopsis leaf spot (*Phomopsis* sp.) are some of the reported diseases in Sapodilla (Arya, 1998; Snowdon, 1990). Anthracnose caused by *Colletotrichum gloeosporioides* can be a serious problem in humid areas. Same species of bacteria are associated with fruit latex (Pathak and Bhat, 1952). Effective pre harvest control strategies reduce post harvest lesion development.

Because of the high moisture and nutrient content of the fruit, Sapodilla is especially prone to postharvest diseases. Common diseases include sour rot (*Geotrichum candidum*), Cladosporum rot (*Cladosporum oxysporium*), and blue mold rot (*Penicillium italicum*). Bakar and Abdul-Karim (1994) found benlate (methyl-N-1-butylcarbomoyl), a commonly used fungicide for postharvest treatment, as the best method of control both fungal and bacterial pathogens. Although several non-chemical treatments have been tested, none have proven to be successful against postharvest pathogens of Sapodilla.

Nematodes: General signs of nematode damage include stunting, premature wilting, leaf yellowing, root malformation, and related signs characteristic of nutrient deficiencies. Stunting and poor stand development tends to occur in patches throughout the field as a result of the irregular distribution of nematodes the soil.

Other pests: It may be necessary to spread nets over the trees to protect the fruits from fruit bats and birds during the fruiting seasons.

Harvesting

Sapodilla trees may have harvestable fruits year round, though there is a main season for each cultivar. The fruit maturity is difficult to judge. Immature fruit may not soften for many days, may not develop optimum sweetness and flavor, and may contain pockets of coagulated latex within the flesh. Fruit picked at optimum maturity usually ripen in 4 to 10 days. If the time of fruit maturity is unknown, one may wait until some fruit drop and then begin to harvest those of similar size. Other indicators of maturity are fruit size, loss of peel scurfiness, and a change in skin color from brown to amber. Another test is to lightly scratch the skin; if it is tan it can be picked, but if it is green or oozes latex, the fruit is not fully mature.

The erratic flowering habit and the presence of fruits at all stages of development on the tree make it difficult to determine optimum harvest time (Lakshminarayana, 1980). Fruits harvested later than optimum time usually soften very rapidly and become very difficult to handle. Fruits harvested earlier than physiological maturity may not soften, are usually low in sweetness and high in astringency when ripe, with a rather unappealing alcoholic aftertaste, and form pockets of coagulated latex that lower the quality. Unripe fruit are highly astringent and contain large amounts of leucoanthocyanidins. The sucrose content and pulp-to-peel ratio increase during maturation (Pathak and Bhat, 1952). The fruit shed off brown scaly external material and become smooth when reaching physiological maturity (Lakshminaryana, 1980). Fruit ready for harvest will not show a green tissue or latex when scratched with finger nails. Fully mature fruit will have a brown skin, and fruit will separate easily from the stem without leaking latex. Extent of scurfiness is also a good indicator of maturity (Kute and Shete, 1995). A fruit with a smooth surface, shining potato color and rounded styler end is considered mature (Kute and Shete, 1995).

Grading, Packaging and Storage

Fruit are commonly packed in fiberboard or wood flats with 25 to 49 fruit (4.5 kg) per flat (McGregor, 1987). Post harvest life is 2 to 3 weeks at 12 to 16 °C with 85 to 90% RH. Storage-life is about 13 days at 25 °C, 15 days at 20 °C and 22 days at 15 °C (Broughton and Wong, 1979). Short-term holding of fruit for less than 10 hours at 4 °C before storage and 20 °C extended storage-life up to 24 days with satisfactory quality (Broughton and Wong, 1979). Exposure of fruit to gamma irradiation at 0.1 KGy extended storage-life by 3 to 5 days at 26.7 °C and 15 days at 10 °C without any effect on ascorbate content (Salunkhe and Desai, 1984).

Storage-life of Sapodilla is extended by use of Modified and Controlled Atmosphere (MA) and removal of ethylene (Broughton and Wong, 1979; Yahia, 1998). Storage-life at room temperature increased from 13 to 18 days with 5% CO_2, 21 days with 10% CO_2, and to 29 days with 20% CO_2. However, fruit held in 20% CO_2 failed to ripen, and this level of CO_2 (20%) is deleterious. 'Kalpatti' fruit treated with 6% Waxol or 250 or 500 ppm Bavistin, or hot water at 50 °C for 10 min, and wrapped in 150 gauge polyethylene film with 1% ventilation, ripened later than the controls, but fungal rot was high (Bojappa and Reddy, 1990). Fruit treated with 6% wax emulsion and packed in 200-guage polyethylene covers containing ethylene and CO_2 absorbents had a shelflife of 45 days at 12 °C, 10 days more than controls (Chundawat, 1991).Sapodilla fruit were successfully stored using MAP for 4 weeks at 10 °C and 3 weeks at 15 °C, a week longer than fruit without MAP (Mohamed *et al*., 1996).

Sapodilla fruit are highly susceptible to chilling injury (CI). Exposure to temperatures below 5°C for more than 10 days causes chilling injury as indicated by dark-brown spots on the peel, failure to ripen, off-flavor development, and increased decay incidence after transfer to higher temperatures (Kader, 1992). Storage of fruit at 6 to 10 °C causes irreversible damage and results in poor flavor (Broughton and Wong, 1979; Salunkhe and Desai, 1984). CI also occurred in fruit stored for 21 days at 10 °C. However, fruits waxed with a fatty acid sucrose ester kept for 40 days at 10 °C.

Ethylene production is 2.8, 3.7 and 6.1 µL $kg^{-1}h^{-1}$ at 15, 20 and 25 °C respectively (Broughton and Wong, 1979). Treatment of Sapodilla fruit with Etherel at 1 to 3 mL L^{-1}accelerated ripening, and reduced pectin content, phenolic content, SSC, sugar content and Vitamin C

(Shanmugavelu *et al*., 1971; Das and Mahapatra, 1977; Ingle *et al*., 1982). Removal of ethylene delays ripening (Chundawat, 1991).

The respiration rate at 24 to 28 °C was 16 mg (9 µl) CO2 $kg^{-1}h^{-1}$ (Lakshminaryana and Subramanyam, 1966). Pre-harvest sprays of isopropyl n-phenylcarbamate (IPC) at 100 µL L^{-1} retard respiration, while maleic hydrazide at 0.5 to 1.0 mL L^{-1} accelerate it (Lakshminarayana and Subramanyam, 1966).

Keeping Quality and Storage

Mature, hard Sapodillas will ripen in 9 to 10 days and rot in 2 weeks at normal temperature and relative humidity. More than 50 years ago, Sapodillas were shipped from Java to Holland, held at (4.4 -10º C) for 3 days, and they ripened satisfactorily after arrival. They were smoked over burning straw for a few hours before packing. Storage trials in Malaya demonstrated that mature, hard Sapodillas stored at 20º C will ripen in 10 days and remain in good condition for another 5 days. In Venezuela, mature fruits held at 20º C and 90% relative humidity were in excellent condition at the end of 23 days. Lower temperatures, in efforts to prolong storage life, seriously retard ripening and lower fruit quality. Low relative humidity causes shriveling and wrinkling. Humid conditions promote sogginess. If long storage is necessary, the fruits should be kept at 15º-20º C in a controlled atmosphere of 85-90% relative humidity, 5-10% (v/v) CO_2, with total removal of C_2H_4 to delay ripening.

Firm-ripe Sapodilla fruits may be kept for several days in good condition in a refrigerator. At 1.67º C, they can be kept for 6 weeks. Fully ripe fruits frozen at 0º C keep perfectly for 33 days.

Postharvest Storage : The respiration pattern of Sapodilla follows that of a climacteric fruit (Broughton and Wong, 1979; Selvaraj and Pal, 1984; Abdul-Karim *et al.* 1987; Brown and Wong 1987). Respiration may be slowed by growth retardants such as gibberellic acid (GA), kinetin and silver nitrate (Gautam and Chundawat, 1990b). Gautam and Chundawat (1990a) examined the effects of various growth retardants on post harvest changes in Sapodilla. Application of GA, kinetin, and silver nitrate resulted increase in storage time up to two-days due to the reduction of catalase and pectin methyl esterase activity, and reductions in respiratory activity and ethylene production. The application of these compounds appears to reduce the rate at which fruit ripens as well as affecting fruit quality characteristics such as total sugars, acidity, ascorbic acid, and starch (Gautam and Chundawat, 1990b).

Gibberellic acid prolongs the storage of time before fruit rot occurs, as well as prolonging fruit softness and fruit skin shrinkage (Kumbhar and Desai, 1986). Gautam and Chundawat (1990a; 1990b) used 300 ppm GA solution, although Kumbhar and Desai (1986) found 75 ppm solution to be the most effective in a range of concentrations from 75 to 225 ppm.

Both wax coating and 2,4-Dichloro-phenoxy acetic acid (2,4-D) have been shown to retard the ripening process in Sapodilla, while 2-Chloroethyl phosphonic acid (Ethrel) (Ingle *et al*. 1981; Suryanarayana and Goud 1984) and ethylene (Sastry, 1970) greatly accelerate ripening. The storage in polyethylene bags can also reduce weight loss in Sapodilla by about 50% (Kumbhar and Desai, 1986).

ECONOMICS OF PRODUCTION AND MARKETING

Fruit: The tree is grown widely for its fruit and, where it has been cultivated as an exotic, this is its primary commercial use. The earning potential of Sapodilla in India is estimated at Rs. 10,117-12,140/ha in 4-6 years after planting and Rs 20,234-28,328/ha thereafter (http://sivashakthi.com/Sapota.htm). Sapodilla is grown in an extent of 56,896 ha with a production of 205,360 mt in Maharashtra state in India. Varieties Cricket ball and Kalipatti are exported to Middle East, UK, Singapore and Malaysia in 3 kg packages. Fruit are shipped by sea stored at 15-20 ^{0}C (http://www.msamb.com /English/export/promotion/ sapota.htm).

Chicle: Mexico is believed to be the largest producer of chicle, although Guatemala, which has been a significant producer may recently have surpassed Mexico. The estimated imports to Japan from the two countries for the period 1988-94 averaged approximately 400 t/year (Guatemala) and 370 t/year (Mexico). Other minor producers are

Belize, Honduras, Venezuela and Colombia. Japan is the major market. Total imports of chicle to Japan in recent years are estimated at around 800-1000 t/year.

The economic viability of chicle production from cultivated sources depends on the continued market for chicle as a natural chewing gum ingredient, as well as production factors such as labour costs. If the market can be maintained and production costs are held stable, then some increase in the area under cultivation can be justified. Providing the price of "cultivated" chicle compared with "wild" chicle remains attractive, the market always prefers to meet its requirements from renewable, sustainable resources rather than from wild trees that become increasingly less accessible (Coppen, 1995).

Timber: Sapodilla wood is strong and durable but felling of the trees in some countries (eg. Yucatan) is prohibited because of its value as a source of chicle. Sapodilla timber is not widely used in Sri Lanka.

GENETIC RESOURCES AND IMPROVEMENT

Sapodilla is an open-pollinated crop, hence a high degree of genetic variability exist within the population of seedling trees due to intercrossing among cultivars and segregation. In Sapodilla, morphological characteristics such as tree shape, structure, leaf color and shape, fruit size and shape have long been used to group cultivars. Cultivars have been grouped, based on the growth habit of the trees and shape and color of the foliage, into four major groups: (a) trees with erect growth habit, (b) trees with drooping habit, (c) trees with spreading habit I (leaves green, broad and oval shape) and (d) trees with spreading habit II (leaves light green, narrow elliptical shape) (Bal, 1997). However, this classification appears to be very arbitrary because morphological characteristics are influenced by the environment. Studies with different cultivars have shown the variability for many characteristics. In a study using 20 cultivars, fruit length ranged from 5.3 to 7.9 cm, fruit size from 43 to 160 g, TSS from 15.6 to 23.7^{o} Brix, and seed number from 1 to 6 (Dinesh and Reddy, 2000). In another study involving 12 cultivars, percentage coefficient of variation (CV) varied from 11 to 51 for various characteristics (Ponnuswamy and Irulappan, 1987).

Sapodilla is one of the 10 most important dominant species of Mexican rainforests, both in terms of frequency and food resources for mammals and birds (Toledo, 1982). Sapodilla occurs in two morphologically distinct populations in the Yucatan peninsula of Mexico. Forest populations consist of tall, straight trees, while swamp populations have a short, shrub-like growth form. Swamp populations also have smaller leaves, fruit and seeds. Heaton *et al*. (1999) performed a random amplified polymorphic DNA (RAPD) analysis on four different populations of chicozapote to test if there was a genetic component to this variation. The populations differed in respect to habitat type (swamp vs. forest) and geographical location (east vs. west). Analysis of the RAPD data showed no significant differences between swamp and forest populations.

Meghala *et al*. (2005) examined the extent of genetic diversity and genetic relationships among 20 Indian Sapodilla cultivars using RAPD markers. Cluster analysis and principal components analysis using RAPD data showed two major groups of cultivars. There were no closely formed groups. Most of the cultivars were dispersed in the graphic plane, indicating the presence of wide genetic diversity among the cultivars used in the study. In any introduced crop genetic variation depends on the number of introduced cultivars or genotypes. Generally it is expected to be very narrow, due to small number of introductions. Since Sapota is an introduced crop to India, no information is available on the number of cultivars introduced or the origin of these cultivars, hence it was expected that the variability in germplasm would be less. However, results of this study contradict this. In both the dendrogram and principal components analysis there were no closely formed groups, and the percentage of polymorphic bands amplified was also high (79%), indicating the presence of wide genetic diversity.

In Sri Lanka, Sapodilla has been cultivated as a home garden crop for a long time. However, it has not received enough attention in relation to variety development or conservation. There are no named cultivars recommended for cultivation except for varieties identified in terms of fruit shape, round or oval fruit shape (Plates 4 and 5). Recently, a program was initiated at Fruit Crops Research and Development Center, Horana to collect genetic resources of Sapodilla and six accessions has been collected and propagated.

A large number of cultivars have been developed and are being cultivated in countries like India and USA where Sapodilla is cultivated as an economic fruit crop. Some of these cultivars and their special properties are given in Tables 6.3 and 6.4.

Table 6.3. Description of Some Cultivars of Sapodilla.

Name of Cultivar	Origin	Fruit size (g)	Yield/tree	Location	Reference
Addley	Bahamas		Very poor	Florida	Campbell and Malo (1973)
Badam		45		India	Sundarajan and Rao, (1967)
Baramasi		118		India	Sundarajan and Rao, (1967)
Big Pine Key	Florida		Very poor	Florida	Campbell and Malo, (1973)
Black	Florida		Very poor	Florida	Campbell and Malo, (1973)
Brown Sugar			125-200 kg	Florida	Campbell and Malo, (1973)
Calcutta Round		98		India	Sundarajan and Rao, (1967)
Cricket Ball		142	93 kg	India	Chundawat and Bhuva, (1982)
Dwarapudi		90		India	Sundarajan and Rao, (1967)
Gavarayya		112		India	Sundarajan and Rao, (1967)
Guthi		56		India	Sundarajan and Rao, (1967)
Jamaica No. 4	Jamaica		Very poor	Florida	Campbell and Malo, (1973)
Jamaica No. 5	Jamaica		Very poor	Florida	Campbell and Malo, (1973)
Jantung	Malaysia	100		Malaysia	Abdul-Karim *et al.* (1987)
Kalipatti		98	160 kg	India	Chundawat and Bhuva, (1982)
Kirtabarti		84		India	Sundarajan and Rao, (1967)
Long Oval		140		India	Sundarajan and Rao, (1967)
Martin	Florida		Very poor	Florida	Campbell and Malo, (1973)

Modello	Florida	227-340	50-100 kg	Florida	Campbell and Malo, (1973)
Mohangottee		102	107 kg	India	Chundawat and Bhuva, (1982)
Oval		84		India	Sundarajan and Rao, (1967)
Pala		31		India	Sundarajan and Rao, (1967)
Pilipatti		82	115 kg	India	Chundawat and Bhuva, (1982)
Prolific			150-225 kg	Florida	Campbell and Malo, (1973)
Russell			25-100 kg	Florida	Campbell and Malo, (1973)
Saunders	Florida		Very poor	Florida	Campbell and Malo, (1973)
Seedless	Florida	small	<12.5 kg	Florida	Campbell and Malo, (1973)
Tagarampudi		84		India	Sundarajan and Rao, (1967)
Tikal	Mexico	113-170	170-225 kg	Florida	Campbell and Malo, (1973)
Tikal		120	150-175 kg	Florida	Campbell *et al.* (1987)
Vavivalasa		98		India	Sundarajan and Rao, (1967)
Zumakhia		57	55 kg	India	Chundawat and Bhuva, (1982)

Table 6.4. Sapodilla Cultivars of Florida.

Cultivar Name	**Country of origin**	**Fruit shape, Color**	**Fruit weight**	**Pulp color texture**	**Quality**

			(g)		
Alano	USA (Hawaii)	Conical to round, skin light brown, smooth	115-250	Smooth to slightly granular	Very good to excellent
Betawi	Indonesia	Conical	140-315	Light amber - yellow, slightly granular	Very good, juicy
Brown Sugar	United States	Round to ovate, skin light brown, moderately scurfy	133-170	Brown, slightly granular	Very good
Gonzalez	The Philippines	Round to oval, skin very light brown, slightly scurfy	90-260	Light brown to brown, smooth	Very good to excellent
Hasyá	Mexico	Oval to slightly conical, skin light brown, moderately scurfy	150-365	Brownish red	Excellent
Makok (dwarf) tree	Thailand	Conical, skin light brown, slightly scurfy	30-140	Light brown to slightly greenish-red, smooth	Very good
Modello	United States	Elliptic to ovate, skin light brown, moderately scurfy	227-340	Whitish to tan, smooth	Good

Molix	Mexico	Oval	150-360	Brownish red, smooth	Very good to excellent
Morena	Mexico	Oval	170-345	Brownish red, smooth	Very good to excellent
Oxkutzcab (Ox)	Mexico	Roundish	up to 800	Reddish brown	Very good
Prolific	USA	Round to conical, ovate, skin light brown, slightly scurfy	170-225	Light tan to reddish tan and smooth	Very good
Russell	USA	Round to conical to ovate, skin brown with grayish-brown patches, scurfy	284—454	Pinkish tan, granular	Good, mildly fragrant
Tikal	USA	Ellipsoid to conical, skin light brown, slightly scurfy	80-323	Light brown, smooth	Very good, fragrant

Source: Fact Sheet HS-1, Horticultural Sciences Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Available at http://edis.ifas.ufl.edu/MG057

RESEARCH NEEDS

Sapodilla is considered as a minor fruit in Sri Lanka and there is no strong research and development program to promote it as an economic commercial fruit crop. One of the main constraints is the lack of suitable varieties and good quality planting materials. It is necessary to start with the planting materials raised from selected local trees yielding good quality fruits. At the same time an effort should be made to collect the available germplasm in the country and evaluate them for commercial production. In addition, it is necessary to introduce promising cultivars from countries with similar climatic conditions. The true genetic diversity of the existing varieties in the country should be established using molecular techniques and then an attempt should be made to introduce varieties to fill the gaps in existing collection. Conservation of genetic resources both *in- situ* and *ex-situ* are important. A variety development program through conventional breeding as well as through novel biotechnological techniques is necessary. To support such a program basic studies with regard to characterization of existing varieties and studies on floral biology will be required.

At present, planting materials are produced by grafting Sapodilla on Mee (*Basia longifolia*) rootstocks. Alternative rootstocks should be identified which can impart characteristics such as tolerance to ill drained soil conditions, dwarfing, precocity and tree productivity. Existing propagation methods should be standardized. Mass propagation methods have to be developed to cater to the high demands of planting materials.

Sapodilla fruits should be carefully harvested in order to minimize post harvest losses. Dwarfing trees will facilitate harvesting and other cultural operations. Methods to dwarf trees by rootstocks, pruning, growth regulators etc. need to be studied. Maturity indices should be developed and techniques for proper harvesting and post harvest management of fruit should be developed.

Sapodilla fruit can be processed into various types of food products. Therefore, technology development for processing is required. As Sapodilla is not much popular in local markets in fresh or processed from consumer awareness programs are necessary to create market demand for the fresh fruits as well as processed products.

CONCLUSIONS AND FUTURE IMPACT

Due to its hardy nature and ability to thrive under different soil and climatic conditions, Sapodilla is becoming a commercial crop in many tropical countries (Bal, 1997). Commercial fruit production is concentrated in Mexico, southeast Asia, and on a small scale in south Florida. Improved selections in recent years in Florida, USA have tremendously enhanced public opinion of both the tree and the fruit.

Sapodilla is an example of an important non timber (mostly) forest product of tropical America, as a source of the chicle latex base for chewing gum (Balick and Cox, 1996). Although chicle is no longer a popular source of gum, the growing realization that petroleum products are non renewable and probably not healthy may swing opinion back in chicle's favor. Pressure for renewable organic products should assist in this movement. Fruits and latex can represent more than 90% of the total market value of tropical forests, over time far exceeding the value of timber (Peters *et al.,* 1989).

The future of Sapodilla appears to be promising, given the attention the crop is receiving from growers and consumers in many countries. Indian production of Sapodilla continues to grow and there is an active research program in that country with specific goals toward improving storage, transport, and marketing strategies. Sapodilla has been identified by the Ministry of Agriculture in Malaysia to be promoted under the program for development of its fruit industry (Bakar and Abdul-Karim, 1994). The fruit is also gaining popularity as a specialty fruit in restaurants in north America. Therefore, production of Sapodilla as a commercial crop seems to be a possibility in areas where environmental conditions are suitable for the crop. Sapodilla has huge potential for commercial cultivation, hence it should be included in the research agenda of the Department of Agriculture, Sri Lanka.

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