MANGO

Post-harvest Operations

INPhO - Post-harvest Compendium

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MANGO: Post-harvest Operations

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1. Introduction

The Mango (Mangifera indica L.) is the most economically important fruit in the Anacardiaceae (Cashew or poison ivy family). Other important members of this family include cashew and pistachio. The mango is the most important foodstuff for inhabitants of the tropics after the banana. There are 150 cultivars of mangoes produced around the world. Producing areas can be grouped in 6 regions (See Figure 1 for Mango producing areas):

- Florida (USA), Mexico, Central America
- West Indies (Caribbean Islands)
- South America
- Africa/Arabian Peninsula
- Indian Subcontinent
- Indochina (China)/Indonesia/Pacific

Figure1. Mango producing areas.

The percentage composition of the typical Tommy Atkins mango is: stone wet (8.5 percent), skin (12 percent) and pulp (79.5 percent) (See Figure 2 for photo of typical Tommy Atkins mangoes and Figure 3 for the percentage composition of the Tommy Atkins mango). The fruits produce either monoembryonic or polyembryonic seeds. Polyembryonic seeds contain more than 1 embryo and most of the embryos are genetically identical to the mother tree. Monoembryonic seeds contain 1 embryo and this embryo possesses genes from both parents (Crane and Campbell, 1999).

Figure 2. Typical Tommy Atkins mango.

Figure 3. Tommy Atkins mango percentage composition.

a) Origin

Native to southern Asia, specially Eastern India, Burma and the Andaman Islands, mango has been cultivated, praised and even revered in its homeland since ancient times. Buddhist monks are believed to have taken the mango on voyages to Malaya and eastern Asia in the 4th and 5th Centuries BC. Persians are said to have taken mangoes to East Africa around the 10th Century AD. The fruit was grown in the East Indies before the earliest visits of the Portuguese who apparently introduced it to West Africa in the early 16th Century and also into Brazil. After becoming established in Brazil, the mango was carried to the West Indies, being first planted in Barbados about 1742 and later in the Dominican Republic. It reached Jamaica about 1782 and, early in the 19th Century, reached Mexico from the Philippines and the West Indies (Morton, 1987).

Experts at the Birbal Sahni Institute of Palaeobotany (BSIP) here have traced the origin of mango to the hills of Meghalaya, India from a 65 million year-old fossil of a mango leaf. The earlier fossil records of mango (Mangifera indica) from the Northeast and elsewhere were 25 to 30 million years old. The 'carbonized leaf fossil' from Damalgiri area of Meghalaya hills, believed to be a mango tree from the peninsular India, was found by Dr R. C. Mehrotra, senior scientist, BSIP and his colleagues. After careful analysis of the fossil of the mango leaf and leaves of modern plants, the BISP scientist found many of the fossil leaf characters to be similar to mangifera.
An extensive study of the anatomy and morphology of several modern-day species of the genus mangifera with the fossil samples had reinforced the concept that its centre of origin is Northeast India, from where it spread into neighbouring areas, says Dr. Mehrotra. The genus is believed to have disseminated into neighbouring areas after the formation of land connections between India and Malaysia through Burma after the collision of the Indian plate with the Asian plate. After the land connection was established between India and Asia, the ancestral stock of mangifera migrated east and west and species diversified extensively in the Malaysian and Sumatran rain forests. (Times Internet Limited, 2000).

b) Taxonomy

The genus Mangifera belongs to the order Sapindales in the family Anacardiaceae, which is a family of mainly tropical species.
Division: Magnoliophyta
* Class: Magnoliopsida
* SubClass: Rosidae
* Order: Sapindales
* Family: Anacardiaceae
* genus: Mangifera
* Species: indica

SCIENTIFIC NAME: Mangifera indica L.
There are hundreds of mango cultivars distributed throughout the world, of which Asia and India have over 500 classified varieties (some say 1 000) have evolved and have been described and 69 species mostly restricted to tropical regions. Perhaps some of these varieties are duplicates with different names, but at least 350 are propagated in commercial nurseries. The highest diversity occurs in Malaysia, particularly in peninsular Malaya, Borneo and Sumatra, representing the heart of the distribution range of the genus. The natural occurrence of all the Mangifera species extends as far north as 27° latitude and as Far East as the Caroline Islands (Bompard and Schnell, 1997). Wild mangoes occur in India, Sri Lanka, Bangladesh, Myanmar, Sikkim, Thailand, Kampuchea, Vietnam, Laos, southern China, Malaysia, Singapore, Indonesia, Brunei, the Philippines, Papua New Guinea and the Solomon and Caroline Islands. Maximum species diversity exists in western Malaysia and about 28 species are found in this region.
However, in the Western Hemisphere, a few cultivars derived from a breeding program in Florida are the most popular for international trade. Locally, many cultivars are used and often seedling trees are grown as a backyard food source (Rieger, 2001). The Horticulture Research Unit of the U.S. Department of Agriculture and the Agricultural Research and Education Centre of the University of Florida, together maintain a germplasm 125 of mango cultivars as a resource for mango growers and breeders in many countries.

c) Botanical description

Mango trees, grown from seeds are known as "seedlings" have a long straight bole. Tree is sympodially branched. Grafted trees on the other hand are dwarf with spreading branches. However, the shape of the canopy also depends on the space available for its development. Isolated trees, getting sufficient space for their growth may differ in tree shape with the same variety grown in the orchard. On shallow soils the growth is stunted. The compactness of the canopy, branching pattern and leaf component also show ecogeographical dependence. Seedling trees live much more than 100 years whereas grafted ones live only 80 years or less. One of the largest trees known is that from Chandigarh (India), with a trunk of 3.5 m in diameter, limbs of 75 cm diameter. Seedling tree measuring a spread of 125 ft and a girth of 25 ft has been reported to exist in Brazil.

Mango tree

Tree is medium to large (10 to 40 m in height), evergreen with symmetrical, rounded canopy ranging from low and dense to upright and open. Bark is usually dark grey-brown to black, rather smooth, superficially cracked or inconspicuously fissured, peeling off in irregular, rather thick pieces. The Philippine mango trees often reach 15 to 18 m (50 to 60 feet) in height and attain great age. (Figure 4 Manila mango tree) is a large spreading and evergreen with a dense crown, early-ripening. The tree has a rounded canopy ranging from low and dense to upright and open. The leaves are alternately arranged, lanceolate shaped, 6 to 16 inches (15 to 40.6 cm) in length and leathery in texture. Pinkish, amber or pale green-coloured when young, leaves become dark green at maturity. The inflorescence is a many-branched panicle borne at shoot terminals, 2.5 to 16 inches long (6.4 to 40.6 cm), possessing from 550 to more than 4 000 flowers. Flowers are small, pinkish-white, with the majority staminate and the remainder perfect. In Florida, mangoes bloom from December to April depending upon climatic conditions and variety. Pollination is made by various insects such as thrips, flies and to a small extent, honeybees and the fruit is classified as drupes. Mangoes vary in shape (nearly round, oval, ovoid-oblong), size and colour depending upon the variety. Ripe mangoes may be greenish, greenish-yellow, yellow, red, orange, or purple and weigh from a few ounces to more than 5 pounds (2.3 kg). The skin is smooth and leathery, surrounding the fleshy, pale-yellow to deep-orange edible portion. The fruits possess a single large, flattened, kidney-shaped seed that is enclosed in a woody husk. Although the fruit will ripen on the tree, commercially it is usually picked when firm and green for shipment to market. The crop is considered mature when the shoulder of the fruit broadens (fills out) and some fruits on the tree have begun to change colour from green to yellow. Prior to this external colour break, the fruit is considered mature when the flesh near the seed changes colour from white to yellow.

Root

The tree forms a long unbranched long taproot (up to 6 to 8 metres and more) plus a dense mass of superficial feeder roots. Feeder roots develop at the base of the trunk or slightly deeper; these produce anchor roots and sometimes a collection of feeder roots develops above the water table. The fibrous root system extends away from the drip line. Effective root system of an 18 year old mango tree may observe a 1.2 m depth with lateral spread as far as 7.5 m.

Figure 4. Manila mango trees.

Leaf

The leaves are simple, with no stipules, alternately arranged, 15 to 45 cm in length (Figure 5 Manila mango leaves). The petiole varies in length from 1 to 12 cm, always swollen at the base. It is grooved on the upper side. The phyllotaxy (Inflected forms of leaves on a steam) is usually 3/8 but as the leaves are arranged very closely at the tips they appear to be whorled. Leaves are variable in shapes like oval-lanceolate, lanceolate, oblong, linear-oblong, ovate, obovate-lanceolate or roundish-oblong (Singh, 1960). The apex ranges from acuminate to nearly rounded. The margin is usually entire, sometimes slightly undulated and wavy, rarely twisted or folded. The length and breadth varies from 12 to 45 cm and 2 to 12 cm, respectively, depending on variety and growth. The secondary veins are quite prominent and in some of the varieties range from eighteen to thirty pairs. The upper surface is shining and dark green while the lower is glabrous light green. The leaves appear in flushes. They are flaccid and pendulous when young. The colour of young leaves generally vary form variety to variety, generally being tan-red, pink, yellow-brown in colour. As the leaf grows, its colour changes from tan-red to green, passing through many different shades and become dark green at maturity. The leaves have fibres and crackle when crushed. They strongly smell of turpentine (some cultivars do not smell). The leaves contain considerable amounts of mangiferin (xanthone). In India, this pigment was obtained as "Indian Yellow" from the cow's urine. Cows were fed exclusively with mango leaves and ultimately excessive feeding on leaves lead to their death.

Figure 5. Manila mango leaves.

Inflorescence

(Please see Figure 6. Inflorescence of manila mango). The inflorescence is pseudo-terminal, originating from a bud, together with the new leafy sprout; there are cultivars with lateral inflorescence. The inflorescence is a narrowly to broadly conical panicle up to a 45 cm long depending upon cultivar and environmental conditions during its development. It is usually bracteate (leaflike plant part) but may sometimes be ebracteate. The bract if present is leafy, elliptical and concave. The colour of the panicle may be yellowish-green, light green with crimson patches or with crimson flush on branches. It is generally pubescent but sometimes may be glabrous. The branching of the inflorescence is usually tertiary, rarely quaternary, but the ultimate branching is always cymose (Singh, 1960). The panicle bears 500 to 6 000 flowers of which 1 to 70 percent are bisexual, the remainder are male depending on the cultivar and temperature during its development.

Figure 6. Inflorescence of Manila mango.

Flowers

Hermaphrodite and male flowers are produced in the same panicle, usually with a larger number of the later. The size of both male and hermaphrodite flowers varies from 6 to 8 mm in diameter. They are subsessile, rarely pedicellate and have a sweet smell. Pedicels are very short or missing; they are articulate with a panicle branch of the same diameter, which is often mistaken for the pedicel. The calyx is usually five partite. The lobes are ovate-oblong and concave. The corolla consists of five pale yellow petals (rarely four to eight) that are twice as long as the calyx and contain three to five ridges on the ventral side. The petals are in bud imbricate and slightly contorted. They are thin, yellowish and after expanding horizontal, the upper half rather irregularly and not very pronouncedly reflexed, they are free at their base. The ridges are slightly dark. The upper half and the margin of the petal are white. On fading, the petals become pinkish. Between the corolla and androecium there is an annular, fleshy and five-lobed disc (Singh, 1960; Kostermans and Bompard, 1993). The androecium consists of stamens and staminodes, altogether five in number, of which usually one, or rarely two, is fertile and the rest are sterile. However, in cultivar Pico, three fertile stamens have been reported (Juliano and Cuevas, 1932). As many as ten stamens, which occur in other members of the genus, may also occasionally be found in the form of primordia only. All the stamens are inserted on the inner margin of the disc. The position of the fertile stamen and pistil may be either parallel or oblique to each other. The fertile stamens are longer than the staminodes and are nearly equal to the length of the pistil. The colour of the anther is pink, which turns purple at the time of shedding. The ovary is sessile, one-celled, oblique and slightly compressed in its lateral aspect. It is placed on the disc. The ovule is anatropous and pendulous and shows one-sided growth. The style arises from the edge of the ovary and ends in a simple stigma. Sometimes three carpels may develop in a flower.

Pollen and pollination

The pollen grains are of variable shapes, with the size varying from 20 to 35 micron. Small amounts of pollen are produced in mango. The grains of pollen are sphaeroidal to prolate sphaeroidal, radially symmetrical, subangular in polar view, isopolar, with a few giant triploid ones of up to 50 micron. Further they are 3-monocolporate, goniotreme, sides convex-subprolate; apertures equidistant and zonal with ecto-aperture (colpus) extends slit-like from pole to pole. The mango inflorescence is a branched terminal panicle, 4 to 24 inches long, comprising from a few hundred to several thousand individual flowers, requiring up to a month for all to open. The number of panicles may range from 200 to 3 000 per tree with 500 to 10 000 flowers per panicle yield 100 000 to 30 million flowers per tree. The proportion of perfect to staminate flowers may vary from 1:4 to 2. Sometimes, the entire tree comes into bloom at one time, covering itself with sweet-scented flowers. There are perfect and staminate flowers on the same panicle. The perfect flower, 5 to 8 mm long, has a globular ovary (rarely two or three) and a lateral style, which is absent in the staminate flower. Both generally have one, but sometimes two or even three functional stamens and several sterile staminodes. There are usually five greenish-yellow sepals and three to nine, but usually five, cream-coloured petals that take on a pinkish tinge before falling (Naik and Rao 1943). In the perfect or hermaphrodite flower, a nectar-secreting fleshy disk surrounds the ovary. The stamen is on the outer margin of this disk. The pistil and stamen are the same length; therefore, pollinating insects that feed on either nectar or pollen are likely to transfer pollen from the anther to the stigma (Juliano and Cuevas 1932, Sturrock 1966). The flower opens early in the morning and the stigma is immediately receptive. Maximum pollen shedding is from about 8 to noon. This delayed pollen shedding can result in inadequate stigma

fertilization (Spencer and Kinnard 1956). When the flowers open, they secrete nectar in considerable quantity, which attracts a large number of insects (Mukherjee, 1953); however, relatively little pollen is produced on the anther (Rajans, 2001).

Pollination Requirements: There has been some lack of agreement on the pollination of mangoes. Young (1942) made pollination studies on the 'Haden' mango in Florida, which he said made up 90 percent of the commercial plantings in the state (the 'Tommy Atkins' is the current popular cultivar) and found no significant difference between percentages of set in self- and cross- pollinated flowers. Sturrock (1944) also considered the flowers self-fertile. This self-fertility was supported by the earlier work of Popenoe (1917), who stated that the mango is self-fertile but cross-pollination increases fruit set. However, Singh et al. (1962) reported that cross fertilized flowers produced set fruit whereas self fertilized ones did not, indicating a certain degree of self-sterility. The actual degree of self-fertility and sterility in individual cultivars has not been determined, but there is apparently some variation. Self-sterility is not, however, a major problem in fruit set (McGregor, 1976).
Within the cultivar there is a definite need for transfer of pollen from anther to stigma by an outside agent. Popenoe (1917) stated that some of the embryos are capable of development without fertilization; however, Naik and Rao (1943) obtained no parthenocarpic fruit set of more than 100 000 flowers studied. Fraser (1927) stated that fruit bud formation and pollination were the two big problems in growing mangoes. He pointed out that in some cases only 2 to 3 percent of the flowers on a panicle are perfect while in others 60 to 70 percent are flawless. Wolfe (1962) concluded that getting flowers to set fruit was more of a problem than getting the trees to produce flowers. The effect of cool weather adversely affects pollen tube growth, but this was not considered to be a factor of major importance by Young (1955). The studies indicate that the need for cross-pollination between mango cultivars is not critical, at least for most cultivars, but there is need for pollinating insects to transfer the pollen from anthers to stigma within the cultivars to obtain satisfactory crops of fruit.

Pollinators: Several agents have been given credit as pollinators of mango. Wagle (1929) showed that there was some self fetilization and some wind pollination, but insects (bees, ants and flies) played an important part. Popenoe (1920) disagreed with other writers that the mango is wind pollinated. He pointed out that the flowers have none of the characteristics of a wind-pollinated flower and he considered the mango to be an insect-pollinated plant. Galang and Lazo (1937) and Singh (1969) agreed with him. Recent studies in India showed that plants caged to exclude all insects set no fruit and gall-midges were ineffective as pollinators, but a plant caged with a colony of honeybees where harmful insects were excluded set a heavy crop. Singh (1961) reported that over 65 percent of the perfect flowers were never pollinated. This is a strong indication that wind is not an effective pollinating agent. Complaints about lack of adequate fruit set in larger plantings particularly of monoclonal cultivars are frequent (Singh, 1969). Fraser (1927) concluded that the important problem was finding out which insets were important as pollinators. The statement was made by Singh (L.B.) (1960) that honeybees do not visit mango flowers, but Singh (1954) listed this plant as a source of pollen and nectar for bees. Popenoe (1917) reported that honeybees were the most important hymenopterous insect visitor to the mango flowers, but the number present was variable, possibly because of the location of apiaries or other relatively more attractive flora. This probably explained the low population of honeybees reported by Simao and Maranhao (1959).
Pollination Recommendations and Practices: There is no indication that the recommendation by Young (1942) to place colonies of honey bees in mango groves has become an accepted practice; however, the chances are likely that such bee usage is needed today much more so

than when his studies were made. The evidence is quite strong that concentration of colonies of honeybees within the mango grove would result in increased floral visitation and possibly more stabilized set of fruit, particularly in some years. The mango flowers do not appear to be overly attractive to honey bees and they tend to open in large numbers at a time of year when many other flowers are also available, so visitation in commercial groves is likely to be far below that necessary for maximum floral visitation. If such is the case, a heavy concentration of colonies in the grove, possibly three to six per acre, may be necessary to obtain maximum fruit set.

Fruit

(Please see Figure 7. Typical mangoes of Manila, Ataulfo and Oro varieties). The fruit is a more or less compressed, fleshy drupe. It varies considerably in size, shape, colour, presence of fibre, flavour, taste and several other characters. The most characteristic feature of the mango fruit is the formation of a small conical projection developing laterally at the proximal end of the fruit, known as the beak. It may be quite prominent in some, less so in others, while in some varieties it is represented merely by a dot. A wide sinus is always present just above this beak. The pistillate area of the fruit located near the base of the beak is known as the nak. The shape of the fruit varies from rounded to ovate-oblong or longish, with the length varying from 2.5 to 30 cm in different varieties. The base may be depressed or elevated or may be intermediate. The skin is gland-dotted and at maturity its colour exhibit different mixtures of green, yellow and red shades. It may be smooth or rough. Each mango has a single flat seed, surrounded by flesh, which is either yellow or orange. This flesh is rich in vitamins A, C and D. The acrid juice, with turpentine like smell, present in the stalk or sometimes in the fruits, is known as chenp in Hindi is due to myrcene and ocimene. Its main irritating constituent has been identified as an allergenic urushiol, 5-heptadecenylreorcinol. The harvesting itself is a delicate process because the fruit is easily bruised, so harvesting is usually done by hand.

Figure 7. Typical mangoes of Manila, Ataulfo and Oro varieties.

d) Cultivars (See Figure 8. Manila mango trees).
Apart from numerous seedling varieties, more than a thousand vegetatively propagated mango cultivars have been reported. Most of these have originated as chance seedlings selected earlier and further maintained asexually. Majority of these cultivars is of Indian origin and representation from other parts of the world is limited in number (Table 1).

Table 1. Fruit characteristics of mango cultivars in major producing countries.

Cultivar	Country of origin	Fruit Characteristics
Carabao	Philippines	Fruit medium (10 oz.) elongated, kidney-shaped, light green blushed yellow, fibreless Seed very large, flesh stringy, acid and juicy.
Edward	Miami, FL. USA	Hybrid of Haden X Carabao. Intermediate between Indian and Philippine forms. Fruit medium to large, elongated ovate, apex often oblique, yellow green with red blush. Flavour excellent.
Haden	Miami, Fl. USA	Fruit large (to 24 oz.), regular ovate, yellow almost covered with red, flavour mild, little fibre.
Irwin	Miami, Fl. USA	Fruit medium, 12-16 oz., elongated, ovate regular in form, orange yellow with deep blush, flesh bland, fibreless.
Julie	Trinidad - Tobago	Fruit small (6-10 oz.), flat oblong, obliquely almost two-nosed, orange, rather fibrous, juicy and sweet.
Keitt	Homestead, Fl. USA	Fruit large (20-26 oz.), ovate with slightly oblique apex, green, flesh rich, fibre only around seed.
Kent	Coconut Grove, Fl. USA	Fruit large (20-26 oz.), regular ovate, greenish yellow with red shoulder, flesh rich, fibreless.
Manila	Veracruz, Mexico	A seedling strain from Hawaii. Philippine type. Fruit small to 10 oz., shaped long, flat, yellow, flavour sharp.
Tommy Atkins	Fort Lauderdale, Fl. USA	Fruit medium to large, 16 oz. with thick skin, regular ovate, orange-yellow covered with red and heavy purple bloom. Firm, juicy, medium fibre, fair to good quality.
Alphonso	India	The fruit quality is excellent and keeping quality is good. It has been found good for canning purposes.
Banganpalli	India	Fruit is large in size and obliquely oval in shape. The colour of the fruit is golden yellow. Fruit quality and keeping quality are good. It is a mid season variety and is good for canning.
Dashehari	India	The fruit size is medium, shape is oblong to oblique and fruit colour is yellow. Fruit quality is excellent, keeping quality is good.
Bombay Green	Jamaica	The fruit is completely fibreless and freestone so that it is frequently served cut in half and eaten with a spoon.
Madame Francis	Haiti	It is a large, flattened, kidney-shaped mango, light green, slightly yellowish when ripe, with orange, low-fibre, richly flavoured flesh.
Tee-Vee-Dee	Ghana	Fibrous fruit, is so well flavoured and aromatic that it is locally extremely popular.
Mamuang	Thailand	This fruit is considered like the most delicious mangoes in the world. Ripe mangoes are eaten for dessert while pickles and chutney are prepared from unripe fruit.

Figure 8. Manila mango trees.

e) Growth habit

Mangoes are well adapted to many soil types. In Florida, trees growing in light sand and limestone soils must be fertilized periodically for satisfactory growth and fruit production. Generally, mango trees (See Figure 9 for soil type for Manila mango) tolerate some flooding or wet soil conditions; however, the response among trees is variable. Flooding stress symptoms include leaf wilting and desiccation, stem dieback, reduced growth and tree death. Previous and current environmental conditions and plant size and health affect the response to wet conditions (Crane and Campbell, 1994).

Figure 9. Soil type for Manila mango.

Description of mango tree
Mango trees are very tall in height and have thick, leathery leaves. From their branches, long stems hold clusters of fruits that can range from a few ounces to a few pounds.

Foliage and flowers (See Figure 10 Manila mango tree inflorescence)

Figure 10. Manila mango tree inflorescence.

f) Traditional practices
(See Figure 11. Traditional practices for Manila Mango). For best results, irrigation water should contain less than 1 000 ppm total salts. It is essential to provide adequate water from the first sign of flower spikes through to harvesting. The critical time for irrigation is during fruit development; water stressing the trees at this time can reduce yield.
The irrigation schedule will depend on the tree age, growth stage of the fruiting trees, prevalent temperature and rainfall.
· Growth stage 1: Pre-flowering (six to eight weeks before flowering);
· Growth stage 2: Flowering to end of harvest; and
· Growth stage 3: End of harvest to pre-flowering.
Only generalized recommendations of mango fertilizer requirements can be made. It is important to take regular leaf samples for good nutritional management. As nutritional levels will change in the tree during the season, be sure to sample the trees at the same time each season. The most stable time of year for sampling is just prior to flowering. Take leaf samples from the last mature flush, from dormant shoots.
Young trees in all areas require a basal fertilizer at planting time and in small regular NPK applications to ensure maximum growth during the juvenile phases. When fruiting

commences, nutrition must be closely monitored. Excessive applications of nitrogen contribute to poor quality fruit - soft nose, green fruit, uneven ripening and poor blush. For the first three years, fertilize young trees every three months with 40 g of urea per tree, per year of age, that is, up to 120 g of urea applied four times per year in the third year. From the fourth year, apply fertilizer after flowering to increase fruit size and after harvesting to provide strong shoot growth on which the following year's crop will be borne. Do not apply during the stress period of flower initiation in July and August (AWA, 1998).

Figure 11. Traditional practices for Manila Mango.

Planting

Prior to planting, field should be deeply ploughed, harrowed and levelled. Pits of proper size should be dug at appropriate distances and filled by adding sufficient quantity of farmyard manure. The grafts to be planted should be procured from reliable nurseries few days before actual transplanting.

a) Time of planting: The best time for planting is when there is sufficient moisture in the atmosphere. In the area of heavy rainfall, the best time of planting mango is the end of the rainy season. In tracts where the rainfall is less, the planting can be done in the early part of the monsoon for better establishment. The planting should be done in the evening; otherwise if the day turns out to be unusually hot or dry, the plants may wither due to excessive loss of water. If the sky is overcast, planting can be done during daytime also

b) Planting distance: The planting distance varies according to variety, the fertility level of the soil and general growth conditions in the area. Where the growth is excessive, the distance should be 12 x 12 m, but in the dry zones where the growth is less, it can be regulated to about 10 x 10 m. For high density planting, the distance can be 5 x 3 or 5 x 2.5 or 3 x 2.5 or 2.5 x 2.5 m.

c) Size of pits: In locations where the soil is loamy and deep, pits of 0.5 x 0.5 x 0.5 m be dug at desired distances. However, in shallow and hill soils, the pits should at last be of 1 x 1 x 1 m size.

d) Filling of pits: The pits should be filled with the original soil mixed with 50 kg well rotten farmyard manure. In the top two-third portion, the proportion of the manure and soil may be kept as 1:3. If the soil is having infestation of white ants, 200 to 250 g of aldrex or BHC dust may also be mixed. In case of stony soils, it is better to remove all the stones from the excavated material and remaining soils should be mixed with soil scrapped from the left over area and FYM. The pits should invariably be filled before the rainy season, so that there is maximum settling down before the advent of heavy rainfall and much before planting.
e) Planting of grafts: The plant with its ball of earth intact should be taken out of the soil or pot. The plant can then be placed with the help of a planting board in the centre of the pit by excavating as much soil as necessary to accommodate the root-ball. The moist soil of the pit is then pressed all around the root ball to complete the planting process. A small basin is then made and the plant is properly watered. The planting should not be done so deep as to bury the graft-union in the soil or so high as to expose the upper roots. It is always better to adjust it at the same height/depth at which it was in the pot or the nursery bed.
f) Training and pruning: Normally, mango trees require very little or no pruning. However, the training of the plants in the initial stages is very essential to give them proper shape. Especially when the graft has branched too low, the process of training becomes very important. At least 75 cm of the main stem should be kept free from branching and the first leader/main branch may be allowed after that. The main branches should be spaced in such a way that they grow in different directions and are at least 20 to 25 cm apart, otherwise there are chances of breakage due to smaller crotch angles and heavy top. The branches which exhibit tendency of crossing and rubbing each other should be removed in the pencil thickness stage, otherwise they break by rubbing each other at a later stage and create complications. Secondly, if the centre is closed the fruits produced are of poor quality having less colouration in the absence of sufficient sunlight. By following the above practice and after giving proper shape to the trees, there will be much less scope for future pruning except removal of diseased, pest infested or dried shoots/wood.

Labour

Training and supervision of labour are critical to a successful harvesting operation. Constant supervision is necessary to maintain quality and reduce subsequent spoilage of produce. Training is required in both general principles and crop specific techniques relating to maturity selection, detachment method, maintenance of equipment, field hygiene and division of labour. Some of the more important areas are:

Division of labour

Teams of workers must work systematically through a plot or field, experienced staff removing the crop and others carrying it to collection points. If crops are relatively inaccessible, as with older mango trees, pickers climbing in the trees if fruit is to be harvested must take great care free of damage. Whenever possible, planting densities and pruning techniques should be chosen which minimize tree size. Mangoes are harvested with the aid of a picking device attached to the end of a long bamboo pole. The picking device consists of a pair of string-operated shears and a collection sack. When picking mangoes, it is very important to leave a long stem. Immediately after being picked, all mangoes that are to be exported to countries such as the United States of America undergo a post harvest hot water treatment. Mangoes are harvested several times during the season. On any individual tree, fruits may be harvested daily, since the earliest bloom matures and ripens weeks before the later bloom.

g) Planting and Preliminary Actions

Propagation

(See Figure 12 and Figure 13. Propagation of Manila mango).

Mangoes are raised from seed or propagated vegetatively. Propagation from seed, though easy and cheap, is unable to perpetuate characters of the parent tree because most commercial varieties in India are cross-pollinated and monoembryonic. Plants also take more time to bear fruit. Accordingly, several methods of vegetative propagation have been tried with varying degree of success. However, it is essential to raise seedlings to be used as rootstocks. For this purpose, stones should be sown in June to July in beds mixed with well-decomposed farmyard manure at the rate of 8 to 10 tonnes/ ha. Alternatively, 25 kg nitrogen (N) per hectare may be applied in the form of urea, can or any other available inorganic source in two split doses at about two months interval after the leaves have become green. When the seedlings attain the age of 2 to 3 months, they should be transplanted in well-prepared beds or pots. In this season, proper care should be exercised in irrigating the young transplanted seedlings. The seedlings should also be protected from frost by putting the pots under big trees or thatching the young seedlings in the field.

Figure 12. Propagation of Manila mango.

Plants are generally propagated using random seedling rootstocks. The polyembronic rootstocks, however, have shown a promise in producing plants of uniform size and vigour. Moreover, these rootstocks have indicated possibility of inducing dwarfing and earlier bearing and are under test. Various methods employed in vegetative propagation of mango are described below:

a) Inarching: The method of inarching or approach grafting is quite cumbersome and time consuming, but it is still the leading method for commercial propagation of mango plants. The method consists of uniting the selected shoot (scion) of a desired parent tree (mother plant) with the potted or transplanted seedling (rootstock) by approach grafting. For this purpose, about one-year-old seedlings are most suitable when they attain a height of about 30 to 45 cm and thickness ranging from 0.75 to 1.5 cm. These seedlings are either grown in pots or under the mother plant from which the grafts are to be prepared, depending upon the availability of suitable branches. Generally, one-year-old twigs of the scion tree about 60 cm in length and nearly of the same thickness as that of the stock is chosen for grafting. Young and non-bearing trees should not be selected as mother plants.

Inarching should be done during the growing period when the tree is in active sap flow condition termed as active growth period. A hot and very dry period, as well as heavy rainfall during the inarching period is not suitable. The end of the monsoon in heavy rainfall areas and early monsoon in the light rainfall areas is the best period for inarching. In north India, July is the best month for inarching. In the more equitable climate of south India, the operation can be done any time between July and February. A thin slice of bark and wood, about 5 cm in length, 7.5 mm width and 2 mm deep, is removed by means of a sharp grafting knife from the stem of the stock as well as from the scion branch. The dimensions can be proportionately increased or decreased according to the thickness of the stock and scion. The cuts thus made should be absolutely flat, clean, boat shaped, even and smooth. The ends of these cuts should be round and not angular. The cut surfaces of both, i.e., stock and scion are made to coincide facing each other so that there remains no hollow space between the two. These are then tightly tied by polythene / alkathene strips of about 1.5 cm in width and preferably of 200 gauge thickness, which has proved to be a good tying material.

After about one month of operation, the scion below the graft union and stock above the graft union should be given light; shape cuts at weekly intervals such that grafts can finally be detached while giving the fourth cut. In the last stage, the top of the stock above graft union should also be removed completely.

Figure 13. Propagation of Manila mango.

b) Veneer grafting: This method of propagation possesses promise for mass scale commercial propagation. The method is simple and can be adopted with success. The rootstocks as mentioned, for inarching are suitable for this method also. For conducting this grafting operation, a downward and inward 30 to 40 mm long cut is made in the smooth area of the stock at a height of about 20 cm. At the base of cut, a small shorter cut is given to intersect the first so as to remove the piece of wood and bark. The scion stick is given a long slanting cut on one side and a

small short cut on the other so as to match the cuts of the stock. The scion is inserted in the stock so that the cambium layers come on the longer side. The graft union is then tied with polythene strip as recommended for inarching. After the scion takes and remains green for more than 10 days the rootstock should be clipped in stages. The scion wood to be used for veneer grafting requires proper preparation. The desired shoots should be defoliated at least one week prior to grafting so that the dormant buds in the axis of leaves become swollen. The best time for this method is the same for different regions as for inarching.

c) Budding: Although success of budding in mango was reported in the beginning of this century, budding still continues to remain in experimental stage as far as commercial mango propagation is concerned.

d) Stone Epicotyl grafting: Mango is generally propagated by inarching and veneer grafting. These methods are time consuming. Stone epicotyl grafting is a new technique of mango propagation. This method is simple, cheap and quick. Fresh mango stones are sown in the nursery beds. After germination, seedlings with tender stems having coppery leaves are lifted with stones still attached. The roots and stones are dipped in 0.1 percent Bavistin solution for 5 minutes after washing the soil. The seedling stems are headed back leaving 6 to 8 cm long stems. A 4 to 6 cm longitudinal cut is made running down through the middle of the stem. A wedge shaped cut starting on both sides is made on the lower part of scion stick. The scion stick should be 4 to 6 months old and 10 to 15 cm long containing plump terminal buds. The scion stick is then inserted in the cleft of the seedlings and tied with polythene strips. The grafts are then planted in polyethylene bags containing potting mixture. The bags are then kept in the shade protecting from heavy rain. When the scion sprouts and the leaves become green, the grafted plants should be planted in nursery beds. July is the most suitable month for stone grafting.

e) Softwood grafting: The technique of softwood grafting is similar to that of cleft or wedge grafting. In this case, grafting is done on newly emerged flush having bronze coloured leaves and stem. This method is useful in in-situ grafting. The scion wood to be used should be defoliated 10 days prior to the grafting and having same thickness as that of terminal shoot. The graft should be secured firmly using 1.5 cm wide and 4.5 cm long, 200-gauge polyethylene strip. July and August are the best months for softwood grafting.

f) Air layering: Air layering can be done successfully in mango using indolbutyric acid (IBA) or naphtalen acetic acid (NAA) 10 000 ppm in lanolin paste. Success up to 50 percent has also been obtained by using a root promoter. The air-layers can be used for permanent planting or for raising uniform rootstocks.

Irrigation

Amount and frequency of irrigation depends upon the type of soil, prevailing climatic conditions, especially rainfall to be given and its distribution and age of trees. No irrigation is required during the monsoon months unless there are long spells of drought. During the first year when the plants are very young with shallow root system, they should be watered every 2 to 3 days in the dry season. Trees in the age group of 2 to 5 years should be irrigated at 4 to 5 days interval. The irrigation interval could be increased to 10 to 15 days for 5 to 8 years old plants during dry season. When trees are in full bearing stage, generally 2 to 3 irrigations are given after the fruit set. Profuse irrigation during 2 to 3 months proceeding the flowering season is not advisable. Irrigation should be given at 50 percent field capacity. Generally, intercrops are grown during the early years of plantation and hence frequency and method of irrigation has to be adjusted accordingly. It is advisable to irrigate the mango plants in basins around them, which can be connected in series or to the irrigation channel in the centre of rows. The ntercrops need to be irrigated independently as per their specific requirements.

In monocropping of mango also, basin irrigation is preferable with a view to economize water use.

Fertilization

Soil fertility has a direct effect on all aspects of crop growth and development. In some cases, post-harvest disorders can be linked directly to the deficiency of a particular mineral, but often other environmental factors such as water stress are involved. "Spongy tissue" symptoms in mango have been linked to mineral deficiency and copper and iron deficiencies cause abnormal peel development in citrus fruits.

Nutrient uptake in mango is from large volume of soils. Therefore, it is able to sustain growth even in low fertility soils. However, its efficient management involves the replenishment of the nutrients used-up by the tree for its growth and maintenance, harvested produce and natural losses from soils through leaching and run off. Even the under-nourished trees can be revived by suitable supplementation of nutrients through fertilizers. The idea of applying manure to fruit bearing trees is also to secure regular fruit production. Recommendations based on very limited research and also on experience gained by the orchard experts are given below (Rajans, 2001).

Application of manure to mango plants starts right from planting operation in the orchard. First application is made at the time of filling of the pits. Fertilizer application during the first year of planting may be given as 100 g N, 50 g P_2O_5 and 100 g K_2O per plant. The above dose should be increased every year up to 10 years in the multiple of first year's dose. Accordingly, a 10-year-old tree should receive 1 kg N, 500 g P_2O_5 and 1 kg K_2O.

This dose should continue to be applied in subsequent years also. Application of 50 kg well-decomposed organic manure should be given each four year to create proper soil physical environment. For trench application of fertilizers, 400 g each of N and K_2O and 200 g of P_2O_5 per plant should be given.

The application of micronutrients is not recommended as a routine. Need based supplementation are essential when these become a limiting factor for production. It is advisable to apply micronutrients through foliar sprays. Fertilizers may be applied in two split doses, one half immediately after the harvesting of fruits and the other half 2 to 3 months later, in both young and old orchards, followed by irrigation if there are no rains. Foliar application of 3 percent urea in sandy soils is recommended before flowering. First of all, the weeds should be removed from basins. The mixture of recommended dose of fertilizers should be broadcast under the canopy of plant leaving about 50 cm from tree trunk in old trees. The applied fertilizer should be amalgamated well up to the dept of 15 cm soil. To increase fertilizer use efficiency, fertilizers should be applied in 25 cm wide and 25 to 30 cm deep trenches dug around the tree 2 m away from trunk.

Interculture

Interculture in orchards is necessary for the proper upkeep of mango plantation. The removal of weeds not only avoids the competition for essential nutrients but also creates better physical soil environment for plant growth, particularly root development. It also helps in water movement in soil and in controlling some of the insect pests. Moreover, it ensures proper incorporation of the applied plant nutrients in soil and reduces their loss. Frequency and the time of interculture operations vary with age of the orchards and existence of intercrops. Immediately after planting the mango, the weed problem may not exist, but it is advisable to break the crust with hand hoe each time after 10 to 15 irrigations. However, subsequent hoeing may be done depending on weed growth in the basin. If the intercrops are not being raised in the pre-bearing stage due to some reasons, the area between the basins should be ploughed at least three times a year, i.e., pre-monsoon, post-monsoon and in the

last week of November. Interculture operations are equally important for the bearing mango orchards. First ploughing should be done before the onset of rains. This will help in checking run-off losses and facilitate maximum retention of water in the soil. Orchard may be ploughed again after the rainy season is over in order to suppress weed growth and to break capillaries. Third ploughing may be done in the last week of November or first week of December with a view to checking the population of mango mealy bugs. (Rajans, 2001).

1.1 Economic and social impact of mangoes

Global production of mangoes is concentrated mainly in Asia and more precisely in India that produced in 12 Million Mt. Mangoes are grown in 85 countries and 63 countries produce more than 1 000 Mt a year. Total world production (Table 2) was 24 420 116 Mt in 1999 (FAOSTAT, 2000), where mangoes play an integral part in their lives not only by being rich nutrient source but also by serving as a common good that is shared in the culture, the life style and the religion. In 1960 mangoes were not commonly known among the consumers outside of the tropics and there was virtually no international trade of fresh fruit.

In recent years, mangoes have become well established as fresh fruit and processed products in the global market. India is still by far the major producer of mangoes in the world; although, it's relative share in the world production has been gradually declining. In the United States of America fruit eaters now regularly choose mangoes over apricots, cherries and plums. World demand for mango is now increasing however, particularly from temperate countries, where mangoes are rapidly gaining in popularity. The increase in mango production in non-traditional mango-producing areas has been notable and includes parts of Asia, West Africa, Australia, South America and Mexico. International trade of mangoes is dominated by varieties like "Keitt" and "Tommy Atkins" (Emex, 2000).

Table 2. World mango production by country (Source: FAOSTAT, 2000)

Country	Production (Mt)	Country	Production (Mt)	Country	Production (Mt)
China	2 561 522	Gambia	720	Panama	5 800
Antigua and Barbuda	1 300	Ghana	4 000	Paraguay	29 000
Argentina	1 800	Grenada	1 800	Peru	191 495
Australia	37 000	Guadeloupe	1 032	Philippines	931 500
Bangladesh	186 760	Guam	50	Puerto Rico	17 375
Belize	1 000	Guinea	84 720	Réunion	5 000
Benin	12 000	Guinea-Bissau	4 500	Saint Lucia	27 000
Bolivia	7 500	Guyana	3 200	Saint Vincent/Grenadines	1 400
Brazil	600 000	Haiti	225 000	Samoa	4 900
Burkina Faso	5 000	Honduras	5 400	Senegal	75 236
Cameroon	350	Indonesia	801 777	Sierra Leone	6 500

Country	Production (Mt)	Country	Production (Mt)	Country	Production (Mt)
Cape Verde	4 500	Iran, Islamic Rep of	10 656	Somalia	900
Cayman Islands	36	Israel	21 500	South Africa	37 731
Central African Republic	9 300	Jamaica	5 000	Sri Lanka	86 240
Chad	32 000	Kenya	24 000	Sudan	190 000
Colombia	98 000	Laos	2 100	Tanzania, United Rep of	189 000
Congo, Dem Republic of	210 000	Madagascar	206 000	Thailand	1 250 000
Cook Islands	2 700	Malawi	34 000	Togo	10
Costa Rica	13 139	Malaysia	23 000	Trinidad and Tobago	430
Cuba	43 002	Mali	50 000	United Arab Emirates	9 655
Côte d'Ivoire	9 000	Martinique	197	United States of America	2 720
Dominica	1 750	Mexico	1 449 478	Venezuela, Rep of Bolivia	130 180
Dominican Republic	180 000	Montserrat	140	Viet Nam	188 557
Ecuador	68 693	Morocco	20	Wallis and Futuna Is	12
Egypt	231 000	Mozambique	36 000	Yemen	16 262
El Salvador	18 000	Nigeria	729 000	Zimbabwe	450
Fiji Islands	246	Oman	12 000		
French Guinea	391	Pakistan	916 454		

Processed mango is an exotic product in the US and gaining in popularity. Over the years the imports of this product have been increasing. Importers in the US think imports will increase even more in the coming years. Americans prefer canned mangoes because they like to have something out of the ordinary. Additionally, mangoes enjoy an ethnic market among Asian and Hispanic Americans.

The top supplier of canned mangoes in 1993 was Mexico, which held 50 percent of the value and 45 percent of the imported volume. World production of mango in 1997 was 22 million tonnes. India was then the world's largest producer accounting for almost 50 percent of total world production, China and Mexico contributed with 9 percent and 6 percent respectively. World imports of fresh mangoes are expected to increase by 53 percent to 459 000 tonnes by 2005 due to the increasing consumption worldwide.

Processed tropical fruits trade transactions, mostly by developing countries amounted to approximately US$1 500 in 1997. Asia accounts for over 85 percent of the world exports of processed tropical fruits. The consumption of processed mango products such as mango-flavoured beverages either singly flavoured or in multi-flavoured is rapidly increasing, particularly in Europe. The demand for processed mango pulp (puree) has similarly expanded. In 1996, the world production of mango pulp and juice amounted to 807 000 tonnes and 136 780 tonnes respectively. Exports were only 5.7 percent (45 951 tonnes) and 4.9 percent (6 752 tonnes) of the production. Major suppliers of mango pulp (13 to 18 °Brix) and concentrates (28 to 32° Brix) are Peru, India and Ecuador. Other processed mango products: dried, jam, jellies, syrup and other retail-packed products are fast gaining markets and commanding better prices than other tropical fruits.
Organically grown mangoes are currently produced in South Africa and India and exported in fresh frozen form. In Thailand, about 301 946 hectares are planted to mango, which are about 26 percent of the total land area allocated to fruit trees planting. Major planting areas are located in the north eastern and northern regions accounting for 34 percent and 28 percent of the total mango area. Thailand grows over 100 native mango cultivars. Thailand promotes a crossbreeding program to develop an "industrial mango" through breed selection. The aim is to produce cultivars appropriate for processing or for raw or ripe consumption. One of the persistent problems in mango is damage caused by insects and diseases, which are now being addressed by a number of researchers in Entomology and Plant Pathology (NFIT, 1999).

1.2 World trade

Among internationally traded tropical fruits, mango ranks only second to pineapple in quantity and value. Major markets for fresh and dried mangoes in 1998 were: Malaysia, Japan, Singapore, Hong Kong and The Netherlands, while for canned mango in 1998 were: Netherlands, Australia, United Kingdom, Germany, France and USA. World market for fresh, dried and canned mango is distributed as follows: North America with 43 percent, Europe with 26 percent, Far East with 18 percent and the Near East with 14 percent (NFIT, 1999). Mango growing In Florida, Haiti, Guatemala and Brazil has increased steadily over the years. Mexico has a large share of the international market for mango exports and this is due to the good quality of its products and the great natural conditions of Mexico. Today the Mexican Mango Export Industry is building a powerful quality culture directed to satisfying the specific tastes of consumers all over the world. Mexico has a big potential in varieties like Manzano, Plátano, Oro, Ataulfo, Manila, Haden, Tommy Atkins, Keitt and Criollo, with an overall production yield of 12 tonnes/ha. (Emex, 2000).

Southeast Asian buyers consume mangoes all year round. Their supplies come from India, Pakistan, Indonesia, Thailand, Malaysia, the Philippines, Australia and most recently South Africa. Production figures during 1999 are presented in Table 3.

Table 3. Country mangoes production for Southeast Asian buyers.

Country	Production (Mt)
India	12 000 000
Pakistan	937 705
Indonesia	53 452
Thailand	91 241
Malaysia	50 000
Philippines	931 500
Australia	51 389
South Africa	115 152

Source: FAOSTAT, 2000

Each exporting country has its own varieties, which differ in shape, colour and flavour. Prices vary from very low for Indonesian and Thailand fruit too expensive for Indian fruit. In the United States of America, the prices vary with the season, higher prices found during February and March, when mango availability is lowest (Figure 14).

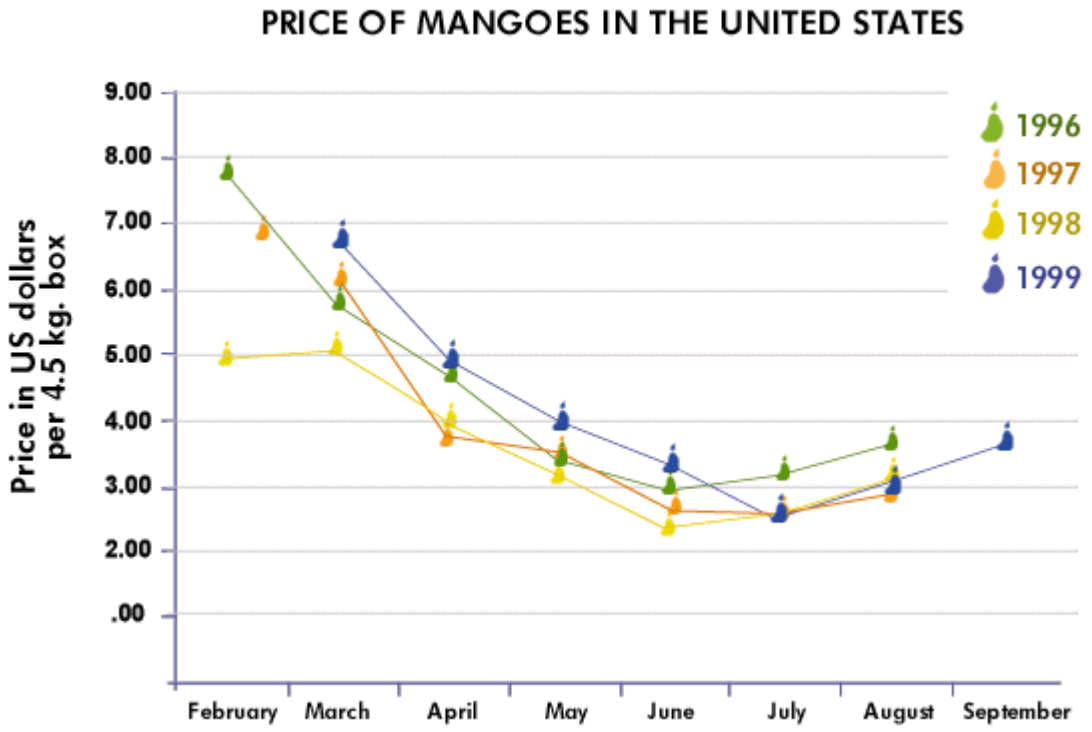


Figure 14. Yearly prices of mangoes in the United States of America. (Source: Emex, 2000)

a) World Trade in Fresh Mangoes

Most international trade in fresh mangoes takes place within short distances. Mexico, Haiti and Brazil account for the majority of North America s imports. India and Pakistan are the

predominant suppliers to the West Asian market. Southeast Asian countries get most of their supplies from the Philippines and Thailand. European Union buyers source mangoes from South America and Asia. Although Asia accounts for 75 percent of world production, its dominance does not translate into international trade.

The European Market

Although domestic consumption has grown dramatically in developed markets in Europe, the United States and East Asia, per capita consumption is still low. Yet given the trend toward consumption of exotic fruits, these markets will likely continue to grow. The European Union has witnessed some of the greatest growth in mango imports, which rose from 17 161 MT in 1985 to 52 800 MT in 1993. Although the U.S. import market is nearly twice the size of the European Union import market, Asian producers find expanding sales to the European Union is easier. European acceptance of different varieties is greater, because of a large demand from Asian immigrant groups. Phytosanitary restrictions, such as those in place in the United States to prevent importation of fruit flies, are also less stringent in the European Union. Transportation costs are not as big a factor in exporting mangoes to the European Union as in exporting to the United States market: for example, India and Pakistan are able to compete with non-Asian suppliers to the European Union, whereas proximity gives Mexico and Haiti a clear advantage in supplying the United States market.

Fifty-four percent of European Union imports enter during the periods May to July and November to December, with peak imports in June. French imports for 1993 peaked in April and May, whereas United Kingdom imports were concentrated during the May to July period. German imports were spread more evenly throughout the year. Of the top suppliers, Brazil provided chiefly during the period November to December, the United States (Puerto Rico) during June to October, South Africa during January to April and Venezuela during April to July. Pakistan supplied the majority of its exports to the European Union during June and July; Indian exports peaked in May (Patanik and Klotzbach, 2000).

1.3 Primary product

Selecting the ripeness of mangoes can be determined by either smelling or squeezing. A ripe mango will have a full, fruity aroma emitting from the stem end. Mangoes can be considered ready to eat when slightly soft to the touch and yielding to gentle pressure, like a ripe peach. The best-flavoured fruit should have a yellow tinge when ripe; however, colour may be red, yellow, green, orange or any combination. The ideal post harvest storage temperature for mangoes is 12ºC. When stored properly a mango should have a shelf life of 1 to 2 weeks. The best way to ripen a mango is to leave it on the kitchen counter at 20ºC. If you wish to accelerate the maturing process place the mango in a paper bag overnight (some people place an apple with the mango in the bag to create more natural ethylene gas and further decrease the ripening time). Once ripened the mango can be refrigerated for a few days, but should be used shortly thereafter.

How to eat mangoes

Mangoes are one of the most flavourful and refreshingly juicy fruits available! Let's talk about how to eat mangoes, because they can be tricky to pit and slice. Pay close attention so you can master mango preparation! The most direct way to enjoy a mango is to peel it and eat it like a peach, nibbling off every last bit of flesh connected to the pit (Figure 15. How to eat a mango Step1, Figure 16. How to eat a mango Step 2, Figure 17. How to eat a mango Step 3, Figure 18. How to eat a mango Step 4, and Figure 19. How to eat a mango Step 5).

Figure 15. How to eat a mango Step 1.

Figure 16. How to eat a mango Step 2.

Figure 17. How to eat a mango Step 3.

Figure 18. How to eat a mango Step 4.

Figure 19. How to eat a mango Step 5.

Figure 20. How to eat a mango Step 6.

Remove part of the skin. Put the mango on top of a stick and enjoy like a lollypop (you can add salt, lemon and chilli. (Figure 20 How to eat a mango Step 6).

Some people use more efficient methods. The first one is called the "Quick Mango Cube." First, slice each side of the mango along the seed to give two halves, and then hold one portion of the mango with the peel side down. Score the fruit down to the peel in a tic-tac-toe fashion. With both hands, bend the peel backwards. Cut the cubes along the peel to remove from the skin. Remove the remaining fruit on the seed by cutting along the seed.
Another way to prepare a mango is called "Easy Slices". (Figure 21. How to prepare a mango Step 1, Figure 22. How to prepare a mango Step 2, Figure 23. How to prepare a mango Step 3, Figure 24. How prepare a mango Step 4, Figure 25. How prepare a mango Step 5).

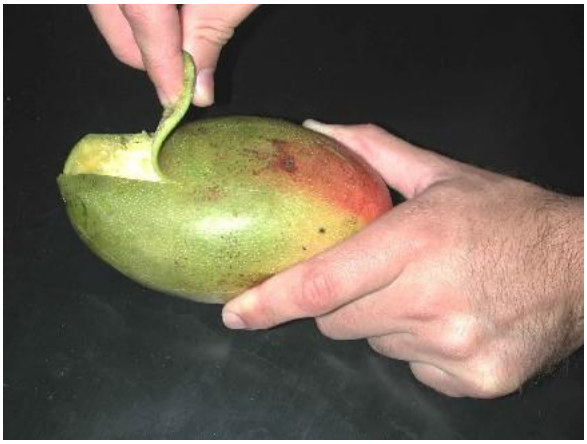


Figure 21. How to prepare a mango Step 1.

Figure 22. How to prepare a mango Step 2.

1.Cut off both ends of the fruit. Place fruit on flat end and cut away peel from top to bottom along curvature of the fruit. Cut fruit into slices by carving lengthwise along the pit. With the peel still on, slice through the mango lengthwise, getting as close as you can to the large fibrous pit in the centre. You will now have one large mango slice, with the skin still on.
2. Turn the mango over and cut off the other side just above the other side of the pit.
3. Slice the flesh into cubes without cutting all the way through to the skin.
4. Turn the fruit section inside out and cut the flesh off the skin, or just eat it from the skin.
5. Peel the remaining band of flesh on the pit, and eat it right off the pit, or slice it off. If you want to be messy, just peel the mango with a paring knife and eat it like a pear. Have a lot of napkins to clean up the juice.
6. Put the fruit on a flat surface and peel the skin by cutting it from the top to the bottom along the curve. Slice the fruit along the seed. Use a sharp knife to cut along the cheeks of the mango. With a sharp thin-bladed knife, cut off both ends of the fruit. Place the fruit on its flat end and cut away the peel from top to bottom along the curvature of the fruit.
7. Cut into slices by carving lengthwise along the pit. Separate the halves to keep the delicious centre. With a spoon, scoop the pulp of the halves.

Figure 23. How to prepare a mango Step2. **Figure 24. How to prepare a mango Step 3.**

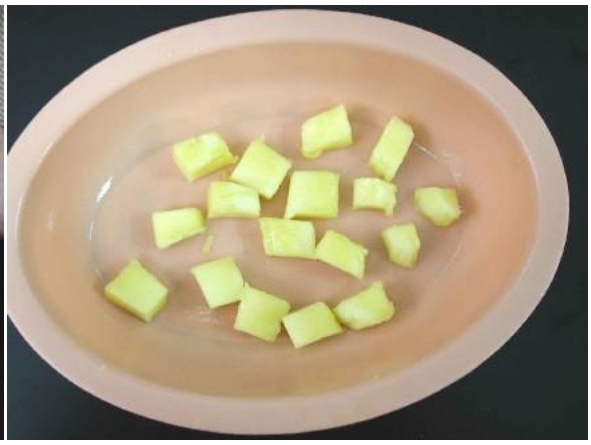


Figure 25. How to prepare a mango Step 4. **Figure 26. How to prepare a mango Step 6.**

Cubes

1. Start with the Mango "cheek"; Fillet off its pit lengthwise. Cut them into cubes using a sharp knife. (Without cutting the skin).
2. Turn the half outside separating the cubes. Remove the cubes from the skin by the knife or eat them directly on a fork or stick.
3. Cut skin on top of mango crosswise.
4. Pull skin away from fruit in quarters or eighths.
5. Place mango on a fork and serve.
6. Cut cross-wise the skin of the head.

a) Unripe and mature mangoes

Mangoes vary in colour depending on the variety and exposure to sunlight. Most mangoes start off with a dark green skin colour and develop patches of gold, yellow, or red as they mature. The skin is smooth and encloses yellow to orange flesh that is softly moist and richly flavoured. Mangoes emit a pleasant scent of pine and peach from the stem when ripe. Here is a helpful tip when selecting mangoes. If you do not detect a fragrant aroma, it usually means the mango has no flavour. Mangoes may be round, oval or kidney shaped and are about the size of a small melon or large avocado. The most popular varieties are Tommy Atkins, Kent, Keitt and Haden. Mangoes are high in vitamin A and a good source of vitamin C. A whole mango should be sliced in half (lengthwise, like a bagel) with a sharp fruit knife, and then cut

into quarters. Hold each piece down against your plate with a fork, skin-side up, and pull the skin away. The mango can then be cut up and eaten with a spoon .You may also be served one that has already been cut - halved, perhaps, with the seed removed but the skin intact. Eat this like an avocado, with a spoon. Mango fruit matures 4 to 5 months after flowering. In addition to the fruit colour and softness, proper maturity can be ascertained by the snap of the stem after slight pulling. Harvesting fruit with a 4 inch or so stem in tact prevents leakage of milky, resinous sap. Fruit can be picked green and left to ripen at room temperature, usually a week. Harvested fruit should immediately be washed to remove any sap, which will reduce the change of anthracnose. After ripening, fruit keeps at room temperature for one week, or refrigerated for 2 weeks. Mangoes are ready to eat if the flesh gives way slightly when you squeeze them gently. Another good way to tell is to smell the stem end: If it gives off a fruity aroma, you're ready for a real treat. Because mangoes vary from green to yellow to purplish-red, colour is not an indicator of whether a mango is ripe. Fruit should be immature, with shoulders below the stem insertion, white flesh and soft stone. Procedures for post-harvest handling given for the Julie and Graham mangoes also apply to pickling mangoes. Evolution of the colour of the mango pulp during its maturation The following denominations or numbers can be used when specified in reference to the statement of the category, describing the colour of the pulp as an indication of the state of maturation of any lot of mature mangoes.

1. Beige: (not white) means that the pulp of the mango must be completely beige, the shadow of this colour may vary from light to dark.
2. Changing: means that there is a clear change from beige to yellow, over not more than 30 percent of the observed area, and this change of colour starts near from the pit of the fruit
3. Yellow: means that more than 30 percent, but not more than 60 percent of the pulp observed area is of a yellow colour.
4. Yellow-orange: means that more than 60 percent of the pulp is yellow and that there is a clear change of colour from yellow to orange in no more than 30 percent of the pulp, starting this colouration from the nearest part to the pit of the fruit.
5. Orange: means that more than 90 percent of the pulp is orange.

b) For the analysis of the pulp colouration, the fruit pulp must be cut throughout the flat side of the mango, as near to the pit as possible. The pit must be visible.

c) Any lot of mangoes that do not fulfil the requisites colour statements can be called "mixed colours". Evolution of the mango skin colour during the fruit maturation The fruit normal colour after the harvest is mainly dark green, with red veins at the shoulders and a light green to yellow colouration on its end. This stage matches the minimum of maturity and provides the maximum of the mango shelf life between the exporter and the consumer. The skin of Acapulco mangoes (a Mexican variety) does not have any vein at any stage of maturity. The colour of the skin fruit is mainly yellow-orange with few green nuances. Some varieties like Tommy Atkins and Manila have clearly the red veins. The fruit starts losing firmness and this is the best stage to sell it to the consumer.

1.4 Secondary and derived products

a) Medicinal uses

Mango is one of the most recommended fruits to fight beriberi and to heal bronchial diseases since a mixture of mango pulp and honey can be made at home to fight bronchitis. Mango is an excellent depurative for the organism and it is recommended for nervous people, to fight insomnia, to heal brain fatigue, mental depression and as a laxative, besides it is very helpful to fight heartburn. It has excellent results when used to eliminate kidney sand and to assist digestion. An infusion can be made with mango leaves to heal molar ache, to affix weak teeth

and to eliminate pyorrhoea (pus from the gums). This infusion is very helpful to reduce the inflammation of the throat when used for gargling. For those who practice fasting, mango fasting is recommended since it provides a high amount of minerals to the blood. Mango fasting can be extended up to two or three weeks always under supervision. An extract can be made with mango skin and pulp, which is very astringent. The pulp can be used to rub skin affected by scabies, although it is not suggested for people who have delicate skin as this treatment might cause rash. Mango is a good diuretic that helps to evacuate a high amount of toxins through the urine (Grupo Agrícola Arcos, 1999).

Mangoes beyond being delicious and rich in vitamins, minerals and anti-oxidants, contain an enzyme with stomach soothing properties similar to papain found in papayas. These comforting enzymes act as a digestive aid and can be held partially responsible for that feeling of contentment we experience during and after our daily mango ritual. The mango tree yields a gum, tannin and a yellow dye. The bark leaves and seeds are used to prepare a range of traditional medicines (Narasimhachar, 1979).

Mangoes are an excellent source of Vitamins A and C, as well as a good source of Potassium and contain beta-carotene. Mangoes are high in fibre, but low in calories (approx. 110 per average sized mango) fat (only 1 g) and sodium. Mangoes are a good staple for your daily diet.
We all know the importance of fibre in our diets. If you are eating your mango-a-day, irregularity is not a problem for you. It is a great prevention against constipation, piles and spastic colon. Research has shown that dietary fibre has a protective effect against degenerative diseases, especially heart disease, may help prevent certain types of cancer, as well as lowering blood cholesterol levels. An average sized mango can contain up to 40 percent of your daily fibre requirement. For those are physically active, whether working out or constantly on the go, mangoes are also a great way to replenish that lost potassium. A mango-based natural product rich in antioxidant will be introduced in the market in 2001 year. Scientists at the Pharmaceutical Chemistry Centre of Havana discovered this product in Cuba. This product is supposed to be superior to any other existing antioxidants in the global market. The advantages of this Cuban product are these two conditions:
1) No other product has similar antioxidant potential,
2) Unlike other known compounds against oxidation such as vitamin E and C and ß carotene, it doesn't have any pro-oxidant effect. It also serves as nutritional supplement providing remarkable quantities of microelements like selenium, copper and zinc.

b) By- products

During the processing of mango, peel and stone are generated as waste (40 to 50 percent of total fruit weight). They are rich in various nutrients and value-added products could be obtained from them. Good quality jelly grade pectin (6.1 percent) and edible fibre (5.4 percent) could be extracted from ripe mango peel. Acceptable quality vinegar (5.2 percent acetic acid) and citric acid (20 g/kg peel) could be obtained from mango peel through microbial fermentation. Mango peel having low protein value (3.9 percent) is a poor quality animal feed. The peel could be protein enriched more than five times (20 percent) by solid-state fermentation using Aspergillus niger. Mango peel has lignocellulosic composition and hence its complete break down is difficult. It's co-composting with cow dung in 3:1 ratio results in its successful biodegradation.
Mango kernel contains high amounts of fat and starch. The oil extracted from kernel is of good quality and could be used in cosmetic and soap industries. The kernel flour (starch) after

mixing with wheat or maize flour is used in chapaties in India. About ten per cent alcohol could be obtained from mango kernel by co-culture fermentation. In food processing industries, various enzymes are invariably used for pulp liquefaction, juice clarification, etc. Enzymes such as cellulase and pectinase from mango peel and amylase from mango kernel could be produced by microbial fermentation.

Mango seed and kernel oil

Considerable variations occur depending on variety on average the dry stone comprises 10 percent of the fruit weight, while the kernel makes up 75 percent of the seed weight and contains, on average, 10 percent oil. It has been estimated that in India alone some 30 000 tonnes of oil could be extracted from 4 million tonnes of the total annual harvest of 7 million tonnes. Some mango kernel oil has been commercially extracted in India with 150 tonnes being exported in 1976 rising to 850 tonnes in 1978.

The kernels are edible, have a protein content of about 9 percent and are eaten, particularly in times of food scarcity. Oil is commercially extracted from the kernels in India and finds use as a cocoa butter substitute. The cake remaining after oil extraction is used in animal feed. Mango stones have to be dried, usually in the sun, so reducing the kernel moisture content from about 48 percent to 13 percent. Good drying is essential to prevent the growth of Aspergillus niger and to avoid the development of FFA rancidity. FFA levels in raw stones can rise from 2 percent to 7 percent after 20 days and to 46 percent after 120 days.

Oil extraction

Prior to oil extraction the mango kernels are sieved to remove foreign matter and later broken in a hammer mill. The broken kernels are further reduced in size by use of a roller breaker. The material is heated to soften it and finally fed to flaking rollers. The final flakes, which should be very thin and have moisture content of 10 to 12 percent, are extracted with hexane (Bringi, 1999).

Major fatty acid composition of oil

Mango kernel oil is pale yellow in colour. The fatty acid composition varies with both variety and climatic conditions. Typical values are:

Palmitic acid	5.1 to 8.0%
Stearic acid	42 to 48%
Oleic acid	35 to 42%

(Bringi, 1999)

1.5 Requirements for export and quality assurance

a) Export grading

Grading should be carried out to remove fruit outside of the specifications and to meet quality requirements. No separate size grading into specific sizes and counts within cartons are required, assuming that the minimum size is attained. Shredded paper may be included in the base of the carton; no individual fruit wrapping is required.

Pickling Keitt and Kent varieties mangoes should be loose packed to a net weight of between 13 and 18.2 kg. Cartons must not be overfilled during packing.

b) Market requirements

Market factors for the produce

Market factors affecting farmers' decisions on the growing of specific crops are potential purchasers for the produce: neighbours, townspeople, retailers, jobbers or middlemen, commission agents. Quality requirements of the buyer include size, shape, maturity, appearance and perishability of the produce.

A commodity can be "too good" as well as "too bad": one that greatly exceeds market requirements may not bring higher prices and thus be a waste of labour and resources.

An important limitation of most markets is that only certain varieties of a commodity are traded and others are unacceptable. In Indonesia, for example, the Agricultural Seed Experiment Station in East Java has recorded 242 varieties of mango, but only seven have any commercial potential beyond certain villages. The non-marketable mangoes, however, constitute about 70 percent of the total production, and the local grower can effectively increase his market share only by replacing existing trees with those of the desirable varieties.

Pickling mangoes should be when immature with incomplete seed formation, green, free from diseases, scars, mechanical damage, bruises and insect damage.

1.6 Consumer preferences

European consumers prefer a deep-yellow mango that develops a reddish-pink tinge. In Florida, the colour of the mango is an important factor and US consumers admire a handsome mango more or less generously overlaid with red. Red skin is considered a necessity in mangoes shipped to northern markets, even though the quality may be inferior to that of non-showy cultivars. Also, dependable bearing and ship ability are rated above internal qualities for practical reasons. A shipping mango must be one that can be picked 2 weeks before full maturity without appreciable loss of flavour. Too, there must be several varieties to extend the season over at least 3 months.

Varieties and commercial cultivars

Varieties important to mango trade in the world are Haden, Tommy Atkins, Kent and Keitt.

Haden: Averages a little less than a pound and is quite round for a mango, with only a slightly oval shape. Its skin turns from green to yellow-orange when ripe. The flesh is yellow in colour, firm, juicy and is abundant in fibre. The flavour is rich and sweet with a weak pleasant aroma. This variety is on the market from late May through June.

Tommy Atkins: This most common variety averages one pound in weight, is medium-large and neatly oval, with a rounded apex. The skin is quite thick, orangey or rosy yellow, speckled or blushed. The flesh is yellow, mild and sweet with a strong pleasant aroma and contains an average amount of fibre. Tommy Atkins is on the market from late May to July and is the leading mango variety grown in Florida.

Kent: This variety is large, plump and irregularly oval, with an average weight of 1 1/4 pounds. When ripe, the skin is orange-yellow and blushed slightly with deep red. The flesh is yellow-gold in colour, juicy and fibreless. The sweet, richly tropical flavour has a lovely acid-lime finish, with piny overtones. The Kent can be found on the market from late June into August.

Keitt: The Keitt is the heftiest, plumpest, largest commercial mango variety available, averaging 1 3/4 but reaching 3 pounds. It remains green when ripe, with only a very faint yellow or rose blush. The yellow-gold flesh is juicy, fibreless except close to the seed. Light in aroma, it has a full flavour, with pronounced lemony tang and medium sweetness. The Keitt is available from late July through September.

Of Mexican mangoes, 65 percent are Florida selections (Haden, Keitt, Kent, Irwin and Tommy Atkins) and 35 percent are of the type commonly grown in the Philippines (manila). Over a period of 3 years detailed studies have been made of the commercial cultivars in Culiacan, Sinaloa, Mexico, with a view to determining the most profitable for export. Results indicated that propagation of "Purple Irwin", "Red Irwin", "Sensation" and "Zill" should be discontinued and that "Haden", "Kent" and "Keitt" will continue to be planted; the first two because of their colour and quality and the third in spite of its deficiency in colour. "Manila", a Philippine mango, early-ripening, is much grown in Veracruz, Mexico "Manzanillo-Nunez", a chance seedling first noticed in 1972, is gaining in popularity because of its regular bearing, skin colour (75 percent red), nearly fibreless flesh, good quality, high yield and resistance to anthracnose. Ataulfo, another chance seedling originated in Chiapas, México has been exported successfully to the US market. Its fibre-free texture, firmer body and attractive orange colour have encouraged producers to start new plantations with this variety.

"Julie" is the main mango exported from the West Indies to Europe. The fruit is somewhat flattened on one side, of medium size; the flesh is not completely fibreless but is of good flavour. It came to Florida from Trinidad but has long been popular in Jamaica. The tree is somewhat dwarf, has 30 percent to 50 percent hermaphrodite flowers; bears well and regularly. It is adaptable to humid environments and disease-resistant and the fruit is resistant to the fruit fly. "Julie" has been grown in Ghana since the early 1920s. From "Julie", the well-known mango breeder, Lawrence Zill, developed "Carrie", but "Julie" has not been planted in Florida for many years.

Grafted plants of the "Bombay Green" variety, so popular in Jamaica, were brought there from India in 1869 by the then governor, Sir John Peter Grant, but were planted in Castleton gardens where the trees flourished but failed to fruit in the humid atmosphere. Years later, a Director of Agriculture had budwood from these trees transferred to rootstocks at Hope Gardens. The results were so successful that the "Bombay Green" became commonly planted on the island. The author brought six grafted trees from Jamaica to Miami in 1951 and, after they were released from quarantine, distributed them to the Subtropical Experiment Station in Homestead, the Newcomb Nursery and a private grower, but all succumbed to the cold in succeeding winters. The fruit is completely fibreless and stone free so that it is frequently served cut in half and eaten with a spoon. The seed is pierced with a mango fork and served also so that the luscious flesh that adheres to it may be enjoyed as well.

One of the best-known mangoes peculiar to the West Indies is "Madame Francis", which is produced abundantly in Haiti. It is a large, flattened, kidney-shaped mango, light green, slightly yellowish when ripe, with orange, low-fibre, richly flavoured flesh. This mango has been regularly exported to Florida in late spring after fumigation against the fruit fly.

Ghana received more than a dozen cultivars back in the early 1920s. In 1973, it was found that only three of these: "Julie", "Jaffna" and "Rupee" could be recognized with certainty. More than a dozen other cultivars were brought in much later from Florida and India. An

effort was begun in 1967 to classify the seedlings (from 10 to 50 years of age) in the Ejura district, the Ejura Agricultural Station and the plantation of the Faculty of Agriculture, University of Science and Technology, Kumasi, in order to eliminate confusion and have identifiable cultivars marked for future research. After checking with available published material on other cultivars for possible resemblance, descriptions and photographs of 21 newly named cultivars were published in 1973. Of these, 12 are fibrous and 9 fibreless.
In Venezuela, eleven cultivars were evaluated by food technologists for processing suitability: "Blackman", "Glenn", "Irwin", "Kent", "Lippens", "Martinica", "Sensation", "Smith", "Selection 80", "Selection 85" and "Zill". The most appropriate, because of physicochemical characteristics and productivity were determined to be: "Glenn", "Irwin", "Kent" and "Zill".
In Guatemala there are several varieties. After years of studying and observing harvests, one variety named "Criollo" has excellent organoleptic qualities, distinct and unique in its kind. It has a natural Brix of 20 to 22 degrees. However, aseptic mango purees with a natural Brix of up to 28 degrees have been produced, depending on the area the fruit is grown in. Its natural pH varies from 4.0 to 4.2, making its acidification unnecessary. These characteristics allow producers to offer the world-market a unique 100 percent mango puree, with an intense orange colour and an exquisitely deep aroma. Aseptic puree from "Criollo" mangoes is produced during the months of May, June and July.

In Hawaii, "Haden" has represented 90 percent of all commercial production. "Pairi" is more prized for home use but is a shy bearer, a poor keeper, not as colourful as 'Haden', so it never attained commercial status. In a search for earlier and later varieties of commercial potential, over 125 varieties were collected and tested between 1934 and 1969. In 1956, one of the winning entries in a mango contest attracted much attention. After propagation and due observation it was named 'Gouveia' in 1969 and described as: ovate-oblong, of medium size, with medium-thick, ochre-yellow skin blushed with blood red over 2/3 of the surface. Flesh is orange, nearly fibreless, sweet and juicy. Seed is small, slender, monoembryonic. Season: late. Tree is of medium size, a consistent but not heavy bearer. In quality tests 'Gouveia' received top scoring over "Haden", "Pairi" and several other cultivars. Florida mangoes rated as promising for Hawaii were "Pope", "Kent", "Keitt", "Brooks" (later than "Haden") "Earlygold" and "Zill" (earlier than "Haden").
In the Philippines, the "Carabao" constitutes 66 percent of the crop and 'Pico' 26 percent. These cultivars, apparently of Southeast Asian origin have remained the most commonly grown and exported for many years.

The mango, known as "mamuang" in Thailand, is one of Thailand's premier tropical fruits and Thailand produces some of the most delicious mangoes in the world. Ripe mangoes are eaten for dessert while pickles and chutney are prepared from unripe fruit. Thailand's tropical climate is perfect for high quality and abundant mango growth. As well as the long tropical rainy season from July to October, Thailand's equally long dry season from November to March gives the mango tree its much-needed protection from bacteria and fungus. It is significant that the mango season occurs towards the end of the dry season and just months before a new rainy season. When the country's tropical heat reaches its height in April and May, the mangoes ripen.

In Israel, "Haden" has been popular for a long time though it is sensitive to low temperatures in spring. An Egyptian introduction, "Mabroka" is later in season and escapes the early frosts. "Maya", a local seedling of "Haden" has done well. Perhaps the most promising today is "Nimrod", a seedling of "Maya", open pollinated, perhaps by "Haden", planted in 1943,

observed for 20 years and budded progeny for another 9 years; named and released in 1970. The fruit is round ovate, large; skin is fairly thin, olive-green to yellow-green, blushed with red; attractive. Flesh is deep yellow, nearly fibreless, of good flavour.
It is impressive to see how the early favourite, "Haden", has influenced mango culture in many parts of the world. Today, the Subtropical Horticulture Research Unit of the U.S. Department of Agriculture and the Agricultural Research and Education Centre of the University of Florida, together maintain 125 mango cultivars as a resource for mango growers and breeders in many countries (Morton, 1987).
Mango production in Mexico
The season for mangoes in Mexico starts in February and continues until September. Mangoes bound for export are mainly produced in states of Michoacán, Sinaloa, Nayarit, Jalisco and Chiapas. The types of mangoes that are cultivated in Mexico are Ataulfo, Haden, Tommy Atkins, Irwing, Keitt, Kent, Manila, Palmer, Sensation and Van Dyke (Emex, 2000).

2. Post-Production Operations

2.1 Harvesting

Mango harvest criteria can vary with local consumption patterns and distance to the market. Time from flowering combined with fullness of mango cheeks is the commonest criteria. Producers must decide whether to harvest as soon as the market price ensures a reasonable return or to leave the crop in the field to obtain maximum yield. However, waiting too long for yield increase may drastically shorten the marketable life of the produce and lower the sale price. This balance is a critical factor in determining the grower's income from the crop. In practice the total harvest period is very short and the grower has very little time in which to make the correct decision. Mango fruits fall into this category and are best harvested using clippers and placed in harvesting bags carried by the harvester. With large trees, fruits are harvested by the use of picking poles, with or without attached clippers, equipped with bags into which the fruit fall (See Figure 27. Harvest tool with mangoes and Figure 28. Mango harvest tool).

Figure 27&28. Harvest tool with mangoes.

This method is rather slow and requires considerable experience and skill, but is essential if high quality fruit is required. Alternatively the fruit is picked by the harvester either on a ladder or who climbs the trees and throws the fruit to a skilled 'catcher' on the ground or into

a large net. Pulling out of stems from fruit when harvesting has to be avoided at all costs because broken skin at the point of attachment of the stem is particularly susceptible to a decay condition known as stem end rot.

Mangoes normally reach maturity in 4 to 5 months from flowering. Fruits of "smudged" trees ripen several months before those of untreated trees. Experts in the Philippines have demonstrated that "Carabao" mangoes sprayed with ethephon (200 ppm) 54 days after full bloom can be harvested 2 weeks later at recommended minimum maturity. The fruits will be larger and heavier even though harvested 2 weeks before untreated fruits. If sprayed at 68 days after full bloom and harvested 2 weeks after spraying, there will be an improvement in quality in regard to soluble solids and titratable acidity.
When the mango is fully-grown and ready for picking, the stem will snap easily with a slight pull. If a strong pull is necessary, the fruit is still somewhat immature and should not be harvested. In the more or less red types of mangoes, an additional indication of maturity is the development of a purplish-red blush at the base of the fruit. A long-poled picking bag which holds no more than 4 fruits is commonly used by pickers. Falling causes bruising and later spoiling. When low fruits are harvested with clippers, it is desirable to leave a 4 inch (10 cm) stem to avoid the spurt of milky/resinous sap that exudes if the stem is initially cut close. Before packing, the stem is cut off 1/4 in (6 mm) from the base of the fruit.

Yield

The yield varies with the cultivar and the age of the tree. At 10 to 20 years, a good annual crop may be 200 to 300 fruits per tree. At twice that age and over, the crop will be doubled. In Java, old trees have been known to bear 1 000 to 1 500 fruits in a season. Some cultivars in India bear 800 to 3 000 fruits in "on" years and, with good cultural attention, yields of 5 000 fruits have been reported. There is a famous mango, "Pane Ka Aam" of Maharashtra and Khamgaon, India, with "paper-thin" skin and fibreless flesh. One of the oldest of these trees, well over 100 years of age, bears heavily 5 years out of 10 with 2 years of low yield. Average annual yield is 6 500 fruits; the highest record is 29 000.
Average mango yield in Florida is said to be about 30 000 lbs/acre. One leading commercial grower has reported his annual crop as 22 000 to 27 500 lbs/acre. Maturity Mangoes are generally harvested at physiological mature stage and ripened for optimum quality. Fruits are handpicked or plucked with a harvester. After harvest the fruits are usually heaped under a tree on the ground. Bruised and injured fruits develop brown to black spots during storage making the fruits unattractive. Moreover, injuries to the peel or to the stalk end serve as avenues for invasion of microorganisms and lead to rotting of the fruits. Post harvest losses in mangoes have been estimated in the range of 25 to 40 percent from harvesting to consumption stage. If proper methods of harvesting, handling, transportation and storage are adopted, such losses could be minimized. The harvesting in mango should be done in the morning hours and fruits should be collected in plastic trays and kept in shades. The fruits should not be allowed to fall on the ground as the injured fruits cause spoilage to other healthy fruits during packaging and storage. Fruits harvested with 8 to 10 mm long stalks appear better on ripening as undesired spots on skin caused by sap burn are prevented. Such fruits are less prone to stem-end rot and other storage diseases. Fruits harvested by stick are injured and/or bruised due to impact resulting in decay, poor quality and attract low price. To overcome these problems, a simple, low cost and portable mango-harvesting device has been designed and developed at CISH, Lucknow (Central Institute of Sub-tropical Horticulture (CISH), India). Mango fruits are taken into the pouch and held between the divider and knife and as the device is pulled the blade cuts the pedicel. The fruits are then conveyed through a

nylon chute to collecting boxes without bringing down the device every time. This saves time and protects fruits from mechanical damage; it also protects operator's hand from the sap (plant fluid), which flows from the point of detachment.

Transportation

Mangoes are hand-packed in single layer fibreboard trays. Plastic and papier-mâché inserts with moulded cups or channels are available in a range of counts. (The most commonly used vary between 10 for large fruit to 20 to 25 for smaller fruit). These inserts help speed up the packing process. Trays also come in different depths to accommodate larger fruit. Trays should packed so that fruits hold each other firmly in place, with no movement when the lid is closed and should weigh at least 6.8 kg. A carton can lose around 400 g in transit resulting in a very loose pack at the market. After transit a standard carton should weigh 6.5 to 7 kg. This method is costly both in carton cost per kilogram of fruit as well as time and labour. A cost saving method would be by volume filling large cartons. Using this method fruit is still graded to size but the carton is simply filled until a required weight is reached. Trials using 10 kg and 18 kg cartons transported by refrigerated trucks arrived at markets in good condition of both fruit and cartons. Despite the fact that the mangoes were in good condition, prices received were relatively low. This may be the way to send consignments to supermarket chains and other bulk purchasers in the future, but at present the highest prices are still received for trays. (Poffley et al., 1999).

Grading

Fruit may be sized by eye, dimension or weight using mechanical or electrical sizing equipment. Within each package fruit may not vary in diameter by more than 10 mm. If the fruits are graded according to their size, weight, colour and maturity, both the producer and consumer are benefited. It has been observed that bigger size fruits take 2 to 4 days more in ripening than smaller ones. Hence, packaging of smaller fruits with larger ones should be avoided to achieve uniform ripening. Immature, overripe, damaged and diseased fruits should be discarded.

Packing

Fruit can be prepared for packing in three ways:

1. With stems removed. A sap flow will occur if the stems are removed. The initial spurt of sap will burn the fruit, leaving a blemish that will develop during storage and transport. Sap burns must be avoided. Clip the stems short, while holding the fruit with the stem end down. Place the fruit on a de-sapping bench and allow them to drain for 20 to 30 minutes until the sap flow has stopped. A fine water spray over the fruit helps to reduce the chances of sap burn. Recent trials in Queensland have found that dipping fruit in water containing 1 ml/l of wetting agent reduces the risk of sap burn even further.
2. With stems attached. Trim stems as described in the Harvesting section. More care is required when handling this fruit so that stems are not accidentally broken.
3. In a 450 x 290 x 105 mm (internal dimensions) telescopic tray. This package is robust and it presents and protects the fruit well. A plastic cup insert, called a plix liner, is used. This acts as a packing guide and also 'nests' the fruit. For best presentation, pack the fruit with the stem end down and convex curve up. This position also prevents any sap that oozes after the fruit has been packed from spoiling the appearance of the fruit. The package must be packed firmly and have a gross weight of 7 to 7.5 kg. Stickers identifying the brand are important. They should be distinctive in colour and simple in design. Fruit, which is nearly always

removed from the package for retail display, cannot be identified without a sticker (Agriculture Western Australia, 1998).
Full-telescopic two-piece fibreboard carton ("banana" type) or one-piece waxed self-locking ("bushel" type) cartons may be used. The bursting strength is 275 psi. Central dividers and shredded paper may be used to assist with carton strength and product protection. Where staples are used for carton construction, care should be taken to ensure complete staple closure to avoid fruit damage. Carton internal dimensions: 20 by 51 by 34 cm (7.9" by 20" by 13.4") and 29.5 by 44 by 29.5cm (11.6" by l7.3" by 11.6").
Wooden boxes are commonly used for packaging and transportation of mango fruits. Under dynamic transport conditions nails come out due to vibration and puncture the fruits, which result in bruising, decay and low price of fruits. Further, too much ventilation affects the quality of fruits due to shrinkage, loss in weight, colour, etc. To overcome these problems, CFB (carton fibreboard) Boxes of 5 kg and 10 kg capacity for packing and shipping of mango fruits successfully as an alternative to traditional nailed wooden boxes. The use of CFB boxes for packaging for the domestic market is also the need of the hour due to scarcity of the wood and environmental concerns. For export purposes, CFB boxes are already in extensive use. Paper scraps, newspapers, etc., are commonly used as cushioning material for the packaging of fruits which prevent them from getting bruised and spoiled during storage and transportation. Low-density polyethylene (LDPE) lining has also been found beneficial as it maintains humidity, which results in lesser shrinkage during storage. Wrapping of fruits individually (Unipack) with newspaper or tissue paper and packing in honeycomb structure helps in getting optimum ripening with reduced spoilage. Normally the lid of the wooden boxes is nailed with an area of 5 to 7 cm high in the middle. This puts pressure on the fruits during transport and results into reduced quality. Therefore, farmers should be very careful while packing the fruits.

Export Grading and Packing

The fruits are checked prior to packing to ensure the absence of blemishes, bruises, insect and mechanical damage. Fruits are graded in each carton according to the variety, size (giving a range of counts for each shipment) and maturity. Mangoes are packed in single layer one- or two-piece full-telescopic, self-locking fibreboard cartons (bursting strength requirement 250 to 275 psi). Ventilation and handle holes provide adequate ventilation and ease of handling (Medlicott, 2000).
Some mango varieties required to meet specifications for export, are presented in Table 4.

Table 4. Specifications for export varieties.

Varieties	Julie	Graham	Grenada	Peach
Size	Minimum weight: 250 g Minimum length: 9.0 cm Minimum width: 7.5 cm Minimum breadth: 6.5 cm	Minimum weight: 350 g Minimum length: 10.0 cm Minimum width: 9.0 cm Minimum breadth: 9.0 cm	Minimum weight: 200 g Minimum length: 8.0 cm Minimum width: 7.0 cm Minimum breadth: 7.0 cm	Minimum weight: 170 g Minimum length: 7.0 cm Minimum width: 6.0 cm Minimum breadth: 6.0 cm
Appearance	*	*	*	*
Colour	#	#	#	#
Condition	&	&	&	&

Medlicott, 2000
*Clean. Free from blemishes, insect damage, fungal infection, uniform size and ripeness
Peel colour of mainly red, yellow and green. Pulp colour yellow-orange
& No latex stains; no harvest wounds, bruises or punctures. No insect or disease damage. Fruit at the required stage of ripeness

Storage

Storage is essential for extending the consumption period of fruits, regulating their supply to the market and also for transportation to long distances. The mature green fruits can be kept at room temperature for about 4 to10 days depending upon the variety. Shelf life of fruits could be extended by precooling, chemical treatments, low temperature, etc. The harvested fruits are precooled to 10 to 12°C and then stored at an appropriate temperature. The fruits of Dashehari, Mallika and Amrapali should be stored at 12°C, Langra at 14°C and Chausa at 8°C with 8 to 90 percent Relative Humidity. The fruits could be stored for 3 to 4 weeks in good condition at low temperature. It is a general practice to harvest fruits early in the season (premature stage) to capture early market. These fruits do not ripe uniformly without any ripening aid. Such fruits could be ripened uniformly by dipping in 750 ppm ethrel (1.8 ml/litre) in hot water at 52 ± 2°C for 5 minutes within 4 to 8 days under ambient conditions. Mature fruits can similarly be ripened with lower doses of ethrel for uniform colour development. Green seedling mangoes, harvested in India for commercial preparation of chutneys and pickles as well as for table use, are stored for as long as 40 days at 5.6 to 7.2°C with relative humidity of 85 percent to 99 percent. Some of these may be diverted for table use after a 2-week ripening period at 16.7 to 18.1°C.

2.2 Packinghouse operations

Inspection

After harvesting the fruit should be given a quick rinse with a hose to remove any dust or accidental sap on the skin (this prolongs the life of dips by reducing the source of contamination). As stated earlier, the fruit should be de-sapped.

In a sophisticated Florida operation, harvested fruits are put into tubs of water on trucks in order to wash off the sap that exudes from the stem end. At the packinghouse, the fruits are transferred from the tubs to bins, graded and sized and packed in cartons ("lugs") of 8 to 20 each depending on size. The cartons are made mechanically at the packinghouse and hold 6.35 kg (14 lbs) of fruit. The filled cartons are stacked on pallets and using forklifts placed into refrigerated trucks with temperature set at no less than 12.8°C for transport to distribution centres (Morton, 1987).

Anthracnose and stem end rot (Botryodiplodia theobromae) are the most important post harvest rots found in mangoes. Both develop in ripening fruit, so are not noticed in the grading and packing process. The fruit can be dipped as a precaution against rot. There are two methods for anthracnose, stem and rot control:

a. Hot benomyl dip controls anthracnose and partially controls stem end rot. Fruit should be stored for 12 to 16 hours before dipping to prevent scalding. Rain within 36 hours of harvest increases the risk of scalding. Do not dip fruit treated with oil at de-sapping. Hot benomyl dips should be applied before dimethoate. The fruit is totally submerged for 5 minutes in hot water (52°C) to which 100 g/100l of benomyl 50 percent (Benlate®) has been added. The temperature must be carefully maintained; too high a temperature will damage fruit and too cool will reduce effectiveness. The dip must be constantly agitated to prevent the fungicide settling to the bottom. The dip should be replaced every 3 days or sooner with a fresh batch, if heavy contamination occurs from sap and dirt.

b. Unheated prochloraz can be used as a non-recirculating spray. This is not effective against stem end rot and at present is not approved as a dip. Solution concentration should be 250 ppm. This can be achieved by using 55 ml of Sportak® (45 percent prochloraz) per 100 l of water. Prochloraz is compatible with fenthion and should be mixed with it and applied as a low volume non-recirculating spray. See appropriate fruit fly treatment for application method (Poffley et al., 1988).

Washing

Washing the fruits immediately after harvest is essential, as the sap, which leaks from the stem bums the skin of the fruit making black lesions, which lead to rotting.

Grading

Inspect fruit on a grading table with good lighting. Developing a reputation for quality demands that fruit exported is always of a high standard. Do not pack fruit that is wind-marked, sunburnt, damaged by insects, sap-burnt or mechanically damaged Resist the temptation to put one or two borderline fruit in a tray; importers will use blemished fruit as a reason to reduce the price of the consignment. The simple rule is to send no marked, misshapen or damaged fruit. The fruit are re-checked to ensure quality specifications have been met before being separated into groups for packing by count. Grading should be carried out as soon as possible after harvest and fruit left under ambient conditions to continue ripening or placed at 10° to 12°C for cooling and storage. On arrival in the packing facility, fruit should be washed in water to remove latex and debris and then treated in a 0.05 percent Thiabendazole solution for anthracnose control. Washing, treatment and grading can be carried out using mechanized or manual systems, depending on the volumes of fruits. Grading in each cartoon is required in terms of size, sex (shape) and stage of ripeness. Female and hermaphrodite fruit cannot be mixed in the same carton; all fruits must be of a similar size in each carton resulting in a range of counts and separations must be made for the degree of ripeness. Carton net weight is dependent on the importer, ranging from 3.5 to 5 kg (8 to 11 lbs) and must not be overfilled during packing (DA, 1999).

Fruit should be graded in each carton according to variety, size by weight or diameter (giving a range of "counts" for each shipment) and maturity (firm, green full-mature and half-mature fruit will ripen at different rates and should not be packed in the same carton). Minimum weight and size specifications for the required market should be followed (Tropical seeds, 2001).

Hydrothermic process (rural installations and certification of automatic systems)

EMEX, (Mexican Packers of mangoes for export) has been pursuing the incorporation of better technologies to achieve highest quality in their mangoes for exports. To achieve this improvement EMEX is working on the following projects:

-Project of an Automated System for Hydrothermic Treatment Certification.

-Development of a Quality Assurance Program for Fresh Mexican Mangoes together with particular and educational government institutions.

-Market Studies of Mexican mangoes in the United States.

Hot-Water Immersion

Hot-water immersion consists of submerging the fruit in a hot-water bath at a specific temperature for a specified time, based on the weight of the commodity being treated and the pests that may be present (APHIS, 1993). For perishable food commodities, the mandated probity 9 level of fly control can be achieved by heating the core of the fruit to 43 to 46.7°C with exposure times varying from 35 to 90 minutes. Variations are noted for different commodities, pest species and life stages of insect pests. Hot water is an effective heat transfer medium and, when properly circulated through the load of fruit, quickly establishes a uniform temperature profile (Couey, 1989). Hot-water immersion also has the additional benefit of controlling post harvest microbial diseases such as anthracnose and stem end rot (Couey 1989, McGuire, 1991). Hot-water immersion is currently used to successfully treat mangoes infested with the Mediterranean fruit fly and several different Anastrepha species of fruit fly before importation into the United States from Mexico, the Caribbean and Central and South America (APHIS 1993). Research performed by ARS on mangoes, which are relatively resistant to heat damage, led to approval by USDA-APHIS of hot-water immersion quarantine treatments for mangoes infested with immature fruit flies (Sharp and Picho-Martinez, 1990).

A hot-water immersion system, can be easily assembled; and may be durable, mobile and inexpensive (Sharp, 1989). A hot water immersion is inherently more efficient than vapour heat as a heat transfer medium. (See Figure 29. Hot water immersion)

Figure 29. Hot water immersion.

Hot water immersion is the only approved quarantine treatment for mangoes. More than 75 commercial hot water treatment facilities operate in Mexico, Haiti, Puerto Rico, South America and Florida. The cost for each facility averages about $200,000. Additional facilities are planned or being constructed. APHIS/PPQ (Animal and Plant Health Inspection Service Plant Protection and Quarantine) must certify each facility and ensure that inspectors are on site.

Thermal disinfestation treatments (USDA -APHIS, 2001)

Mango (Kent, Keitt, Tommy, Haden and Ataulfo varieties) from Mexico

Pest: Anastrepha ludens (Mexican fruit fly), Anastrepha obliqua (West Indian fruit fly) and Anastrepha serpentina (black fruit fly)

Treatment consists of 103°C administered in one single-stage high temperature forced air application. Size of fruit will range from standard sizes 8 to 14.

Weight of fruit must not exceed 1½ pounds (700 g).

The steps must occur in the following order:

1. Probe at least three of the largest mangoes at the seed's surface. Insert probes into the thickest portion of the fruit's pulp.
2. Record temperatures at least once every two minutes until the Treatment is concluded.
3. Introduce air heated to 122°F (50°C) in the chamber.
4. Conclude the Treatment once the temperature at the seed's surface (based on the coolest part of the fruit) reaches 118°F (48°C).

IMPORTANT: Treatment time will vary depending on the size of the fruit and the number of boxes treated.

If the origin of the fruit is	And the shape is	And the weight is	Then dip
Puerto Rico, U.S. Virgin Islands or West Indies (Excluding Aruba, Bonaire, Curacao, Margarita, Tortuga or Trinidad and Tobago)		(g)	(min)
	Flat, elongated varieties*	Up to 400	65
		400 to 570	75
	Rounded varieties**	Up to 500	75
		500 to 700	90

* Such as `Frances,' `Carrot,' `Zill,' `Ataulfo,' `Carabao,' and `Irwin.' ** Such as `Tommy Atkins,' `Kent,' `Hayden,' and `Keitt.'

If the origin of the fruit is	And the shape is	And the weight is	Then dip
Mexico or Central America (north of and including Costa Rica)		(g)	(min)
	Flat, elongated varieties*	Up to 400	65
		400 to 570	75
	Rounded varieties**	Up to 500	75
		500 to 700	90

* Such as `Frances,' `Carrot,' `Zill,' `Ataulfo,' `Carabao,' and `Irwin.' ** Such as `Tommy Atkins,' `Kent,' `Hayden,' and `Keitt.'

If the origin of the fruit is	And the shape is	And the weight is	Then dip
Panama, South America or West Indies islands of Aruba, Bonaire, Curacao, Margarita, Tortuga or Trinidad and Tobago		(g)	(min)
	Flat, elongated varieties*	Up to 400	65
		400 to 570	75
	Rounded varieties**	Up to 425	75
		425 to 650	90

* Such as `Frances,' `Carrot,' `Zill,' `Ataulfo,' `Carabao,' and `Irwin.' ** Such as `Tommy Atkins,' `Kent,' `Hayden,' and `Keitt.'

Alternatively, vapour heat and forced hot air treatment systems are less damaging to commodities and more versatile than other treatment systems. Though these treatment systems cause less damage to produce, they are more expensive.

For Mango, Anthracnose caused by the mould Colletotrichium gloesporoides is a main disease causing decay and commercial devaluation of harvested mangoes. Liu (1984) suggested that pathogenic fungi diseases such as anthracnose on mango fruit are latent and a main cause of serious decay. Huang and Yang (1988) demonstrated that a 53°C hot treatment in combination with fungicide could reduce the decay. Mango fruit can be stored at ambient temperatures up to 15 days and at low temperature for about 30 days.

Jiang (1995) demonstrated that the activation of latent pathogenic fungi in mango was related to the development of fruit ripening and chitinase and ß-1, 3-glucanase increased gradually during fruit ripening and pathogenesis. Ji et al. (1994) also made some studies on storage of mango at low temperature and its chilling injury.

Experiments in Florida have demonstrated that 'Irwin', 'Tommy Atkins' and 'Kent' mangoes, held for 3 weeks at a storage temperature of 13°C, 98 percent to 100 percent relative humidity and atmospheric pressure of 76 or 152 mm Hg, ripened thereafter with less decay at 21°C under normal atmospheric pressure, as compared with fruits stored at the same temperature with normal atmospheric pressure, stored at 152mm Hg took 3 to 5 days longer to ripen than those stored at 76mm Hg. Decay rates were 20 percent for 'Tommy Atkins' and 40 percent for 'Irwin' varieties. Spoilage from anthracnose has been reduced by immersion for 15 minutes in water at 51.7°C or for 5 minutes at 55.6°C. Dipping in 500 ppm maleic hydrazide for 1 minute and storing at 32°C also retards decay but not loss of moisture. In South Africa, mangoes are submerged immediately after picking in a suspension of benomyl for 5 minutes at 55° C to control soft brown rot.
In Australia, mature-green 'Kensington Pride' mangoes have been dipped in a 4 percent solution of calcium chloride under reduced pressure (250 mm Hg) and then stored in containers at 25° C in ethylene-free atmosphere. Ripening was retarded by a week; that is, the treated fruits ripened in 20 to 22 days whereas controls ripened in 12 to 14 days. Eating quality was equal except that the calcium-treated fruits had slightly higher ascorbic acid content.

High Temperature Forced Air

Recirculated air that has been heated and humidified can be forced over fruit surfaces to raise the temperature to a level that is lethal to target pest species. Heated air treatments of 40 to 50 °C (usually at four incrementally increased temperatures) for less than eight hours are becoming more common for fruit fly control in tropical commodities (UNEP, 1994). Condensation on fruit surfaces or in the treatment chamber is prevented by keeping the dew-point temperature 2 to 3°C below the dry-bulb temperature throughout the duration of the test. This precise control of temperature and relative humidity is advantageous because it prevents condensation inside the treatment area and on the fruit surface, thus preventing fruit desiccation and scalding (Gaffney and Armstrong, 1990; Sharp et al., 1991). USDA-APHIS has approved forced air treatments for mango (APHIS, 1993). Fruit flies of concern are Mexican fruit fly, West Indian fruit fly and black fruit fly in mango from Mexico (APHIS, 1993).

Packing and packaging materials

Packaging practices (See Figure 30 Packing practices of Tommy Mango)
Experts on Manila variety advise picking of mango at the ripe stage at 120 to 130 days after flower induction. If done at 110 days, mangoes do not develop enough sweetness and shrink as they turn yellow when ripening. Trimming and placing mango's stem-end downward and in-between wooden slots can also prevent damage by latex or the milky liquid. This accelerates latex flow, which may be completed in 30 minutes. Detergents, the researchers said, are good washing agents to prevent latex stain and burns. But hot water treatment along with detergent is more effective against latex damage. In the packinghouse, less strict sorting system can also spell confusion. Extra care is necessary to separate export-grade (160 g and above) from local market-bound mango (DOST, 2001).

Figure 30. Packing practices of Tommy Mango.

Figure 31. Carton packages for Tommy mangoes.

Palletization (See Figure 32. Tommy mango palletization).

Figure 32. Tommy mango palletization.

Containers

Refrigerated containers operate with the refrigerated air supplied across the t-section floor, circulating around the container and returning to the system via the top of the cargo. The "temperature set point" is the temperature entered into the controller or microprocessor, of a temperature controlled container. This determines the air temperatures supplied to the container.

However good the container and however well cooled, packed and stowed the cargo, there is of necessity a temperature gradient within the container, which is dependent on outside conditions. Such gradients are known and understood by container operators and the reason for temperature variations include: effects of ambient temperature, container thermal properties, air circulation rate, air flow patterns, refrigeration control system and loading temperatures.

Integral containers in chilled mode control the air temperatures via the supply air probe. Modern integral units are fitted with dehumidifiers and in-built data-loggers measuring temperatures, relative humidity and events. Digital displays allow visual monitoring of temperatures. The software installed in these integrals also prevents fans from blowing warm, moist air into the container until the refrigeration system has restarted and the evaporator coil has cooled. This helps maintain the integrity of the temperature chain. Air must circulate around the cargo to absorb the small amount of heat that enters the container through the insulated walls, ceiling and floor. It is imperative that cargo is not loaded above the load limit line on the walls, to ensure air circulation occurs. Air must be allowed to flow between the door and the rear cargo stow, which must not extend beyond the end of the t-section floor. Space (chimneys) must not be left between pallets or cartons, ensuring air does not short circuit back to the refrigeration unit. Gaps must be plugged with dunnage material to ensure that the maximum volume of air flows around the door area. Shippers of very small cartons sometimes cover the floor of the container with a form of hardboard that is covered with pinholes.
Cargo stability is important and shippers must ensure the cargo is well braced before closing the container's doors. Care must be taken when opening containers in case cargo has been displaced, thus creating a safety hazard. Each country has its own maximum load weight regulations, as do the containers; we can advise shippers of the relevant requirements. Shippers must ensure they take full advantage of the available cube space in a container, re-designing the packaging may improve the utilization of available volume and thus reduced transport costs.

Container Preparation

The procedure involves a physical and technical inspection of each unit to make sure the unit performs as required. Cleaning of the container involves removal of any solid matter, using hot water, detergent wash and steam as required. The container needs to be dry before being moved to the stuffing point. Shippers must inspect and accept that each container has been supplied clean and free from odour (P&O Nedlloyd, 2001).

2.3 Cooling system

Figure 33. Cooling room for mangoes.

Storage of mangoes

Pinhead-sized black spotting is not a defect but is a characteristic of some varieties (Haden). Avoid mangoes that are wilted, have greyish discoloration of the skin or are pitting. Some varieties will yield to gentle pressure when ripe. Most varieties will turn yellow as they ripen, except for green varieties. Red mangoes will not become redder after harvest. Area around the stem should look plump and round when the mango is ripe. Mangoes are susceptible to chilling injury. The handling and storage must be at 12.8°C and relative humidity of 85 to 90 percent. The typical shelf life is of 7 to 14 days.

Pre-treatments

Forced ripening

Fruit may require ripening at the packinghouse to satisfy importer requirements. Mangoes are triggered to ripen by Ethylene injected into the atmosphere around the fruit. Temperature then controls the rate of ripening. Conditions for controlled ripening are: ethylene (1 day) shot method with 200 ppm injected twice or by the trickle method with 10 ppm continuously at 18 to 22°C and 85 to 90 percent relative humidity.

Following the ethylene treatment, store the fruit at 18 to 22°C until it is ready for transport to the export dispatch port. Avoid temperatures higher than 25°C. At high temperatures, the flesh will soften but the skin colour will not change completely from green to yellow. Fruit rots are also severe at high temperatures. The temperature regime required to partly ripen the fruit depends on the time lag before transport.

In India, mangoes are picked quite green to avoid bird damage and the dealers layer them with rice straw in ventilated storage rooms over a period of one week. Quality is improved by controlled temperatures between 15° to 21°C. In ripening trials in Puerto Rico, 'Edward' mango was harvested while deep green, dipped in hot water at 51°C to control anthracnose, sorted as to size, then stored for 15 days at 21°C with relative humidity of 85 percent to 90 percent. Those picked when more than 3 in (7.5 cm) in diameter ripened satisfactorily and were of excellent quality. Ethylene treatment causes green mangoes to develop full colour in 7 to 10 days depending on the degree of maturity, whereas untreated fruits require 10 to 15 days. One of the advantages is that there can be fewer pickings and the fruit colour after treatment is more uniform. Ethylene treatment is a common practice in Israel for ripening fruits for the local market. Some growers in Florida depend on ethylene treatment. Generally, 24 hours of exposure is sufficient if the fruits are picked at the proper stage. It has been determined that mangoes have been picked prematurely if they require more than 48 hours of ethylene treatment and are not fit for market.

Recent experiments in Mexico with Manila mangoes were able to reduce in half the ripening time when mature green mangoes were treated with 500 to 750 ppm ethylene. The fruit ripened homogeneously and attained similar compositional parameters than control mangoes at their edible stage.

Some cultivars, especially 'Bangalora', 'Alphonso', and 'Neelum' in India, have much better keeping quality than others. In Bombay, 'Alphonso' has kept well for 4 weeks at 11.1°C 6 to 7 weeks at 7.2°C. Storage at lower temperatures is detrimental inasmuch as mangoes are very susceptible to chilling injury. Any temperature below 13°C is damaging to 'Kent'. In Florida, this is regarded as the optimum for 2 to 3 weeks storage. The best ripening temperatures are 21.1°C to 23.9 °C (Morton, 1987)

Controlled atmospheres treatment

According to Kader (2000), optimum controlled atmospheres (CA) of mangoes (Kader, 2000) consist of 3 to 5 percent O2 and 5 to 8 percent CO2. CA delays ripening and reduces respiration and ethylene production rates. Post harvest life potential at 13 °C is 2 to 4 weeks in air and 3 to 6 weeks in CA, depending on cultivar and maturity stage. Exposure to CA

below 2 percent O2 and/or above 8 percent CO2 may induce skin discoloration, greyish flesh colour, and off-flavour development. (Figure 34 AC chamber1 for mango and Figure 35 AC chamber 2 for mango)

Figure 34. AC chamber 1 for mango.

Figure 34. AC chamber 2 for mango.

Coating films

Wrapping fruits individually in heat-shrinkable plastic film has not retarded decay in storage. The only benefit has been 3 percent less weight loss. Coating with paraffin wax or fungicidal wax and storing at 20 to 32°C delays ripening 1 to 2 weeks and prevents shrivelling but interferes with full colour development. Recently a maltodextrin-based coating was able to retard manila mango ripening for three weeks at ambient temperature and exerted limited fly larvae and anthracnose control (Diaz-Sobac et al., 1997)

Irradiation

Gamma irradiation (30 Krad) causes ripening delay of 7 days in mangoes stored at room temperature. The irradiated fruits ripen normally and show no adverse effect on quality. Irradiation has not yet been approved for this purpose.

Refrigerated storage

Cooling

As soon as is practical after harvest, fruit is to be cooled to 13°C, in 85 to 90 per cent relative humidity. The fruit shall be maintained at this temperature for the period before shipping, including the time spent on the orchard; during transport export fruit should not be stored with other ripe or ripening mangoes.

2.4 Compatibility groups for storage of fruits

The best storage environment for an individual fruit or vegetable depends on its unique requirements for temperature, relative humidity, and ethylene exposure. Most compatibility charts for mixing products during postharvest handling divide fruits and vegetables into eight groups. In practice it is very difficult to separate products into this many groups-very few wholesale or retail handling facilities, if any, have eight temperature-controlled rooms.

We have developed a three-group chart that is easier to use and still provides good product life : (Thompson, Kader and Sylva,1999)

Group 3- Fruits

code thermometer

55-65 ° F, 13-18 °C & 85-95% rh (relative humidity)atemoya rambutan

banana sapodilla
breadfruit sapote
canister soursop
casaba melon cherimoya
crenshaw melon honeydew melon
jaboticaba jackfruit
mamey
mangosteen papaya
Persian melon plantain
- Ethylene level should be kept below 1 ppm in storage area.
· products marked with an asterisk are sensitive to ethylene damage.
*Source : (Thompson, Kader and Sylva,1999)

Bibliography: Thompson J., Kader A and Sylva K.1999. University of California-Division of Agricultural and Natural Resources. Publication 21560

2.5 Transportation System

Marketing and physical distribution of fresh produce inherently means moving the produce. The commodities are handled, either manually or mechanically, many times from harvest and through the distribution process before the consumer buys and prepares them to eat.
For domestic transportation the use of road vehicles offers substantial advantages of convenience, availability, flexibility permitting door-to-door delivery, and reasonable cost of transport. The use of road transportation for fresh produce is increasing and likely to increase in countries all over the world. Produce may be transported by pick-up, enclosed truck, open truck or refrigerated vehicle.(Harris, 1988).
For mangoes, pick-ups and open trucks are the commonest type of road transport.
Perishable products as mangoes are increasingly transported by sea to Asia and Europe from the U.S. and from other suppliers like Mexico and Chile. Trans-ocean transportation costs are still much higher for mangoes. However, new developments in ocean shipping have made it possible to preserve the quality of perishables during transport and still bring down transportation costs. For example, successfully shifting perishable products from air to ocean transport can reduce transportation cost by as much as 75 percent. In addition, satellite technologies, particularly global positioning systems (GPS). Which are becoming increasingly available and less expensive, enable shippers to follow their cargo around the world electronically.
For perishable products, however, the increased speed of handling and reduced transport costs that came with containerization were not enough. Ocean transport of cooled and frozen cargo received a substantial boost with development of mobile refrigerated cargo ships that lack this flexibility. Increasingly efficient and accurate cooling systems have allowed refrigerated carriers to maintain temperatures with great accuracy (plus or minus a quarter degree Celsius) for dome time. More recently, however, controlled atmosphere (CA) technologies added refinements that have extended the shelf life of mangoes. CA technologies allow operators to lower the repiration rate of produce by monitoring oxygen, carbon dioxide ans nitrogen levels within a reefer. In this way, CA can slow ripening, retard discoloration, and maintain freshness of mangoes. Although it is likely that container ships will dominate the perishable trade between North America, East Asia and Europe, conventional refrigerated vessels can serve many smaller ports, especially in the developing world, that are unable to handle large container vessels. Thus, in north-south trade and in

certain niche markets, conventional refrigerated ships may have a brighter future, but even here, competition from container vessels is bound to increase as cost decline (Agricultural Outlook, 1999)

Bibliografía:
-Agricultural Outlook. 1999. Economic Research Service/USDA. January-February.
-Harris S.R. 1988. Production is only half of the battle. A training manual in fresh produce market for the Eastern Caribbean. Food and Agriculture Organization.

2.6 Processing

Essentially a prime table fruit, mango pulp is perfectly suited for conversion to juices, nectars, drinks, jams, fruit cheese or to be had by itself or with cream as a superb dessert. It can also be used in puddings, bakery fillings, and fruit meals for children, flavours for food industry, and also to make the most delicious ice cream and yoghurt. While the raw fruits are utilized for products like chutney, pickle, amchoor (mango powder), green mango beverage, etc. ripe ones are used in making pulp, juice, nectar, squash, leather, slices, etc. Major export products include dried and preserved vegetables, mango and other fruit pulp, jams, fruit jellies, canned fruits and vegetables, dehydrated vegetables, frozen fruits, vegetables and pulp, freeze dried products and traditional Indian products like pickles and chutneys. Processed mangoes enable exporters to serve their markets even during off-season period for fresh mangoes. Ripe mangoes may be frozen whole or peeled, sliced and packed in sugar (1 part sugar to 10 parts mango by weight) and quick-frozen in moisture-proof containers. The diced flesh of ripe mangoes, bathed in sweetened or unsweetened lime juice, to prevent discoloration, can be quick-frozen, as can sweetened ripe or green mango puree. Immature mangoes are often blown down by spring winds. Half-ripe or green mangoes are peeled and sliced as filling for pie, used for jelly, or made into sauce, which, with added milk and egg whites, can be converted into mango sherbet. Green mangoes are peeled, sliced, parboiled, then combined with sugar, salt, various spices and cooked, sometimes with raisins or other fruits, to make chutney; or they may be salted, sun-dried and kept for use in chutney and pickles. Thin slices, seasoned with turmeric, are dried, and sometimes powdered, and used to impart an acid flavour to chutneys, vegetables and soup. Green or ripe mangoes may be used to make relish (Morton, 1987).

Industrial Processing Possibilities

Several options have become available for large scale processing of mango products.

1. Mango pulp
2. Juice (See Figure 36 Mango Juice)
3. Nectar
4. Fruit sauces
5. Fruit cocktails
6. Dried mango slices
7. Mango wine
8. Glazings
9. Flavoured yoghurt (See Figure 37 Mango yoghurt)
10. Ice cream

Figure 36. Mango Juice.

Figure 37. Mango yoghurt.

Pulping and juicing

A key step for preparation of the above products is pulping, as described below. Flowcharts are included which depict the manufacturing steps for mango products.

1. Fruit selection. Several requirements need to be met:

Lack of insect infestation
Lack of mechanical injuries
Stage of maturity
Uniform colour and texture
Minimum soluble solids of 13 ° Brix
pH value of 3.5 to 4.0

The receiving area must be clean, well ventilated, and free of insects, rodents or other animals. It is not advisable to hold the fruits too long before processing to avoid spoilage.

2. Washing

The washing pit should be filled with water containing 15 ppm chlorine in order to reduce microbial load and impurities from the fruit. A second washing with clean water is made to eliminate residual chlorine.

3. Blanching

This operation is done to inactivate enzymes, eliminate air inside the fruit tissues, remove off-flavours and aromas, fix fruit colour and soften the tissues for further pulping.

Two methods are currently used to effect blanching: dip in boiling water or direct steam injection. The thermal treatment is applied such that internal fruit temperature reaches 75°C. This usually requires 10 minutes in boiling water, or 6 minutes with steam. Fruit is blanched unpeeled.

4. Peeling and cutting

Pulp is separated from the seed manually with knives made of stainless steel, on a working bench. Mango pieces are placed in clean plastic containers and taken to the pulping machine.

5. Pulping

Mesocarp pieces are passed through a fine mesh to remove undesirable particles. After pulping, a smooth puree is obtained. Recommended mesh size is 0.5 mm. coarser material is separated in the process and disposed properly. The pulp is transferred in containers to the kettle.

6. Thermal treatment

A heat treatment is applied in the kettle to prevent chemical and microbial spoilage. In this treatment the pulp reaches 95 ° C and is held for 10 min. with continuous stirring.

7. Additives

The use of additives is recommended to extend the pulp shelf life. Commonly used additives include 0.39 percent citric acid to decrease pH and prevent microbial growth and enhance effectiveness of preservatives as sodium benzoate (0.5 percent).

To prevent discoloration 0.1 percent ascorbic acid is used as antioxidant. Additives are incorporated to the pulp right before the thermal treatment is finished (ca. 5 min before) by dispersing in hot water or pulp and proper stirring. Final product should have 13 °Brix and pH values between 3.4 to 3.5.

8. Packing

The pulp is packed when hot in plastic containers, sealed immediately and flipped over so the internal part of the lid gets in contact with the hot product. All packing materials must be clean before used.

9. Cooling

Hot containers are cooled with fresh water at the lowest temperature attainable. After cooling, lid closings should be inspected. Finally, containers are cleaned and labels affixed to be sent to a fresh, clean storage place.

Specification of Alphonso Mango Pulp

Physical, Chemical and Organoleptic Characteristics.		
T.S.S. (° Brix)		Min 16
Acidity (% as citric acid)		Min 0.5
pH		< 4.00
° Brix /Acid Ratio		32
Ascorbic Acid (ppm)		Min 200
Additives		Nil
Pesticide residue		Absent
Colour		Golden yellow
Flavour		Characteristic
Taste		Characteristic
Microbial Characteristics		
T.P.C.	CFU/g	< 50
Yeast	CFU/g	< 50
Mould	CFU/g	< 10
Source: Agafruits (2000)		
Average composition of pulp (100/g)		
Edible Portion	(%)	74.00
Moisture	(g)	81 .00
Protein	(g)	0.60
Fat	(g)	0.60
Minerals	(g)	0.40
Fibre	(g)	0.30
Carbohydrates	(g)	16.90
Energy	(Kcal)	74.00
Calcium	(mg)	16.00
Phosphorus	(mg)	18.00
Iron	(mg)	1 .60

Vitamin C	(mg)	20.00
Vitamin B complex	(mg)	1.07
Vitamin A	(mg)	2 743

Source: Agafruits (2000)

Drying

Dryers around the world are using improved methods to make all sorts of new dried fruit products. Many of these make great natural snacks. Mango is delicious as a snack, in a sauce or in a salad. Snacks are packed in transparent plastic bags. (See Figure 38 Tommy Atkins mango stripes) mangoes are dried in the form of pieces, powders, and flakes. Drying procedures such as sun drying, tray drying (See Figure 39 Tray dryer) tunnel dehydration, vacuum drying, osmotic dehydration may be used. Packaged and stored properly, dried mango products are stable and nutritious.

Figure 38. Tommy Atkins mango strips.

One described process involves as pretreatment dipping mango slices for 18 hr (ratio 1:1) in a solution containing 40°Brix sugar, 3 000 ppm SO2, 0.2 percent ascorbic acid and 1 percent citric acid; this method is described as producing the best dehydrated product. Drying is described using an electric cabinet through flow dryer operated at 60°C. The product showed no browning after 1 year of storage.

Figure 39. Tray dryer.

Drum drying (See Figure 40 Drum dryer) of mango purée is described as an efficient, economical process for producing dried mango powder and flakes. Its major drawback is that the severity of heat pre-processing can produce undesirable cooked flavours and aromas in the dried product. The drum-dried products are also extremely hygroscopic and the use of in-package desiccant is recommended during storage. The stone removed, the fruit is cut in slices, dried and afterwards ground to a pale grey powder. This powder is used frequently instead of tamarind, the other important sour element in Indian cuisine; mango powder is, however, much weaker than tamarind and has a subtle, resin-like taste. It is mainly used when only a hint of tartness is desired or when the dark brown colour of tamarind is to be avoided. Mango powder is generally more popular with vegetables than with meat, but is frequently found in tikka spice mixtures for barbecued meat. To prepare the barbecued meat of Northern Indian cuisine, an Indian clay oven (tandoor) is required, but substitution by a Western baking oven is acceptable. Meat to be grilled is seasoned with a mixture of several spices (cumin, coriander, fresh ginger, garlic and mango powder, but little or no chiles) with red food colouring and plain yoghurt. After a few hours, it is quickly roasted in the very hot tandoor. Mango powder here serves not only as a tart and sour spice, but also as a meat tenderizer.

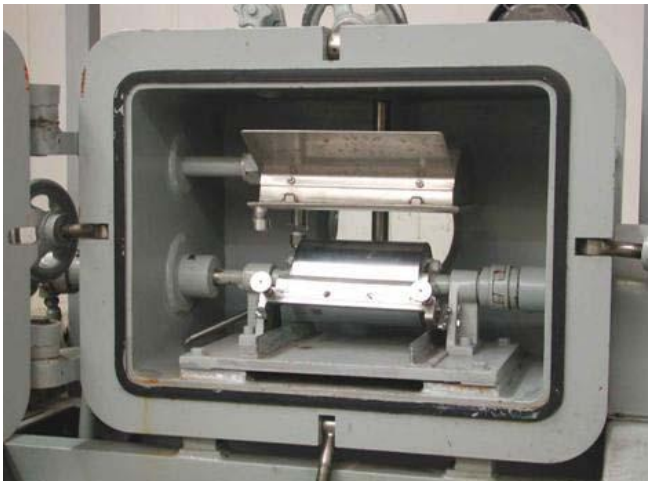
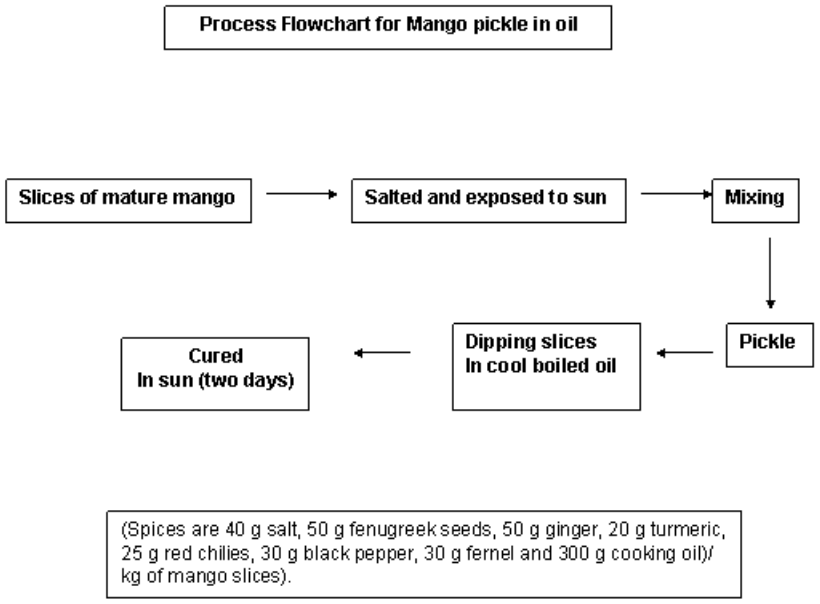


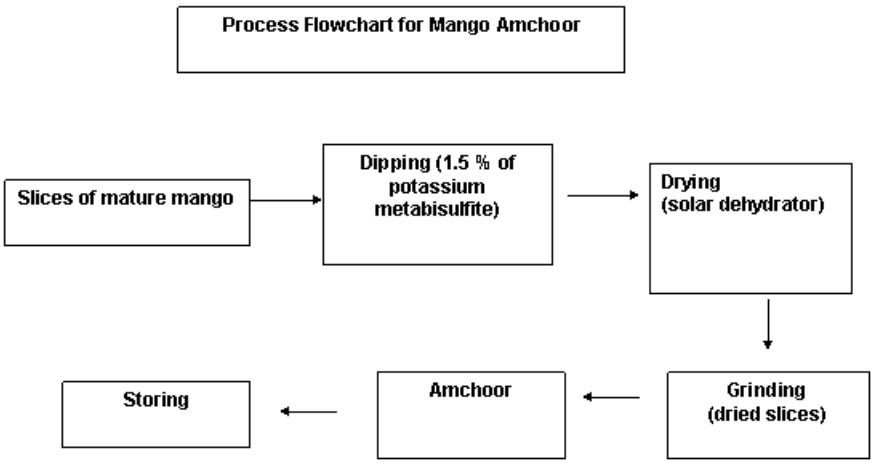
Figure 40. Drum dryer.

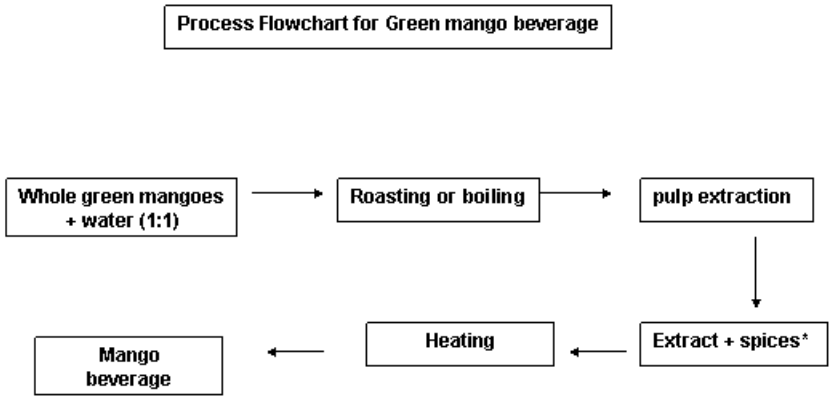
Ripe mangoes are a popular fruit and may be used for stewed fruits, fruit jam, fruitcakes and many other standard fruit applications; they can, however, even used for savoury dishes. Indonesian fruit salad (rujak) combines fresh fruits (not too ripe mango, pineapple, papaya, in Java frequently cucumber) with a pungent sauce of palm sugar (won from coconut or other palm trees), fresh red chiles and salt; on Bali, a hint of shrimp paste is never omitted. The result tastes even more delicious that the recipe looks strange! Mexicans sometimes use ripe mangoes or other tropical fruits for their fiery salsas (Katzer, 2000).
Mango fruits have been utilized for long time at every stage of growth. While the raw fruits are utilized for products like pickle, amchoor, green mango beverage, etc. ripe ones are used in making pulp, juice, nectar, squash, leather, slices, etc.

Raw mango products

Mango fruits during early stages of growth are commonly used for sweet or sour chutney. As the fruits attain stone hardening stage, they become suitable for some other useful products like amchoor (seasoning made by pulverizing sun-dried, unripe (green) mango into a fine powder. Amchoor has a tart, acidic, fruity flavour that adds character to many dishes including meats, vegetables and curried preparations. It's also used to tenderize poultry, meat and fish), pickle, etc.



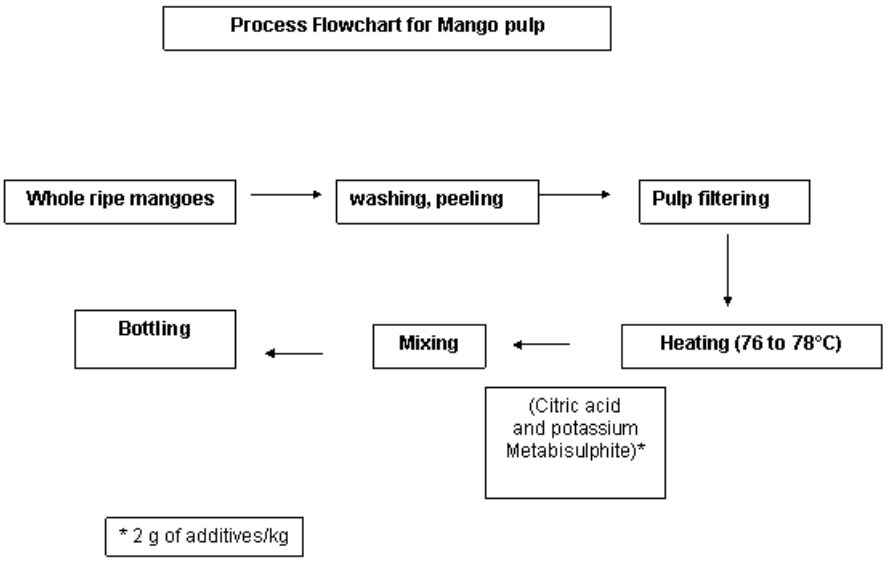


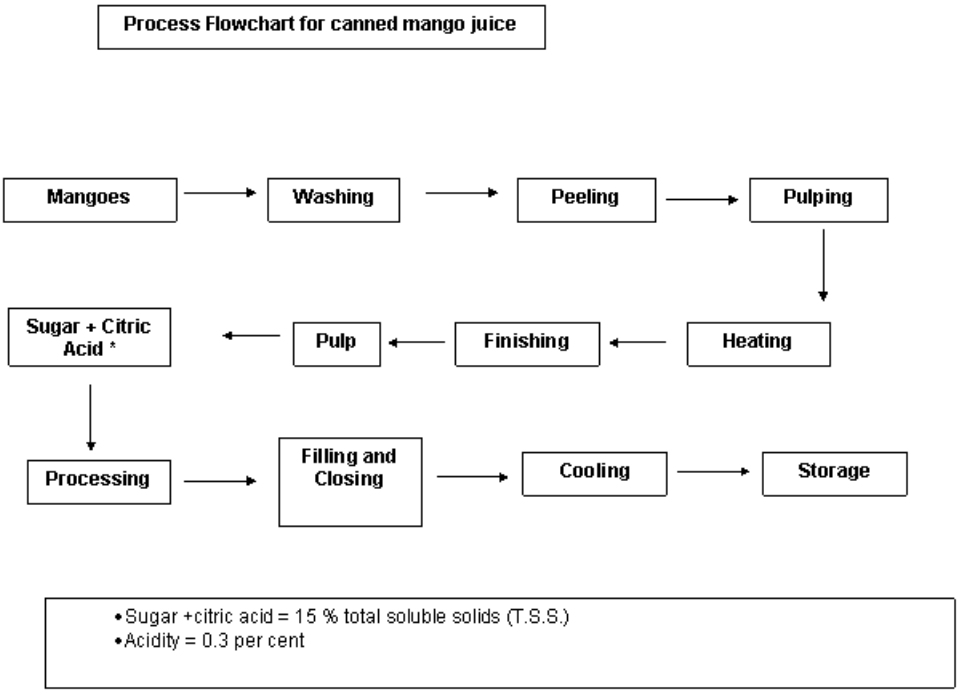


* To one kilogram of extract, 1.6 kg sugar, 1.6 litre water, 80 g salt, 20 g mint, 10 g cumin, 4 g black pepper and 20 g citric acid are mixed

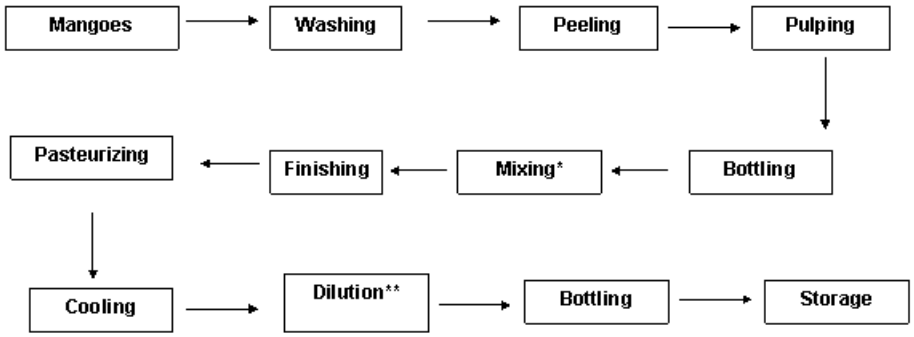
Ripe mango products

Ripe mango fruit has a characteristic blend of taste and flavour. It contains important amounts of sugar, pectin, carotenoids, etc. Due to comparatively shorter storage life of mango fruits, it is essential to prepare their products immediately.



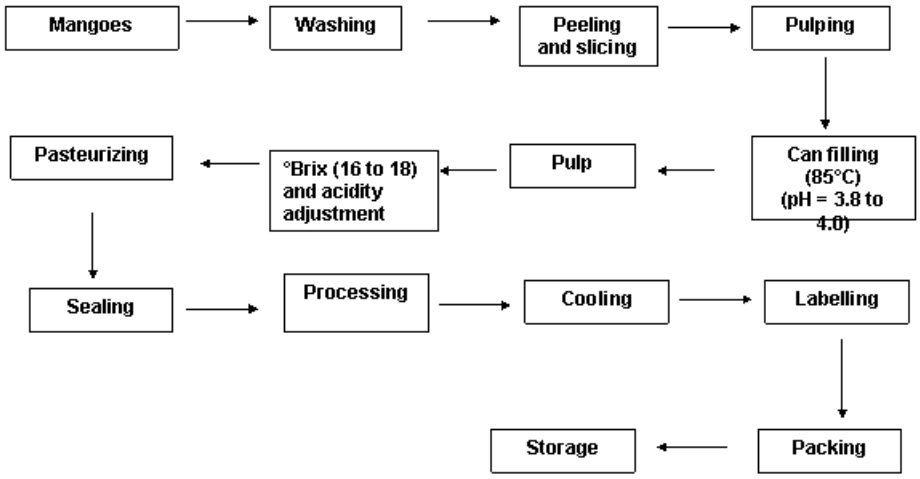


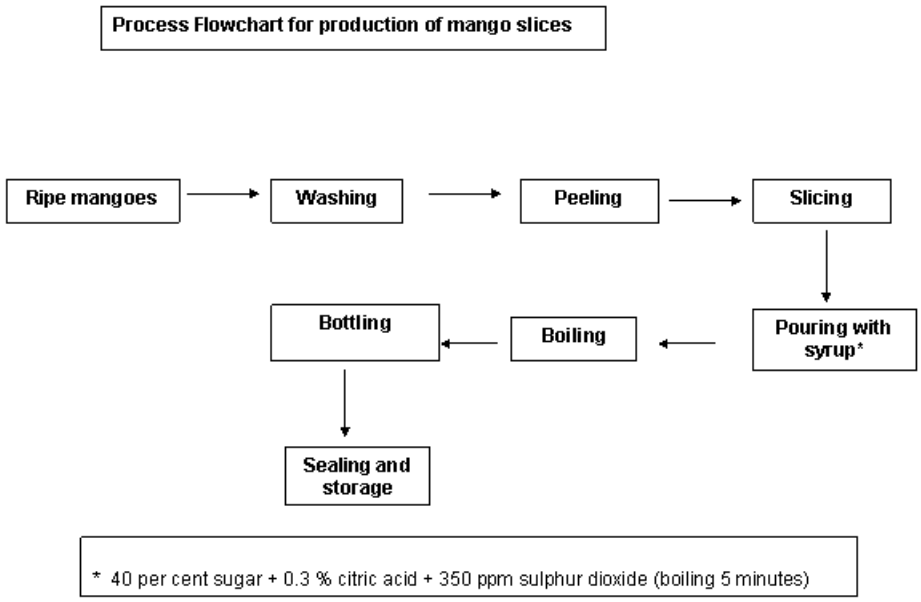
Process Flowchart for bottled Mango squash



- *1 kg of pulp + 1 kg sugar (in 750 ml water)
- ** three parts of water + one part of squash

Process Flowchart for canned mango pulp





Mango Leather or Aam Papad: Homogenized mango pulp is prepared and potassium metabisulphite is added to it at a rate of 2 g/kg of pulp. The pulp is then spread on trays smeared without and kept for drying in solar dehydrator or sun. After drying of one layer, another layer is spread over it and dried. The process is repeated until the desired thickness is attained. Finally the leather slabs are cut into pieces and wrapped in butter paper or plastic sheets.

Fresh-cut Mangoes

Mangoes could be an attractive addition to the growing market for fresh-cut produce, but browning and drying have prevented such marketing. Researchers at the USDA-ARS Horticultural Crops Quality Laboratory found that fresh-cut mangoes could be preserved by treating the slices with a combination of hexylresorcinol, isoascorbic acid and potassium sorbate (all food-safe compounds derived from natural products) and storing the slices in plastic containers to prevent drying. Treating whole fruits with methyl jasmonate (an inexpensive product derived from plant essential oils) prevented the development of chilling injury during cold storage and hence markedly increased fruit quality after storage. The treatment worked on fruits at various stages of maturity and had no effect on ripening, softening processes or water loss.

Canning

Canned mangoes do not have to meet any specific standards, but CODEX Alimentarius (Latin, meaning Food Law or Code, UN Commission for Food Standards) is developing international standards. In general, mangoes are processed in cans or in glass jars. FDA requires nutritional facts written on containers. Mangoes are the common product name of the

canned food that is made from properly prepared fresh mango varieties, that have the peel (rind), stems and pits (stones) removed; shall be packed in a packing medium consisting of water, with or without a sweetening ingredient, or natural reconstituted, concentrated fruit juice or juices, or fruit puree or nectar, with or without a sweetening ingredient; and may contain: pectin, a suitable acid ingredient, calcium-based firming agents, and beta-carotene. Styles. The styles of mangoes are: halves, if the mango is cut into two approximately equal parts along the pit or stone from stem to apex; slices, if the mango is cut into long, slender pieces either lengthwise or crosswise; diced, if the mango is cut into approximately cube-shaped pieces with at least 12 millimetres on the longest side; and pieces, mixed pieces or irregular pieces, if the mango is cut into pieces of irregular shape and size.
Quality Standards: have a colour that is typical of the variety; have a characteristic flavour and aroma of properly prepared, properly processed canned mangoes; in the case of "slices" style, these shall be reasonably uniform in size, and in the case of "halves" style, have at least 90 per cent by count of the units approximately the same size; in the case of "halves" and "slices" styles, shall not have more than 20 per cent of the units cut other than parallel to the crease, and not have more than half of those units cut horizontally; have units that are reasonably fleshy with little objectionable fibre, and not excessively soft or excessively firm, and in a 500 g sample of the drained product, not contain more than: six square centimetres in the aggregate of rind, one-eighth of a stone equivalent of pit material, and one piece of harmless extraneous plant material not greater than 10 millimetres in any dimension; and not have more than 30 per cent by count of units that: are blemished by discolouration or dark spots on the surface or that penetrate into the flesh, or in the case of "halves" and "slices" styles, have trim damage with gouges in the units serious enough to detract from the appearance of the product, and five per cent by drained weight of units that are crushed and severed into two or more parts or have lost their normal shape. Mangoes, when properly packed, shall have a minimum drained weight that is not less than 55 per cent of the weight of distilled water at 20°C that the sealed container will hold when full. Varieties most suited for canning include Creole, Mora, Filipino, Irwin and Haden.

3. Pest species and pest control and decay

3. 1 Pest species

Fungi, bacteria and insect larvae can infect mango tree and fruits either directly or indirectly. The latter is related to phytosanitary problems of the crop.
More than 492 species of insects, 17 species of mites and 26 species of nematodes have been reported to be infesting mango trees, about 45 per cent of which have been reported from India. Almost a dozen of them have been found damaging the crop to a considerable extent causing severe losses and, therefore, may be termed as major pests of mango. These are hopper, mealy bug, inflorescence midge, fruit fly, scale insect, shoot borer, leaf webber and stone weevil. Of these, insects infesting the crop during flowering and fruiting periods cause more severe damage. The insects other than those indicated above are considered as less injurious to mango crop and are placed in the category of minor pests (Rajans, 2000)

3.2 Relative status of major pest species

Indirect Pests of Mango

1. White wax scale (Cascardia destructor), is a pest of subtropical and temperate climates with relatively high humidity in summer. High temperatures kill it in summer. It thrives best on vigorous trees, where it produces the largest individuals and, subsequently, the greatest

numbers of eggs. The adult female is enveloped in soft white wax, and may be about 10 mm. long and 7 mm high, although many are only half that size. The chemical composition of the wax has been examined by Hackman (1951). The body of the insect beneath the wax is light red to dark brown, plump and soft. Its hind end narrows into the caudal process that lies flat on the leaf or twig. The Indian white wax scale, Ceroplastes cerifrus, has an elevated caudal process, and the insect's wax covering has a short down-turned horn at one end. Direct injury from the feeding seems negligible, but both larvae and adults produce honeydew, which cause problem of black sooty mould fungi on leaves and fruits. The sooty mould can retard colour development of the new fruit and interfere with photosynthesis. However, no measurable effects have been observed.

2. Mango hopper (Idoscopus niveosparsus, Leth.). This hopper species was first recorded from Saharanpur (Uttar Pradesh, India). Subsequently it has been reported from the Philippines, Thailand, Vietnam, Indonesia, Sri Lanka, Burma, Bangladesh, and Pakistan. In India, I. niveosparsus is more destructive in the Southern peninsula than in the Northeastern states. Profuse egg laying within the stallets and florets causes physical injury, resulting in withering of affected parts. In addition nymphs and adults suck the cell sap of inflorescence during spring and of leaves during summer. The removal of inflorescence sap adversely affects fruit setting while on leaves, growth is stunted. The hoppers also exude 'honeydew' which encourages the development of the fungi Capnodium mangiferum and Meliola mangiferae, which produce black sooty mould on the dorsal leaf surfaces and branches (Figure 41 Black sooty mould). This interferes with the photosynthetic activity of the plant, ultimately resulting in failure of the flowers to set and dropping of immature fruits. A severe attack may result in total loss of the crop.

Figure 41. Black sooty mould.

3. Citrus black fly (Aleurocanthus woglumi, Ashby). Native from Southeast Asia, it has spread throughout practically all the tropical and parts of the subtropical citrus areas. It is found in Pakistan, Malaysia, Indonesia, Philippines, Thailand, Taiwan, China, Korea, and

Africa. It is also found in the United States (Texas and Florida), Mexico, Central America, and South America. Nymphs produce copious honeydew, which encourages sooty moulds on upper surfaces of leaves, followed by gradual weakening of the tree. The 'soot' stains the fruit. Heavy black colonies of the pest occur on the underside of leaves.
4. Bark eating caterpillar (Indarbela quadrinotata, Wlk.). Host plants: Mango, citrus, guava, jamun (Syzygium cuminii), loquat, mulberry, pomegranate, a number of forest and ornamental trees, ber (Ziziphus jujuba), drum stick (Moringa oleifera), litchi (Litchi chinensis), rose, etc. Thick, ribbon like, fine silken webs consisting of wooden particles and excreta are seen hanging on bark and main stems, especially near forks. Below these webs zigzag galleries occur made by the freshly hatched caterpillars and the holes where the caterpillars have bored in. As many as 15 to 16 holes may be seen on one tree and one caterpillar or pupa occupies each hole. A severe infestation may result in death of the stem but not of the main trunk though there may be interference with translocation of cell sap resulting in arresting of the growth of the tree and its fruiting capacity being adversely affected.
5. Florida red scale (Chrysomphalus ficus, Ashm.). Florida red scale was introduced into Florida from Cuba in 1874. It is distributed mainly along the Atlantic coast in Mexico, Central America, and South America. But, in California, it's only a pest in greenhouses. It is also found in Europe and along the Mediterranean. This scale insect was a very serious pest of citrus in Florida and Israel. At one time, heavy populations of this scale caused severe defoliation with resulting loss of crops and subsequent yields. Florida red scale generally causes yellow chlorotic spots when feeding on leaves. When citrus fruits are attacked, yellow spots appear at the feeding sites and the presence of scales on the citrus fruit presents a very unattractive appearance. (Teparkum, 1988).

Direct pests of mango

1. Oriental fruit fly (Dacus dorsalis Hend)
It has a wide host range, mostly fleshy fruits (Figure 42 Manila mango worm). In Hawaii, it has been reared from more than 125 different kinds of fruits. Preferred hosts in Hawaii are guava, mango, citrus, banana, papaya, avocado, peach, coffee, and passion fruit. Females puncture the skin of fruits with their ovipositor and lay a batch of eggs about 6.0 mm below the surface. Malformation of developing fruits may occur or they may drop prematurely. Sap may ooze from the puncture and attract other insects to feed or oviposit in the wound. Also, various decay organisms may enter and cause discolouration and deterioration of the fruits. After hatching the maggots feed on the fleshy parts and with associated microorganisms cause breakdown of the parts of the fruit affected.

Figure 42. Manila mango worm.

2. Mexican fruit fly (Anastrepha ludens, L.W.). Host plants: A. ludens affects the fruit of Citrus species. Grapefruit is preferred, while lemon and bitter orange are not attacked. The highly polyphagous pest also develops in the fruit of mango, guava, pomegranate, avocado, fig, annona, Spondias sp., peach, pear, apple, quince, Eugenia sp., and of other wild and cultivated plants. The damage done by the fruit-inhabiting larvae is like that caused by Ceratitis and Dacus spp. Necrotic lesions form on the peel in places of oviposition, and are often surrounded by a clear zone. Feeding activity destroys the fruit flesh, which is further rotted by bacteria introduced by the female fly on oviposition, leading to premature fruit drop (Teparkum, 1988).
In Mexico (Cotaxtla Experiment Station in Veracruz) researchers have worked to protect the fruits by enclosing the bundle of mangoes with a paper bag until they reach physiological maturity. Paper bags protect the fruits against insects primarily fruit fly (Figure 43 Paper bags for Manila panicles). Results from these experiments had demonstrated that the bags increased the quality of the fruits and minimized fruit fly infestation

Figure 43. Paper bags for Manila panicles.

3.3 Pest control and diseases

Mango suffers from several diseases at all stages of its life. All the parts of the plant, namely, trunk, branch, twig, leaf, petiole, flower and fruit are attacked by a number of pathogens including fungi, bacteria and algae. They cause several kinds of rot, die back, anthracnose, scab, necrosis, blotch, spots, mildew, etc. Some of these diseases like powdery mildew are of great economic importance as they cause heavy losses in mango production. Major diseases of mango and their control measures are discussed below.

a) Powdery mildew (Oidium mangiferae Berthet) is one of the most serious diseases of mango affecting almost all the varieties, it occurs up to latitude of 40° North and South of the equator. It may persist for longer period at an elevation of 600 to 1 200 metres, in many African countries, south of the Sahara, the middle East, Southern Asia and America: from the Southern United States to Peru and Brazil. Sometimes, as high as 70 to 80 percent crop loss has been recorded on individual plant basis. The characteristic symptom of the disease is the white superficial powdery fungal growth on leaves, stalks of panicles, flowers and young fruits. The affected flowers and fruits drop prematurely reducing the crop load considerably or might even prevent the fruit set. Rains or mists accompanied by cooler nights during flowering are congenial for the disease spread. The fungus acts as a parasite on young tissues of all parts of the inflorescence, leaves and fruits.
b) Anthracnose (Colletotrichum state of Glomerella cingulata Ston, Spaull and Schrenk) is of widespread occurrence. The disease causes serious losses to young shoots, flowers (See Figure 44 Anthracnosis in Manila panicles) and fruits under favourable climatic conditions of high humidity, frequent rains and a temperature of 24 to 32°C. It is also affects fruits during storage.

Figure 44. Anthracnosis in Manila panicles.

The disease produces leaf spot (See Figure 45 Manila mango leaf spot 1 and Figure 46 Manila mango leaf spot2), blossom blight, withertip, twig blight and fruit rot symptoms. Tender shoots and foliage are easily affected which ultimately cause 'die back' of young branches. Older twigs may also be infected through wounds, which in severe cases may be fatal. Depending on the prevailing weather conditions blossom blight may vary in severity

from slight to a heavy infection of the panicles. Black spots develop on panicles as well as on fruits.

Figure 45. Manila mango leaf spot 1.

Figure 46. Manila mango leaf spot 2.

Severe infection destroys the entire inflorescence resulting in no setting of fruits. Young infected fruits develop black spots and develop a disease called "roña" which is produced by Elsinoe mangiferae (See Figure 47 Manila mango "roña"), shrivel and drop off. Fruits infected at mature stage carry the fungus and cause considerable loss during storage, transit and marketing. The fungus perpetuates on twigs and leaves of mango or other hosts. Since the fungus has long saprophytic survival ability on dead twigs, the diseased twigs should be pruned and burnt along with fallen leaves for reducing the inoculum potential.

Figure 47. Manila mango "roña".

c) Die back (Botryodiplodia theobromae Pat.) is one of the serious diseases of mango. The disease on the tree may be noticed at any time of the year but it is most conspicuous during Oct.-Nov. The disease is characterized by drying of twigs and branches followed by complete defoliation, which gives the tree an appearance of scorching by fire. The onset of die back becomes evident by discolouration and darkening of the bark. The dark area advances and young green twigs start withering first at the base and then extending outwards along the veins of leaf edges. The affected leaf turns brown and its margins roll upwards. At this stage, the twig or branch dies, shrivels and falls. This may be accompanied by exudation of gum. In old branches, brown streaking of vascular tissue is seen on splitting it longitudinally. The areas of cambium and phloem show brown discolouration and yellow gum like substance is found in some of the cells.

Phoma blight (Phoma glomerata) a new disease of mango, was first reported at Central Mango Research Station, Lucknow. The disease was later detected in the mango-growing belt around Lucknow region. It is gaining economic importance. The symptoms of the disease are noticeable only on old leaves. Initially, the lesions are angular, minute, irregular, yellow to light brown, scattered over leaf lamina. As the lesions enlarge, their colour changes from brown to cinnamon and they become almost irregular. Fully developed spots are characterized by dark margins and dull grey necrotic centres. In case of severe infection such spots coalesce forming patches measuring 3.5 to 13 cm in size, resulting in complete withering and defoliation of infected leaves. The disease could be kept under control by spray of copper oxychloride (0.3 percent) just after the appearance of the disease and subsequent sprays at 20 day intervals.

e) Bacterial canker (Xanthomonas campestris pv. Mangiferae indicae) disease of mango, caused by a bacterium. Besides being pathogenic on several varieties of mango, the organism is capable of infecting wild mango, cashew nut and weeds as well. The disease causes fruit drop (10 to 70 percent, yield loss (10 to 85 percent) and storage rot (5 to 100 percent). Many commercial cultivars of mango including Langra, Dashehari, Amrapali, Mallika, and Totapuri are susceptible to this disease.

The disease is found on leaves, petioles, twigs, branches and fruits, initially producing water-soaked lesions and later turning into typical cankers. The disease first appears as minute water-soaked irregular lesions on any part of leaf or leaf lamina. The lesions are light yellow in colour but with age, enlarge and turn dark brown to black. They become angular, cankerous and raised, and are surrounded by chlorotic halos. Several lesions coalesce to form irregular necrotic cankerous patches. In severe infections the leaves turn yellow and drop off. Cankerous lesions appear on petioles, twigs and young fruits. The water soaked lesions also develop on fruits which later turn dark brown to black. They often burst open, releasing highly contagious gummy ooze contain bacterial cells. The fresh lesions on branches and twigs are water soaked, which later become raised, and dark brown in colour with longitudinal cracks but without any ooze.

f) Red rust (Cephaleuros virescens Kunze), caused by an algae, has been observed in mango growing areas. The algal attack causes reduction in photosynthetic activity and defoliation of leaves thereby lowering vitality of the host plant. The disease can easily be recognized by the rusty red spots mainly on leaves and sometimes on petioles and bark of young twigs and is epiphytic in nature. The spots are greenish grey in colour and velvety in texture. Later, they turn reddish brown. The circular and slightly elevated spots sometimes coalesce to form larger and irregular spots.

The disease is more common in closely planted orchards. Fruiting bodies of the alga are formed in humid atmosphere. The zoospores formed by the sporangia initiate fresh infections. Stem entry is achieved by way of cracks. The affected areas crack and scale off. In severe

infection the bark becomes thickened, twigs get enlarged but remain stunted and the foliage becomes sparse and finally dries up.
g) Sooty mould (Meliola mangiferae) is common in the orchards where mealy bug, scale insect and hopper are not controlled efficiently. The disease in the field is recognized by the presence of a black velvety coating, i.e., sooty mould on the leaf surface. In severe cases the trees turn completely black due to the presence of mould over the entire surface of twigs and leaves. The severity of infection depends on the honeydew secretion by the above said insects. Honey dew secretions from insects stick to the leaf surface and provide necessary medium for fungal growth. The fungus is essentially saprophytic and is non-pathogenic because it does not derive nutrients from the host tissues. Although the fungus causes no direct damage, the photosynthetic activity of the leaf is adversely affected due to blockage of stomata.

Pest Control

Pesticides. Including insecticides, fungicides, and nematicides, are applied primarily to protect the crop and should therefore improve its quality potential. Their effect is also to reduce insect and fungal damage, which detracts from the appearance of the crop and increases storage losses. In some cases, for example the development of 'Anthracnose' spotting in mango, it is necessary to spray with fungicide during growth even though the disease itself may not be seen until after harvest. By removing weed competition, which may impose water stress and mineral stress, herbicides can also have beneficial effects on post harvest behaviour. Since all crop protection chemicals are toxic to animals and humans, they must be applied in concentrations, which will not allow toxic residues to build-up. A safe period specified by the manufacturers must be left between final application and harvest. Produce exported to developed countries is rejected if tests reveal pesticide residues above the permitted level.
Disorders

a) Mango malformation is widely prevalent in Asian cultivars, where more than 50 per cent of the trees suffer from this malady. The malformed panicles remain unproductive and are characterized by a compact mass of male flowers, greenish in colour and stunted in growth. The main and secondary rachis are thick and short and bear flowers with relatively larger bracts, sepals and petals as compared to normal flowers. The malformed panicles remain intact on the trees for a considerable period. Though research efforts hitherto have not been able to ascertain its etiology, the complexity of the disorder is attributed to cultural practices, nutritional, and to many other factors like mites, fungal and viral infestations and hormonal imbalance. The exact cause and control of the malady is yet to be established. However, some remedial measures are recommended as follows: Pruning of shoots bearing malformed panicles and deblossoming of early emerged/infested panicles.
b) Biennial bearing: The term biennial, alternate or irregular bearing generally signifies the tendency of mango trees to bear a heavy crop in one year (On year) and very little or no crop in the succeeding year (Off year). Most of the commercial varieties are biennial bearers. When a tree produces heavy crop in one season, it gets exhausted nutritionally and is unable to put forth new flush thereby failing to yield in the following season. The problem has been attributed to the causes like genetic, physiological, environmental and nutritional factors. For overcoming biennial bearing, deblossoming is recommended to reduce the crop load in the 'On' year such that it is balanced in the 'Off' year. Proper maintenance of orchard by way of effectively controlling pests and diseases and regular cultural operations may also result in better performance of the tree every year.
c) Fruit drop: Despite high fruit set initially, the ultimate retention is quite low in mango.

The fruit drop is more or less a continuous process and can be classified into three groups: (i) Pinhead drop, (ii) Post-setting drop and (iii) May-month drop. The fruit drop in first two groups are insignificant compared to the third group which affects the final yield significantly and needs more attention. Embryo abortion, climatic factors, disturbed water relation, lack of nutrition, disease, pest and hormonal imbalances are the major factors that lead to fruit drop.
d) Black tip: The affected fruits become unmarketable and reduce the yield to a considerable extent. The damage to the fruit gets initiated right at marble stage with a characteristic yellowing of tissues at distal end. Gradually, the colour intensifies into brown and finally black. At this stage, further growth and development of the fruit is retarded and black ring at the tip extends towards the upper part of the fruit. Black tip disorder has generally been detected in orchards located in the vicinity of brick kilns. It has been reported that gases like carbon monoxide, sulphur dioxide and ethylene constituting the fumes of brick kiln are known to damage growing tip of fruits and give rise to the symptoms of black tip. Apart from these factors, irrigation, condition of the tree and management practices also play important role in deciding the severity of the disorder. Planting of mango orchards in North-South direction and 5 to 6 km away from the brick kilns may reduce incidence of black tip to a greater extent. The incidence of black tip can also be minimized by the spray of borax (1 percent) or other alkaline solutions like caustic (0.8 percent) or washing (0.5 percent) soda. The first spray of borax should be done positively at pea stage followed by two more sprays at 15 days interval.
e) Clustering disorder in mango is characterized by the development of fruitlets in clusters at the tip of the panicles. Such fruits do not grow beyond pea or marble stage and drop down after a month or so of fruit set. These fruits do not contain seeds when they are cut open. The disorder seems to be due to lack of pollination/fertilization, which may be attributed to many reasons. Among them, absence of sufficient population of pollinators in the orchards is the major reason (Rajans, 2000).

4. Economic and Social Considerations

4.1 Gender aspects

Role of men and women in post harvest operations
Product destination defines how the tasks are assigned. Among mango exporters such tasks include pickers, carriers, graders, task lifter operators, labellers, conveyor coordinators and selection and packing lines coordinators, among others. Operation for domestic consumption does not demand careful selection; labour is mostly based on picking and packing. However, production for export requires more labour.
Mango packing needs activities that can be done by either men or women. Typically, a community producing mangoes for export opens a 4-week long job market that may incorporate the whole local population and preferably young men and women. Since mango fields and packing facilities are commonly located in rural areas, people from surrounding communities are employed. Young people but no children are allowed in picking because these workers usually carry crates with 50 kg fruit. The same applies to the packinghouse and hence no under age labour is used in these processes. Even though the job demands personnel of both genders, a recent survey in Mexico reported 63 percent males and 37 percent females of which men are more frequently employed for harvesting and women for packing. In the later case the typical age ranges from 15 to 19 years old. This personnel work on a temporary basis and only to supplement the household income. From all female workers, 82.3 percent were 15 to 39 years old and no elderly workers were noted. This was attributed to an over supply of young single women workers (73 percent of the work force). Similarly, 57.6 percent of the workingmen were single, but again, no elderly workers were hired. In the

male-dominated harvest operation, illiteracy was greater (19.6 percent) than for the female-predominant packing operation (6 percent) (Barron et al, 1999).

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