



Mangifera indica (mango)

Anacardiaceae (cashew family)

kangit (Chuuk, Pohnpei), *idele* (Palau), *mago* (Niue, Samoa, Tuvalu), *manako* (Hawai'i), *manggo*, *am* (Fiji), *mangko* (Kiribati), *mango* (English), *mango* (Tonga), *mangot*, *mangue*, *manguier* (French), *mangueira* (Yap)

Ian S. E. Bally



PHOTO: I. S. E. BALLY

Mango tree with heavy crop.

IN BRIEF

Distribution All tropical and subtropical regions.

Size Reaches heights of 15–30 m (50–100 ft); cultivated trees are usually 3–10 m (10–33 ft) high when mature.

Habitat Grows from sea level to 1200 m (3950 ft) in tropical latitudes; however, most commercial varieties are grown below 600 m (1950 ft); rainfall 400–3600 mm (16–140 in), fruits best with a well defined winter dry period.

Vegetation Grows with a wide range of cultivated species.

Soils Tolerates a range of soils; optimal pH 5.5–7.5.

Growth rate Fast, >1.5 m/yr (5 ft/yr) in ideal conditions.

Main agroforestry uses Homegardens, silvopasture.

Main uses Fruit, flavoring, medicinal, timber.

Yields Typically, yields are often less than 5 mt/ha (2.2 t/ac) but can reach 20–30 mt/ha (9–13.5 t/ac); single trees can produce 200–300 kg (440–660 lb) of fruit in heavy cropping years and as low as 5 kg (11 lb) in bad years.

Intercropping Compatible with other similarly vigorous species, as well as animal grazing.

Invasive potential Not an aggressively invasive species.

INTRODUCTION

Mangos belong to the genus *Mangifera* of the family Anacardiaceae. The genus *Mangifera* contains several species that bear edible fruit. Most of the fruit trees that are commonly known as mangos belong to the species *Mangifera indica*. The other edible *Mangifera* species generally have lower quality fruit and are commonly referred to as wild mangos.

Mango has become naturalized and adapted throughout the tropics and subtropics. Much of the spread and naturalization has occurred in conjunction with the spread of human populations, and as such, the mango plays an important part in the diet and cuisine of many diverse cultures. There are over 1000 named mango varieties throughout the world, which is a testament to their value to humankind. Mango is a common garden tree throughout the tropics.

When ripe, this delicious dessert fruit is particularly high in vitamin A. The fruit is also eaten green, processed into pickles, pulps, jams, and chutneys, and is frozen or dried. The fruit is also an important source of sustenance for birds, bats, insects, and mammals.

Although grown widely, mangos prefer a warm, frost-free climate with a well defined winter dry season. Rain and high humidity during flowering and fruit development reduces fruit yields. The tree generally flowers in mid- to late winter, with fruit maturing in the early to mid-summer months. Mango trees are usually between 3 and 10 m (10–33 ft) tall but can reach up to 30 m (100 ft) in some forest situations. The canopy is evergreen with a generally spreading habit. The heavy canopy of the mango is a source of shelter and shade for both animals and humans.

Mangos are well adapted to cultivation and have been grown commercially for centuries. Today, mangos are recognized and eaten throughout the world and are regarded as one of the most popular and esteemed tropical fruits.

DISTRIBUTION

Native range

The genus *Mangifera* originates in tropical Asia, with the greatest number of species found in Borneo, Java, Sumatra, and the Malay Peninsula. The most-cultivated *Mangifera* species, *M. indica* (mango), has its origins in India and Myanmar.

Current distribution

Mango is now cultivated throughout the tropical and subtropical world for commercial fruit production, as a garden tree, and as a shade tree for stock. In the Pacific region, all mangos were introduced from other parts of the world. The earliest recorded introductions into Hawai'i were prior to 1825; however, most introductions to the Pacific islands have occurred over the past 100 years. Few other *Mangifera* species are found in the Pacific. *Mangifera gedeba*, *M. minor*, and *M. mucronulata* are found in the Solomon Islands and *M. minor* in Micronesia, but these either do not fruit or the fruit is inedible.



Mango fruits of the world. PHOTO: I. S. E. BALLY

BOTANICAL DESCRIPTION

Preferred scientific name and author

Mangifera indica L.

Family

Anacardiaceae (cashew family)

Non-preferred scientific names

Mangifera amba Forssk.

M. anisodora Blanco

M. arbor Bontii

M. austroindica Kosterm.

M. balba Gen.

M. domestica Gaertn.

M. equina Gen.

M. fragrans Maingay

M. gladiata Boj.

M. kukula Blume

M. integrifolia Gen.

M. linnaei Korth.

M. maritima Lechaume.

M. mekongensis anon.

M. montana Heybe

M. oryza Gen.

M. racemosa Boj.

M. rostrata Blanco

M. rubra Boj.

M. sativa Roem. & Schult.

M. siamensis Warb.

M. sugenda Gen.

M. sylvatica Roxb.

M. viridis Boj.

Common names

Mangos have been grown throughout the tropical and subtropical world for thousands of years and have become an integral part of many cultures. The many different names for mango around the world today reflect the cultures and languages spoken by people who grow them. Many of the names have common derivations, reflecting the origins and spread of the mango tree along with the spread of human communities. The more popular names for mango fruit in the Pacific and Asia are listed below with the countries or languages from which they come.

Pacific island names:

idele (Palau)

kangit (Chuuk, Pohnpei)

mago (Niue, Samoa, Tuvalu)

manako (Hawai'i)

manggo, am (Fiji)

mangko (Kiribati)

mango (English)

mango (Tonga)

mangot, mangue, manguier (French)

mangueira (Yap)

Common names from other regions include:

aam, am, amb (Hindi)

ampleam (Tamil)

bobbie manja, kanjanna manja, maggo, manggaboom, manja (Dutch)

ma muang (Indochina)

mamung (Thailand)

manga, mango (Spanish)

manga, (Portuguese)

manga, mempelam, ampelam (Malaysia)

mangga (Tagalog)

mangga, mempelam (Indonesia)

mango (Ilokano)

mango (New Guinea, Pidgin)

Mangobaum (German)

mwàngx (Laos)

pabo (Bisaya) (Philippines)

svaay (Cambodia)

tharyetthi (Myanmar)

xoài (Vietnam)

Size

Mangos are long-lived evergreen trees that can reach heights of 15–30 m (50–100 ft). Most cultivated mango trees are between 3 and 10 m (10–33 ft) tall when fully mature, depending on the variety and the amount of pruning. Wild, non-cultivated seedling trees often reach 15 m (50 ft) when found in favorable climates, and they can reach 30 m (100 ft) in forest situations. The trees can live for over 100 years and develop trunk girths of over 4 m (13 ft).

Canopy

Mango trees typically branch 0.6–2 m (2–6.5 ft) above the ground and develop an evergreen, dome-shaped canopy. Variability in canopy shape and openness occurs among varieties and with competition from other trees. Mangos grown in heavily forested areas branch much higher than solitary trees and have an umbrella-like form.

Roots

The mango has a long taproot that often branches just below ground level, forming between two and four major anchoring taproots that can reach 6 m (20 ft) down to the water table. The more fibrous finer roots (feeder roots) are

found from the surface down to approximately 1 m (3.3 ft) and usually extend just beyond the canopy diameter. Distribution of the finer roots changes seasonally with the moisture distribution in the soil.

Flowers

Mango flowers are born on terminal inflorescences (panicles) that are broadly conical and can be up to 60 cm (24 in) long on some varieties. Inflorescences usually have primary, secondary, and tertiary pubescent, cymose branches that are pale green to pink or red and bear hundreds of flowers. The mango has two flower forms, hermaphrodite and male, with both forms occurring on the same inflorescence.

The ratio of hermaphrodite to male flowers on an inflorescence varies with variety and season and is influenced by the temperature during inflorescence development.

Hermaphrodite flowers are small (5–10 mm, 0.2–0.4 in) with four to five ovate, pubescent sepals and four to five oblong, lanceolate, thinly pubescent petals. Only one or two of the four to five stamens that arise from the inner margin of the disc are fertile. The single ovary is born centrally on the disc with the style arising from one side. The disc is divided into a receptacle of four or five fleshy lobes that forms the nectaries. The male flowers are similar to the hermaphrodite flowers but are without the pistil, which has been aborted.

Leaves

The leaves are simple, without stipules, and alternate, with petioles 1–12 cm (0.4–5 in) long. The leaves are variable in shape and size but usually are oblong with tips varying from rounded to acuminate. Leaf form differs among varieties but is more consistent within a variety. However, a range of leaf sizes can be seen on a single tree. Mature leaves are dark green with a shiny upper surface and glabrous lighter green lower surface. New leaves emerge in flushes (episodic growth spurts) of 10–20 leaves. Leaves emerge green, turning tan-brown to purple during leaf expansion and then gradually changing to dark green as the leaves mature. The color of the young, expanding leaf varies with variety and can be from light tan to deep purple; this can be used as a distinguishing character among varieties.

Fruit

Mango fruit is classed as a drupe (fleshy with a single seed enclosed in a leathery endocarp). Fruits from different varieties can be highly variable in shape, color, taste, and flesh texture. Fruit shapes vary from round to ovate to oblong and long with variable lateral compression. Fruits can weigh from less than 50 g (0.35 lb) to over 2 kg (4.4

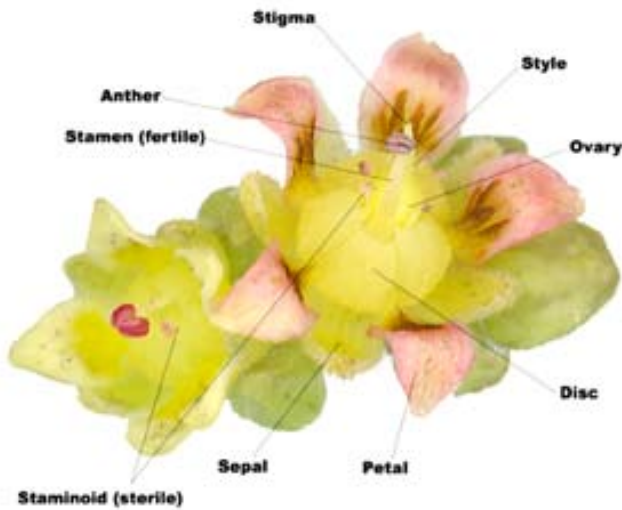


New leaf flush. PHOTO: C. ELEVITCH

lb). The fruit has a dark green background color when developing on the tree that turns lighter green to yellow as it ripens. Some varieties develop a red background color at fruit set that remains until the fruits ripen. In addition to the background color, many varieties also have an orange, red, or burgundy blush that develops later in the fruit development, when the rind is exposed to direct sunlight. The mesocarp is the fleshy, edible part of the fruit that usually has a sweet and slightly turpentine flavor. When ripe, its color varies from yellow to orange and its texture from smooth to fibrous.

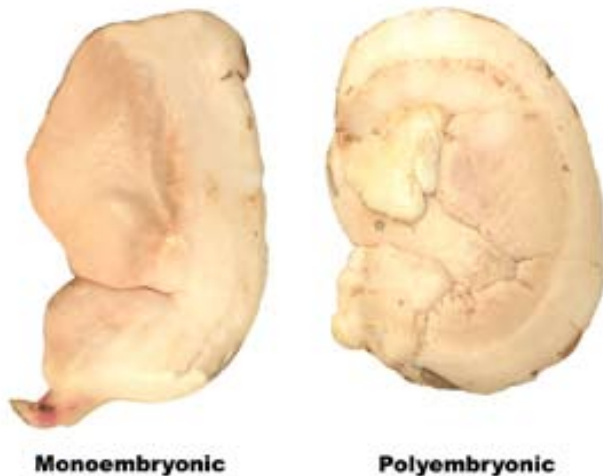
Seed

Mango varieties can be classified as having either monoembryonic or polyembryonic seed embryos. In monoembryonic varieties, the seed contains only one embryo that is a true sexual (zygotic) embryo. Monoembryonic seeds are a cross between the maternal and paternal (pollen) parents. Fruit from monoembryonic seedlings will often vary from the parent trees, so propagation by grafting is used to produce true-to-type monoembryonic trees. Polyembryonic seeds contain many embryos, most of which are asexual (nucellar) in origin and genetically identical to the maternal parent. Polyembryonic seeds also contain a zygotic embryo that is the result of cross-pollination. The monoembryonic seedling usually has less vigor than a nu-



Mango flower types: male (left) and hermaphrodite (right).

PHOTO: I. S. E. BALLY



A monoembryonic seed is a true sexual cross and has one embryo. A polyembryonic seed has several embryos, many of which are identical to the parent tree. PHOTO: I. S. E. BALLY

cellar seedling for use as a rootstock. In some varieties this is reversed and the zygotic seedling is the most vigorous. The occurrence of off-types in orchards is often attributed to use of zygotic seedlings.

GENETICS

Varieties

There are over a thousand mango varieties around the world, with India having the greatest number (over 500 named). The commercial industries of the world rely on

a handful of improved varieties supplemented with local varieties that are less suited to the export trade.

Varieties in the Pacific

The mango varieties found in the Pacific islands have been introduced mainly from India, Florida, and Southeast Asian countries during the past 100 years. Most of the early Indian varieties were monoembryonic, which produced seedlings that did not reproduce true to type. Planting and selection of these seedlings has changed these varieties, with many becoming known as a "common" variety. Common varieties are generally of inferior fruit quality to named, introduced varieties and are usually found growing wild or on roadsides and abandoned home sites.

In Hawai'i, Indian, Floridian, Mexican, and West Indian mango varieties have been introduced and grown since the beginning of the 20th century. Since that time, many improved seedling selections have been made and grown. Popular monoembryonic varieties in Hawai'i include 'Haden', 'Ah Ping', 'Gouviea', 'Momi K', 'Fairchild', 'Pope', 'Rapoza', and 'Harders'. In the Solomon Islands and Fiji, the Australian variety 'Kensington Pride' has been introduced and grown successfully. In Samoa, the mango varieties 'Momi K', 'Fiji', 'Mapulehu', 'White Pirie', 'Rapoza', 'Jara', and 'Kensington Pride' are common. In Tahiti, 'Kopu Reva' is a popular variety.

Selection of mango varieties

The characteristics by which mangos are typically selected are a mix of eating quality, keeping, and growing characteristics. Fruit quality characteristics such as flavor, aroma, flesh texture, and fiber are generally of high importance, as are fruit size, external appearance, and yield performance.

Preferences for mango varieties often differ among countries, regions, ethnicities, and cuisines of markets in which they are consumed. Locally grown and consumed varieties often differ from commercially exported varieties that are selected for their ability to maintain fruit quality after long periods of postharvest storage and transport.

The adaptations of a variety to environmental pressures of drought, wet weather during flowering, temperature, pests, and diseases are also important selection criteria, because they determine the cropping consistency and fruit quality.

Related species

In addition to the many varieties of *Mangifera indica*, there are several other *Mangifera* species that also have edible fruit. The most prominent of these are *M. pentandra* (Malay Peninsula), *M. foetida* Lour. (throughout SE Asia), *M. odorata* Griff. (Philippines, Malay peninsula, Java), and

SOME POPULAR PACIFIC VARIETIES

Ah-Ping

Tree: medium to vigorous tree
Fruit wt: 450–900 g (1–2 lb)
Fruit color: yellow with a crimson blush
Fruit eating: good flavor, low fiber
Seed embryo: monoembryonic
Harvest time: mid-season
Comments: originated at Mapulehu, Molokaʻi, and mainly grown in the Hawaiian Islands

Fairchild

Tree: small tree with dense, spreading canopy
Fruit wt: 150–340 g (0.33–0.75 lb)
Fruit color: green/yellow with an orange yellow blush
Seed embryo: polyembryonic
Fruit eating: mild, slightly acidic flavor; medium fiber
Harvest time: early season
Comments: originating in Panama, this variety bears reasonably well in wetter climates. Suitable as a homegarden variety

Gouviea

Tree: large, vigorous tree with spreading canopy
Fruit wt: 300–400 g (0.66–0.88 lb)
Fruit color: light green with mottled red and yellow shoulders
Fruit eating: rich, acidic flavor; low fiber
Seed embryo: monoembryonic
Harvest time: early to mid-season
Comments: selected in Hawaiʻi 1964; light yielding.

Haden

Tree: vigorous, tree with spreading canopy
Fruit wt: 500–700 g (1.1–1.5 lb)
Fruit color: yellow with bright red blush over half of skin
Fruit eating: good flavor, medium fiber
Seed embryo: monoembryonic
Harvest time: mid-season
Comments: unreliable irregular bearing; susceptible to internal breakdown; not a commercial variety

Kensington Pride

Tree: vigorous tree with spreading canopy
Fruit wt: 300–600 g (0.66–1.3 lb)
Fruit color: yellow-green background with light blush
Fruit eating: excellent flavor, medium fiber
Seed embryo: polyembryonic
Harvest time: early season
Comments: the mainstay of the Australian mango industry; widely grown in Samoa and Fiji

Kopu Reva

Tree: medium-vigor tree with a dense, upright canopy
Fruit wt: 150–250 g (0.33–0.55 lb)
Fruit color: light pink with a red blush
Fruit eating: turpentine flavor; high fiber
Seed embryo: polyembryonic
Harvest time: mid- to late season
Comments: origin Tahiti

Mapulehu

Tree: large tree with an upright canopy
Fruit wt: 300–400 g (0.66–0.88 lb)
Fruit color: yellow/green with pink blush
Fruit eating: sweet-acid turpentine flavor; low fiber
Seed embryo: monoembryonic
Harvest time: mid- to late season
Comments: originally from India; popular in Samoa; is synonymous with Joe Welch from Florida

Momi-K

Tree: medium to large tree, slightly spreading canopy
Fruit wt: 280–400 g (0.62–0.88 lb)
Fruit color: light yellow with a light red/orange blush over the top half of the fruit
Fruit eating: mild flavor; low fiber
Seed embryo: monoembryonic
Harvest time: early to mid-season
Comments: originating in Hawaiʻi, irregularly bearing

Pope

Tree: medium large tree with a dense, spreading canopy
Fruit wt: 250–450 g (0.55–1.0 lb)
Fruit color: green-yellow ground color with a red/pink blush
Seed embryo: monoembryonic
Fruit eating: spicy flavor, stronger around the fruit shoulders
Harvest time: late season
Comments: originated as a seedling of the Florida variety Irwin; regular-bearing and high-yielding

Rapoza

Tree: small tree with an open canopy
Fruit wt: 700–1000 g (1.5–2.2 lb)
Fruit color: yellow orange with a red orange blush
Fruit eating: excellent flavor; low fiber
Seed embryo: monoembryonic
Harvest time: mid- to late season
Comments: yields heavily and regularly

M. caesia Jack. (Malay peninsula, Papua New Guinea, Java, and the Philippines). Although these species are found growing in the Pacific rim region, none are found naturally in the Pacific islands.

ENVIRONMENTAL PREFERENCES AND TOLERANCES

Climate

Mango grows over a wide range of frost-free climates. The trees produce best in climates that have a well defined, relatively cool dry season with high heat accumulation during the flowering and fruit development period. Rain or free moisture (high humidity, heavy dew, and fog) during the flowering and fruiting period is conducive to the development of fungal diseases that cause flower and fruit drop. Mangos are often found growing in the wetter regions, but they rarely bear fruit there.

Elevation

Mango grows and produces fruit over a wide range of elevations from sea level up to 1200 m (3950 ft) in tropical latitudes. Most commercial varieties do not produce consistently above 600 m (1950 ft) elevation.

Rainfall pattern

Mango trees grow over a wide range of rainfall volumes and patterns. The trees produce best when the most rain falls during summer months and there is a well defined winter dry period. In hot, wet, tropical climates, where soil moisture does not limit growth, the trees remain vegetative with little or no fruit production. Rainfall, foggy weather, and persistent dews during the flowering and fruiting seasons predispose the flowers and fruit to the fungal disease anthracnose. Bearing is best when the dry period lasts from 1 to 2 months before flowering to after harvest.

Mean annual rainfall

400–3600 mm (16–142 in)

Dry season duration (consecutive months with <40 mm [1.6 in] rainfall)

Can tolerate drought for up to 8 months in certain situations.

Temperature

Mango's optimum growing temperature is 24–27°C (75–



Popular varieties: Haden (top left), Kensington (top right), Mapulehu (bottom left), Rapoza (bottom right). PHOTOS: I. S. E. BALLY

81°F). They will grow outside this range, however, but frost will kill small mango trees and severely defoliate mature trees. Temperature has a direct effect on tree and fruit growth rates. A leaf flushing cycle takes approximately 20 weeks when growing under 20°C (68°F) days and 15°C (59°F) nights; this is reduced to 6 weeks under 30°C/25°C (86°F/77°F) temperatures. The time taken for fruit to reach maturity is also influenced by temperature. Under high-temperature and low-humidity conditions, mango's photosynthetic efficiency is reduced and respiration is high, resulting in low carbon accumulation, which lowers the tree's ability to hold heavy crop loads. Low temperature stress is necessary for floral induction (see Flowering section below).

Mean annual temperature

24–27°C (75–81°F)

Minimum temperature tolerated

Frost (0°C [32°F])

Soils

Mangos are tolerant of a range of soils from alkaline, calcareous soils to heavy clay soils. The optimal pH range is 5.5–7.5, but the tree will grow outside this range, with low

pH (acid) being the most deleterious to growth. Production is best on well drained sandy or gravelly soils that dry out rapidly after the wet season, forcing the trees into a dormant period, essential for heavy flowering. Mangos will grow on coral atolls but usually produce poorly due to the lack of fresh water. On some of the larger, wetter atolls such as Butaritari and other islands in Kiribati, mangos are known to produce well. Mangos do not grow or produce well in saline soils, but the rootstock variety '13-1' from Israel has some salt tolerance.

Soil texture

Mangos tolerate light to heavy soil textures (sands, sandy loams, loams, sandy clay loams, clays, clay loams, and sandy clays).

Soil drainage

Well drained, lighter soils are preferred.

Soil acidity

The optimum range is pH 5.5–7.5.

Tolerances

Drought

Mango is considered a drought tolerant species, being able to withstand seasonal dry periods for up to 8 months. The mango has many adaptive features that give it drought tolerance, such as deep tap/sinker roots, long-lived, tough leaves with thick cuticles for nutrient retention and recycling, resin ducts to reduce wilting, and irregular fruiting patterns, depending on resource availability. Dry conditions during fruit development will cause excessive fruit drop and very low yields.

Full sun

Mango grows best in full sun because its flowers and fruit are produced at the edge of the canopy (the outside of the tree) in full sun. The best fruits are from sun-exposed branches.

Shade

Vegetative growth, flowers, and fruits from shaded areas are prone to increased pest and diseases.

Fire

Young mangos are easily burned beyond regeneration by grass or forest fires. Larger mature trees are more able to regenerate after fire, although their canopies are no more tolerant of fire than younger trees.

Frost

Young trees will be killed outright by the mildest frosts, but larger mature trees can regenerate, although defoliation and death of some branches will occur. Heavy frosts will kill large mango trees.

Waterlogging

Mango trees vary in their tolerance of flooding, with some trees able to tolerate medium-term flooding (10–50 days) by developing hypertrophic (swollen) lenticels on the trunk just above the waterline to aid in the removal of toxic by-products of anaerobic metabolism. Trees that do not develop hypertrophic lenticels will die after 4–5 days of inundation. Hypotrophic lenticels seen in seedlings in pots are a sign of overwatering or unsuitable potting media.



Hypertrophic lenticels on stem of seedling. PHOTO: I. S. E. BALLY

Salt spray

Mangos will not tolerate continuous salt spray, but if the trees are growing with high-quality fresh water, mild, infrequent salt spray will not adversely affect mature leaves if it does not accumulate on them.

Wind

Mangos are relatively wind resistant and are sometimes used in windbreaks. Windbreaks of other species are often



Simultaneous leaf flushing and flowering on different branches. PHOTO: C. ELEVITCH

used to protect commercial mango orchards to reduce disease, improve pollination, and reduce wind-rub blemishes on the fruit.

Young seedlings trees may benefit from staking if over 0.8 m (2.5 ft) high or planted in abrasive, calcareous soils in wind-exposed situations.

Storm winds can be especially damaging to mangos, causing breakage of major limbs or uprooting the whole tree. Although preventing damage from cyclonic winds is difficult, good post-storm management can hasten recovery and minimize secondary effects. Fallen trees should be straightened immediately following the storm, while the soil is soft, to prevent re-damaging roots. Damaged limbs should be removed to prevent disease infections and to promote new growth.

ABILITIES

Regenerate rapidly

Mangos are tolerant of severe pruning and will regain cropping within one to two seasons.

GROWTH AND DEVELOPMENT

Mango trees start producing fruit 2–4 years after field planting and can continue to produce fruit for more than 100 years. Under ideal conditions, trees can grow to 2 m (6.6 ft) in the first year. Once trees start cropping, their growth rate will slow.

Phenology

Phenology is the annual cycle of growth events. In mature mangos, the phenological cycle is similar for most varieties and environments, varying only in timing and duration. The exception is seen in trees grown close to the equator, where the seasonal fluctuations are minimal and flowering and cropping can occur several times a year. The major phenological growth events are discussed below.

Dormancy

In a typical tree there are two periods of dormancy. The first is immediately after harvest or ripe fruit drop, when the tree becomes dormant for 2–8 weeks, depending on the soil moisture conditions and previous crop load. The second dormant period is after the summer flush period, when dryer conditions set in. The second dormancy period is critical for floral bud development.

Leaf flushing

The postharvest dormancy is broken by the first summer vegetative flush, which usually coincides with the wet season. Vegetative flushing usually continues throughout the wet season, slowing as the climate and soil dry out. The leaf-flushing period can have one to five flushing events, with the whole canopy flushing in synchrony or in patches. In years of poor flowering and cropping, several leaf flushes can occur during the flowering and fruiting period. Although mango is an evergreen tree, large quantities of old leaves are shed during vegetative flushing. The fallen leaves become mulch under the tree, where nutrients are recycled from old leaves to the new leaves.

Flowering

Mango flowering occurs during the coolest months of the year. Flowering requires 4–6 weeks of shoot dormancy and cool night temperatures to trigger floral induction of the terminal buds. The absolute temperature needed for floral induction varies among varieties and climates, but night temperatures between 8°C and 15°C (46–59°F) with day temperatures around 20°C (68°F) are typically needed. Better flowering is seen in trees growing in the subtropics where the seasonal temperature differences are stronger and more reliable than in the hot tropics. In Hawai'i, the main flowering is between December and April.

Pollination

Wind and insects such as wasps, ants, flies, and bees are the main pollinators in mango. Temperatures below 10°C (50°F) during flowering are not conducive to production of viable pollen, and temperatures below 15°C (59°F) during pollination can prevent effective pollen tube growth and fertilization of the ovary. Pollen is generally compatible within and between varieties.

Fruiting

Young seedling or grafted mango trees will produce fruit between 2 and 4 years after field planting. Initially, hundreds of fruits can be set on each flowering inflorescence. The tree naturally thins the crop by shedding fruit throughout the fruit-development period. At full fruit maturity on heavy bearing trees, most mango varieties will hold one fruit for every two or three inflorescences.

Root growth

The volume of feeder roots of the mango varies during the annual cycle, with most root development occurring during the wet periods of the year and declining during the



Mango inflorescence (flower stalk). PHOTO: I. S. E. BALLY

dry periods. Root growth is periodical, slowing or stopping during major canopy growth events.

Fruit development

Mango fruit can take 3–6 months to mature, with temperature being the primary influence on maturity timing. Fruits grow faster and mature earlier in warmer climates. The variety of mango also has an influence on maturity timing, with varieties being classified as early, mid- or late season. The mango harvest season is generally in the hotter summer months but can be outside this period in climates close to the equator, where out-of-season flowering is common. In Hawai'i, the harvest season is between June and September, and in Fiji, between January and February.

Crop yield

Mango fruit yields are generally low compared to other tropical and subtropical fruit species. The yields often reflect irregular annual bearing patterns, and they vary greatly from season to season. The yielding capacity of a tree is dependant on variety, tree age, tree size, seasonal conditions, and previous cropping history. Typically, yields are often less than 5 mt/ha (2.2 t/ac) but can reach 20–30 mt/ha (9–13.5 t/ac) in well managed orchards. Single trees can produce between 200 and 300 kg (440–660 lb) of fruit in

heavy cropping years and as low as 5 kg (11 lb) in bad years. Good irrigation and disease management can greatly improve crop yields.

PROPAGATION

Mango is propagated by seed and various vegetative methods. The genetic quality of a mango seedling depends on the embryo type of the seed. Polyembryonic seeds will usually produce three to ten seedlings from each seed, most of which will come true to type with the tree they came from. Polyembryonic seeds also contain one embryo that is genetically different from the parents; i.e., this embryo will produce an off-type seedling. In contrast to polyembryonic seeds, monoembryonic seeds produce only one seedling for each seed that is always genetically different from the parents. For this reason, most monoembryonic varieties are propagated by grafting onto polyembryonic rootstocks.

Propagating seedlings

Seed collection

Seeds are best collected from fully mature or ripe fruits before the fruits have begun to decay with postharvest diseases. Seeds from the larger fruits generally produce the most vigorous seedlings. If possible, select seeds from trees that are free of seed weevils (*Sternochetus mangiferae* [F.] Coleoptera: Curculionidae). Only polyembryonic seeds will produce seedlings that are true to type (see polyembryonic/monoembryonic discussion above).

Seed processing

The best germination results are achieved when the seed is removed from the leathery endocarp of ripe or nearly ripe fruit that has not been chilled. After removing the flesh, cut the endocarp open using hand pruners and remove the kernel. During this operation, it is important not to cut and damage the seed.

Seed storage

Mango seed does not store well, and seed viability is greatly reduced from infection by fungi if it is not removed from the fruit when the fruit begins to ripen. Once the seeds are removed from the leathery endocarp, they lose viability very rapidly due to desiccation and should be planted immediately or soaked in water for up to 24 hours before planting. Germination percentages will drop off rapidly if seeds are stored for more than a few days after opening.

Planting techniques

Seeds should be planted to a depth of 2 cm (0.8 in) and

oriented on their side to facilitate a straight stem and roots. Monoembryonic seeds can be planted 1–2 cm (0.4–0.8 in) deep into 5–20 liter (1–5 gal) pots containing a loose, well drained potting medium. Polyembryonic seeds, which produce more than one seedling per seed, are commonly planted into seedling beds of sand with an impenetrable root barrier at 15 to 20 cm (6–8 in) depth. The root barrier makes it easier to lift the seedlings when potting up. This is usually done when the seedlings are approximately 30 cm (12 in) high. With healthy polyembryonic seedlings it is common to have germination rates of over 600% and potting up rates of 300–400%. When potting up, only use the three or four most vigorous seedlings from each seed, discarding the rest. Choosing only the most vigorous seedlings will avoid selecting the zygotic embryo that is often the source of off-type trees.

Growing area

Nursery seedlings are best raised in a shade house under 50–80% shade and hardened up in full sunlight prior to field planting. Avoid raising seedlings under the canopies of larger mango trees, as this practice promotes infection of the seedlings with fungal diseases.

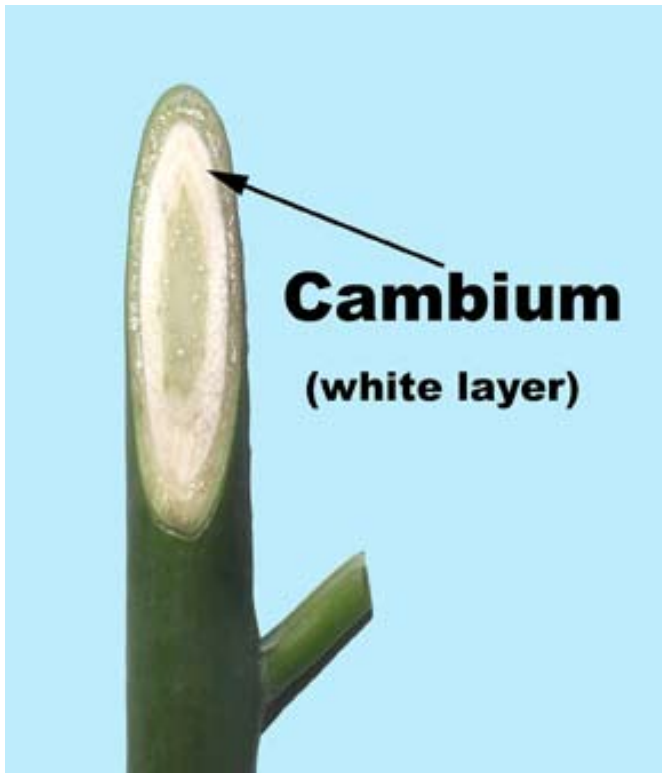
Time to outplanting

Young mango trees can be field-planted when approximately 12 months old and large enough to compete with minor weeds. At the time of planting, seedlings should be at least 1 m (3.3 ft) tall and have a stem diameter of at least 15 mm (0.6 in). If irrigation is available, the best time to field-plant is in early spring when the weather is mild; otherwise, trees should be planted at the onset of the wet season. To avoid transplant shock when field planting, trees should be hardened by holding in full sunlight for at least a week prior to field planting. If trees are excessively vigorous at the time of field planting, they can be pruned to reduce leaf area and water demand on the establishing root system.

Grafting and budding

Many of the better mango varieties have monoembryonic seeds which, when planted, will not reproduce true to type. Grafting is the preferred method of propagating mango varieties. Grafting is used to join the upper part (the scion) of a selected variety to the lower part of another (the rootstock)—the upper part is an identical clone of the desired tree. Grafting is normally done when the young seedlings are in nursery pots.

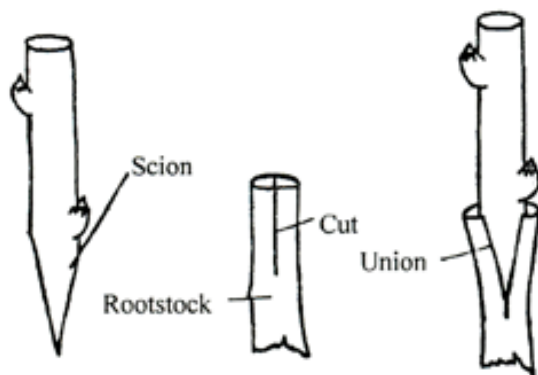
Almost all methods of grafting can be adapted for mango. Two popular methods for mangos are the cleft graft and the whip-and-tongue graft.



Prepared stock showing cambium. PHOTO: I. S. E. BALLY

To achieve a successful graft it is important to have healthy, actively growing rootstocks and select scion wood with swollen buds that are ready to burst. It is also important to match the cambium layers in both the stock and scion, as the cambium is where the cells are actively dividing and the joining of the graft takes place. This is most easily done when the stock and scion wood are the same diameter. In mango the cambium layer is the white woody layer just below the bark.

In the wedge method, the scion is prepared by making two sloping cuts that form a “V” shape. A straight cut is made on the stock to the same depth as the V shape on the scion. The V-shaped scion is then inserted in to the stock, making



Wedge graft

sure the cambium layers of both match up. The whole joint is then wrapped with grafting tape to hold it in place, and a plastic bag is used to cover the scion and union to prevent excessive moisture loss during the healing process.

The whip-and-tongue method is similar to the wedge but uses interlocking cuts that give a stronger graft and greater surface area for healing of the graft.

Scion selection

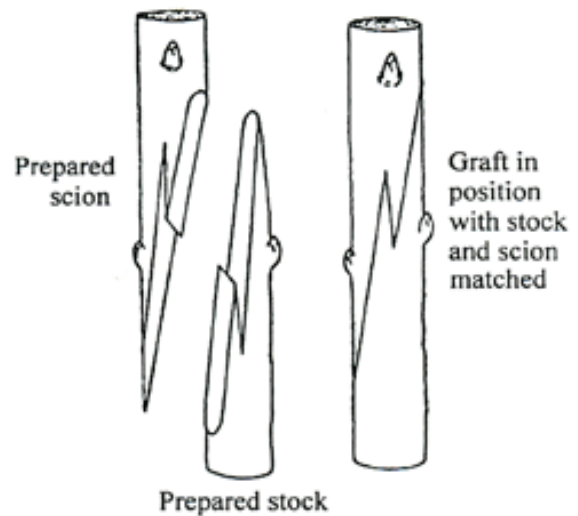
Scion wood should be only collected from actively growing trees that show no signs of disease infection. Scion wood is best taken from terminal shoots with swollen terminal buds about to burst. The scion thickness should match the stock thickness to which it is to be grafted (6–15 mm [0.25–0.6 in] diameter) and be between 100 and 200 mm (2.5–5 in) long.

Scion collection and storage

After selecting and removing an appropriate piece of scion wood from the tree, all leaves should be immediately removed to reduce moisture loss through transpiration. The scion should be placed in a plastic bag and held in a cooled box at 5–10°C (41–50°F). If the scion wood is not be used within 12 hours of collection, it should be wrapped in moist paper toweling inside a plastic bag and stored in the vegetable crisping section of a domestic refrigerator. Scion wood can be kept in this way for up to 2 weeks.

Pre-grafting

Scion budwood should be dipped in a fungicide and insecticide solution to prevent the spread of insect pests and disease.



Prepared stock

Whip and tongue graft



Left: Healed graft union 3 months after grafting. Right: Mango graft 5 days after bag removal. The wedge graft is still wrapped in white tape at bottom. PHOTOS: I. S. E. BALLY

Growing area

Grafting is usually done in the warmer months of the year when trees are actively flushing and night temperatures are between 18 and 21°C (64–70°F). Grafting of young seedlings is best carried out in a shadehouse with greater than 50% shade. When topworking established trees in the field (see below), completed grafts should be shaded with large paper bags.

Post-graft care

Remove any sucker growth below the graft. The scion should start to shoot between 10 and 14 days after grafting. When this happens, the plastic bag should be removed but not the grafting tape. The tape must be left on the graft until the tree has flushed twice from the scion and the graft union is fully healed.

Materials used

To achieve consistent successful grafting, a good grafting knife is needed. These knives differ from ordinary knives because they are beveled only on one side; the other side is flat to ensure a straight cut. You will also need some

grafting tape and plastic bags. Grafting knives and tape are available from most gardening shops.

Field planting

Grafted trees are best planted out in the field after the second growth flush, when the graft has fully hardened. This is usually 1–2 years after germination. At this stage the trees are usually 60–120 cm (24–48 in) tall. If field-planted when smaller, competition from weeds can slow establishment. If the trees are left in pots for longer than 2 years, they become root-bound and will not develop healthy, spreading root systems when field-planted. Transplanting shock at the time of field planting can also hinder a tree's establishment. To avoid transplant shock, it is best to harden the trees by placing them in full sunlight for a week or more before transplanting.

Excessively vigorous trees should be pruned prior to transplanting to reduce the water demand on the establishing root system. Animals will graze on young mango leaves, so the trees should be protected from grazing animals.



Tree grafted in the field (topworked). The upper part of the trunk is painted white, and the new scion wood is grafted to the three slender shoots. PHOTO: I. S. E. BALLY

Other comments on propagation

Grafting is also used to change the variety of a tree already growing in the ground without sacrificing the established rootstock. This technique is often referred to as topworking. Topworked trees will come into production within a couple of seasons, much faster than planting new seedlings.

DISADVANTAGES

Mangos grow and produce in many tropical and subtropical climates, although fruit production is limited by wet weather during the flowering and fruiting period. Inconsistent yields and fruit quality from season to season are also limiting characteristics of many mango varieties. These variations are partly due to the vigorous nature of many mango types that tend to grow leaves and vegetation at the expense of flowers and fruit.

Fruit production, and (rarely) tree growth, can be severely

affected by a range of insect pests and diseases. These, however, can usually be adequately managed in commercial orchards.

Pests

Many insects live in and feed on mango trees, but only a few of these are considered major pests.

Scale insects

Several species of scale insects are known to be pests of mango, including *Phenacaspis dilatata*, *P. cockerelli*, *Ceroplasts rubens*, and *Aulacaspis tubercularis*. The infested areas turn pale green or yellow and eventually die. The insects attack all parts of the tree and are often a serious pest in the nursery.

Tip borers

There are two main species of tip borers, *Penicillaria jocosatrix* and *Chlumetia euthysticha*. The larvae of these species bore into and kill the young developing flushes. The pest activity is worst during hot, wet, summer seasons.

Fruit flies (*Dacus* sp., *Strumeta* sp., *Bactrocera dorsaila*, and *Pardalaspis* sp.).

Fruit fly species differ among regions. Adult flies lay eggs in near-ripe or ripe fruit, and the larvae tunnel and feed throughout the flesh, destroying and decaying it.

Seed weevil

The mango seed weevil (*Sternochetus mangiferae*, *S. gravis*) bores into the seed early in the development of the fruit, with little or no damage to the edible fruit. In the seed, the larvae destroy the cotyledons, thus reducing seed germination. The presence of seed weevils is a major quarantine barrier for the export of mango to many countries.

Other pests

Other insect and mite pests of mango include fruit spotting bugs (*Amblypelta lutescens*, *A. nitida*), seed caterpillars, planthoppers, flower-feeding caterpillars (Geometridae, Lymantriidae, Noctuidae, Pyralidae, and Tortricidae families), thrips (*Selenothrips rubocinctus*), leaf miners (*Acrocercops* sp.), fruit piercing moths (*Othreis* sp.), termites (*Isoptera* sp.), mites (*Eriophyes mangifera*, *Oligonychus coffeae*), and coccids (*Coccus* sp.).

Diseases and disorders

A range of leaf, fruit, and soil diseases can affect mango, many of which can be adequately controlled with good management and judicious use of fungicides and bactericides. Detailed discussions of individual diseases can be

found in the books listed in the recommended reading section. A brief description of the major diseases of concern are listed below.

Anthracnose

Anthracnose (*Colletotrichum gloeosporioides*) is a serious fungal disease of flowers, fruit, and leaves. At flowering and early fruit development, anthracnose causes the flowers and young fruit to develop black lesions and be aborted from the inflorescence. Wet conditions during flowering promote anthracnose development. After the fruit reaches approximately 4 cm (1.6 in) in diameter, the fruit's natural defense mechanisms protect it from anthracnose by inducing the fungus into a quiescent period. When the fruit softens during the ripening process, the natural defense mechanisms break down, and latent infections of anthracnose develop into black lesions that rot the whole fruit in days. Postharvest anthracnose is the major reason for losses of mangos during storage and transport.

Mango scab

Mango scab (*Elsinoe mangiferae*) is a fungal disease that affects leaves, stems, and young fruit. On the stems and leaves, scab lesions form numerous, slightly raised, gray, oval to elliptical lesions. In young fruit, black, scabby lesions develop that in severe infections can cause the fruit to drop off. As the fruits grow, scar tissue develops around the black lesions, making them unmarketable due to blemishes. The lesions do not expand after harvest. Mango scab is more prominent in wetter regions.

Bacterial black spot

Bacterial black spot (*Xanthomonas campestris* pv. *Mangiferaeindicae*) is a bacterial disease of the leaves and fruit. The disease is worse in windy areas and in trees with low vigor. The disease is identified on the leaves by raised black lesions with greasy margins delineated by leaf veins. Fruit lesions initially appear as small, irregular, water-soaked spots around lenticels. Later, lesions become raised with a greasy appearance, cracking, and oozing bacteria-laden sap. The disease is spread in wind-driven water from lesions to natural openings and wounds on the tree.

Internal physiological disorders

Several internal physiological disorders can affect the flesh and eating quality of mangos. Some common forms of these disorders are

- “jelly seed”—premature ripening from around the seed
- “soft nose”—premature softening of the nose of the fruit

- “spongy stem end”—breakdown of the flesh and vascular tissue at the stem end
- “internal breakdown”—premature ripening and cellular breakdown of the flesh.

Symptoms vary among varieties of mango, but all of the above disorders are thought to be associated with low fruit calcium levels.

Other fruit diseases

Alternaria rot (*Alternaria alternata*)

Powdery mildew (*Oidium mangiferae* Berthet)

Stem end rot (*Lasioidiplodia theobromae*, *Dothiorella dominicana* or *Phomopsis mangiferae*)

Mango malformation (*Fusarium* sp.)

Other disadvantages

The sap that spurts and oozes from the fruit and peduncle when harvesting is highly caustic and toxic. Contact with human skin can cause severe dermatitis, rash, and blistering that requires medical attention. These are common ailments of mango pickers. Some people are hypersensitive and contact through picking, peeling, or eating a mango can cause swelling of the lips, throat, face, and other skin.

During harvesting, any sap that contacts the fruit will burn the skin, leaving dark, unattractive, sunken blemishes known as sap burn. Commercial mango farmers go to a lot of effort to prevent the sap from contacting the fruit or contaminating the wash water during the harvest and packing operations.

Potential for invasiveness

Mango is not an aggressively invasive species, but some wild trees can be found in native forest areas suited to their growth. The seeds can be carried by birds, bats, and other animals.

AGROFORESTRY/ENVIRONMENTAL PRACTICES

Crop shade/overstory

Mangos do not make a good overstory tree for cropping shade-tolerant species because their dense canopy produces 100% shade.

Livestock shelter

The dense canopy and tolerance of soil compaction make the mango an ideal tree for sheltering livestock from sun and rain. Trees must be protected from animals until the canopy is higher than grazing height.



Sap oozing from mango stem attachment is highly caustic.

PHOTO: I. S. E. BALLY

Homegardens

Mangos are used as shelter and shade trees in villages and homegardens. Two or three trees make an excellent addition to tropical homegardens in areas favorable to fruit production.

Fence posts

Mango wood is soft and rots rapidly when exposed to the elements, so it is not suitable for fence posts. However, mangos have been used as living fence posts.

Windbreaks

Mangos are sometimes used in mixed-species windbreaks, but their dense canopies cause wind turbulence, reducing windbreak effectiveness. Fruit production and quality is poor on wind-exposed trees.

Silvopasture

Mangos grow well in pastures, although cattle will graze off lower leaves. It is necessary to fence off young trees for the first 3–4 years to protect them from livestock.

Native animal/bird food

Mango fruits are a food source for many birds, fruit bats, wild pigs, and rodents.

USES AND PRODUCTS

Mangos have long been recognized as more than just edible ripe fruit. The edible uses of the fruit include non-ripe

fruit, seed, and processed products such as achar, chutneys, preserves, etc. The fruit is eaten for its nutritional value, its medicinal value, and for its pleasant flavor. The fruit and its by-products are used for animal fodder, and the timber is used for canoe building and making charcoal. Today mango and its flavor are added to many products, such as fruit juices, ice creams, wines, teas, breakfast cereals, muesli bars, and biscuits.

Fruit

Mangos are predominantly grown for their fruit, which is mostly eaten ripe as a dessert fruit. Mature green mangos are also eaten fresh or as pickles. Green eating varieties are distinguished from others by their sweet, non-starchy, non-astringent flavor at the green-mature stage of fruit development. Mature green eating mangos are eaten in several ways throughout the world. In Thailand they are sliced or grated in fresh salad, pickled (ma mung dong), soaked in water and sugar (ma mung chaien), salted and dried (ma mung khem), sliced in vinegar or fish sauce (ma mung pla wa arn), or eaten as a crunchy fruit. In many places, e.g., Samoa, the fruits are eaten green because someone else will eat them if one waits for ripening or because fruit fly larvae are not yet developed. Fresh mangos are processed and preserved into a wide range of products including pulps, juices, frozen slices, dried slices, pulp (fruit leather), chutneys, jams, pickles, canned in syrup, and sliced in brine.

Mangos are a highly nutritious fruit containing carbohydrates, proteins, fats, minerals, and vitamins, in particular vitamin A (beta carotene), B₁, B₂, and vitamin C (ascorbic acid). As the fruit ripens, concentrations of vitamin C decrease and glucose, fructose, and sucrose concentrations increase. Mangos make a significant seasonal contribution to diet of many Pacific islanders that primarily have a starch-based diet.

Flavoring/spice

Mango purees and essences are used to flavor many food products such as drinks, ice creams, wines, teas, breakfast cereals, muesli bars, and biscuits.

Nut/seed

In parts of India the seed is eaten as a boiled or baked vegetable or ground into a starchy flour.

Leaf vegetable

Young leaves, still rose or bronze colored, can be boiled to render them edible. Although the cooked leaves hold their shape and are attractive, their resinous flavor is an acquired taste. Some varieties are more suitable for eating in this manner (Martin et al. 1998). Young leaves of the related

species *Mangifera pajang* are eaten as vegetables in Sarawak.

Beverage/drink/tea

Alcoholic beverages made from mangos include wines and liquors made in Australia and India. Specialty teas are occasionally flavored with fragrant mango flowers.

Medicinal

In addition to mango's food value, it has also been used for its medicinal value. In Samoa, a bark infusion has been a traditional remedy for mouth infections in children (pala gutu), and in Tonga, infusions of leaves of mango, the orange (*Citrus sinensis*), and other species are used to make a potion to treat relapse sickness (kita).

In India, a drink made from unripe mango fruit is used as a remedy for exhaustion and heat stroke. Half-ripe fruit eaten with salt and honey is used for a treatment of gastro-intestinal disorders, bilious disorders, blood disorders, and scurvy. Ripe mangos are a rich source of vitamin A, and are used to treat vitamin A deficiencies such as night blindness. Diabetes has been treated with a drink made from the infusion of fresh mango leaves. Dried mango seed ground into flour is used to treat diarrhea. Diarrhea and throat disorders are treated by gargling bark extracts mixed with water. In India, fruit sap has been used to treat the pain of bee and scorpion stings. Many of the traditional Indian medicinal uses of mango involve eating unripe fruit. It should be noted that unripe fruit contains a lot of the toxic sap that when eaten in excess can cause throat irritation, indigestion, dysentery, and colic.

Animal fodder

Livestock will graze on mango leaves and eat fallen fruit. The leaves can be toxic if consumed in large quantities. Seeds and by-products of processing fruit have been used to feed cattle, poultry, and pigs.

Honey

Mango flowers are a rich source of nectar collected by honey bees.

Timber

Mango timber when properly seasoned has been used in furniture, for carving, as wall and floor paneling, and utensil manufacture. The timber is gray-brown, often with a pink tinge. It is coarse-textured hardwood that is easy to work and finishes well. The timber breaks down rapidly if exposed to the elements without preservation treatment.



Mangos make a wonderful addition to homegardens, such as here in Apia, Samoa where other popular homegarden trees include breadfruit, coconut, citrus, and vi (*Spondias dulcis*). PHOTO: C. ELEVITCH

Fuelwood

Mango wood makes excellent charcoal.

Canoe/boat/raft making

In French Oceania and the Cook Islands, mango wood is used for canoe construction.

Tannin/dye

A yellowish-brown dye used for silk is extracted from the bark.

URBAN AND COMMUNITY FORESTRY

Mangos have traditionally been grown as garden and community trees in many countries. The trees are prized primarily for their delicious fruit, but also valued for their dark green foliage with its periodic splashes of new red-brown leaves. Other aspects such as flood and drought tolerance and a dense spreading canopy that provides shade and shelter for humans and animals, make mangos valued garden trees. Traditionally, mangos have also been grown as shade trees in streets and parks, but their high maintenance and public nuisance have brought them into disfavor in many public situations in recent times.

Size

Mango can reach heights of 15–30 m (50–100 ft). In urban environments cultivated trees are usually maintained to a height of between 3 and 10 m (10–33 ft) when mature.

Rate of growth

Mangos are fast-growing trees, often growing in excess of 1.5 m (5 ft) per year when well tended in urban conditions.

Roots

Mango roots are extensive and build up around water sources such as leaking pipes and water spigots. In mature trees, major roots will come to the surface and may disrupt lawns or paved surfaces for a distance from the trunk equal to the spread of the canopy. Aside from the area under the canopy, there is little danger mango roots will raise pavement or foundations.

Household uses

The fruit from the mango can be eaten as a ripe fruit or processed into a range of products such as achar, chutneys, jams, pulps, juices, and canned or frozen. The unripe green fruit is commonly eaten throughout the Pacific, picked fresh as a snack or dipped in salt or soy sauce. The green fruit is also commonly pickled, peeled, and sliced.

Light requirements

Mangos prefer full sun. Where grown in shaded situations, the canopy becomes thin and weak. Fruiting is greatly reduced and the fruit lose their attractive blush.

Water/soil requirements

Mangos grow in most soil types from heavy clays to light sands but prefer well drained lighter soils. Mangos are generally tolerant of many harsh soil conditions. Over hard, compacted subsoil or smooth lava (such as paho'ehoe) that is impenetrable by the roots, trees may become unstable in high winds, be more subject to drought, and growth may become stunted.

Expected life span in a homegarden

Mango trees are long-lived and can be expected to survive as mature trees for over 100 years.

Varieties favored for use in a homegardens

There are many named and unnamed mango varieties grown throughout the Pacific islands. The most suitable varieties to grow in the homegarden is a matter of personal taste and how the tree is to be used. Small or dwarf mango varieties are suitable for smaller gardens where space is limited. Some of these varieties include 'Keitt', 'Fairchild', 'Rapoza', 'Willard', and 'Irwin'. Larger more vigorous varieties are suitable where the trees are to provide shade and shelter. Some of these varieties include: 'Haden', 'Kensington Pride', 'Gouviea', 'Mapulehu', and 'Ah Ping'. If there is

Nutritional value of 100 g fresh mango pulp. (Source: USDA Nutrient Database for Standard Reference, Release 14 July 2001)

Constituent	Amount in 100 g fresh pulp
Water	81.7 g
Energy	65 kcal (272 kj)
Protein	0.51 g
Fats	0.27 g
Carbohydrates	17.00 g
Total dietary fiber	1.8 g
Ash	0.50 g
Minerals	
calcium	10 mg
iron	0.13 mg
magnesium	9.0 mg
phosphorus	11 mg
potassium	156 mg
sodium	2 mg
zinc	0.04 mg
copper	0.11 mg
manganese	0.027 mg
selenium	0.6 mcg
Vitamins	
vitamin C (total ascorbic acid)	27.2 mg
thiamine	0.056 mg
riboflavin	0.57 mg
niacin	0.584 mg
pantothenic acid	0.16 mg
vitamin B ₆	0.160 mg
total folate	14 mcg
vitamin A, IU	3894 IU
vitamin A, RE	389 mcg_RE
vitamin E	1.120 mg_ATE
tocopherols, alpha	1.12 mg
Lipids	
total saturated fatty acids	0.066 g
total monounsaturated fatty acids	0.101 g
total poly unsaturated fatty acids	0.051 g
cholesterol	0.00 mg
Amino acids	
Tryptophan	0.008 g
Threonine	0.019 g
Isoleucine	0.018 g
Leucine	0.031 g
Lysine	0.041 g
Methionine	0.005 g
Phenylalanine	0.017 g
Tyrosine	0.01 g
Valine	0.026 g
Arginine	0.019 g
Histidine	0.012 g
Alanine	0.051 g
Aspartic acid	0.042 g
Glutamic acid	0.06 g
Glycine	0.021 g
Proline	0.018 g
Serine	0.022 g



A quick-bearing crop such as papaya can be grown between mango seedlings for the first few years, after which the mangos start filling the open space and begin bearing a fruit crop. PHOTO: C. ELEVITCH

room for more than one mango tree, two or more varieties with different bearing seasons can be selected to extend the time ripe fruit is available.

Seasonality of leaf flush, flowering, fruiting

Mangos generally flower in the coolest and driest part of the year and the fruits develop through the spring and early summer to ripen in the hottest part of the year. Leaf flushing (periodic growth of new leaves) can occur throughout the year, but is usually concentrated in the summer months after the fruits ripen and often coincides with summer rains. Mangos shed leaves continuously throughout the year, but most of the annual leaf shedding occurs immediately after each new growth flush.

Ornamental values

Mango flower colors differ among varieties and range from green through yellow and pink to dark red. Inflorescences (flower stalks) vary in length from 12 to 50 cm (5–20 in). The inflorescences are usually abundant and provide an attractive contrast to the dark-green foliage. In many mango

varieties the young expanding leaves are a dark chocolate brown or purple color that turns gradually to dark green as the leaves reach full size and harden.

Bird/bee/wildlife

Mango trees attract a range of wildlife (birds, bats, and other fruit-eating creatures). During the fruiting season, fruit bats and fruit-eating birds are attracted to the tree. Bees visit the flowers, but most pollination is done by flies.

Maintenance requirements

Fertilizer Mangos grown in the homegarden generally do not need regular fertilizer; however, if the foliage appears light green or yellowish, it can be greened up by the application of 0.5–2 kg (1.1–4.4 lb) of a well balanced fertilizer once or twice a year.

Watering Although mangos are able to withstand periodic drought, it is best to water the trees during the dryer months. Watering mango trees when the flowers and fruit are on the tree will improve the fruit set and size of the fruit at harvest.

WHEN TO PICK MANGOS

The maximum eating quality of fresh mangos is obtained when the fruits are harvested when fully mature. Early or immature picking can reduce eating quality.

Not all maturity indicators are useful on all varieties. Some useful maturity indicators are

- the shoulders and beak of the fruit are well filled out, and the skin in these areas takes on a smooth appearance
- the background green coloring of the fruit begins to lighten
- the fruit pedicle (stem) begins to shrivel and is more easily separated from the fruit
- flesh color changes from white to a uniform pale yellow.

Picking the fruit

Once mature, fruit are usually picked as mature, hard, green fruit and then ripened in crates or baskets. If the fruit is left to ripen on the tree, birds and bats usually eat the fruit first.

Care should be taken to avoid sap contact on the fruit or human skin during the picking operation, as it is highly caustic and will cause fruit blemishes and burn human skin. Picking the fruit with long stems (>10 cm, 4 in) and de-stemming the fruit after dipping in detergent will help overcome sap-related problems.

Pruning If left unpruned, mangos can become very large trees (15–30 m [50–100 ft]). Pruning to limit tree size or provide clearance from buildings and roads is common practice and usually needs to be done every 1–2 years. Pruning may also be necessary to thin the canopy and remove any dead branches inside the canopy. Mangos are very tolerant of pruning and limbs of any size can be removed. After heavy pruning it is common for trees to flower and crop poorly the next season, with increasing harvests in following seasons.

Drawbacks

Mangos are considered a messy tree because they tend to continuously drop leaves and other material. At late flowering/early fruit set, the tree drops the aborted flowers and inflorescence branchlets, which can stain concrete or cars parked beneath. Mangos naturally thin their fruit crop, shedding aborted fruit from flowering until fruit are almost full size. These fruits have a high sap content that can stain concrete, kill grass, and strip paint from cars.

Mango branches are brittle and can break during heavy wind storms or with heavy crop loads. It is also common

for branches to snap under the weight of a person climbing the tree to pick the fruit.

Nuisance issues

Fruit that is allowed to ripen and fall to the ground quickly begins to rot. Because they are smelly as they rot, ripe fruits attract vermin such as rodents and feral pigs. Decaying fruit kills grass in patches and clogs up mowing equipment.

Hazards

Mango trees in urban spaces such as car parks, sports fields, and public walkways can be a problem during the fruiting season. Ripe fruit falling from trees is not only a hazard when falling, but rotting fruits on the ground present a hazard as they are slippery if stepped on (just like banana peels). The sap that exudes from the stems of fruit is highly caustic and toxic, and contact with unprotected skin can cause severe blistering and rashes that can require medical attention. Skin and eye protection should be used when picking the fruit. In hypersensitive people, consumption of the fruit can cause swelling of the lips, throat, and face.

Common pest problems

Mangos are susceptible to a range of pests and diseases that affect the tree and fruit. In general, the pests in garden trees exist at low levels in balance with their predators and do not require any specific control measures. For severe pest infestations, see the “Pests” section above.

Other

Along with coconut and breadfruit, mango is one of the most common homegarden fruits in the Pacific. The popularity of the mango comes from the almost universally-loved fruit, which can be too costly for most households to purchase. A mature tree of a selected variety can reliably produce enough fruit for a family, with extra to preserve in various ways or share with friends and neighbors. The shade and shelter provided by the dense, spreading canopy of the mango has traditionally been a focal point for work and social gatherings in the Pacific.

COMMERCIAL PRODUCTS

Commercial mango production is carried out in several

Pacific nations including Hawai'i, Fiji, and the Solomon Islands.

Tree spacing

Tree spacing is governed by the variety and climate. Traditional spacings were wide (up to 12 x 12 m, 70 trees/ha; 40 x 40 ft, 28 trees/ac) as trees were allowed to grow to full size. In more recent times, tree spacing has been reduced and trees are maintained at smaller sizes. This facilitates pest and disease control and harvesting operations. Smaller compact varieties can be planted as close as 7 x 4 m or 375 trees/ha (23 x 13 ft, 152 trees/ac).

Pruning

Managed orchard trees require regular annual pruning to maintain an open canopy of manageable size. This allows air and sunlight to penetrate, which reduces pests and diseases and enhances internal fruit color. Mangos can be heavily pruned with little effect on tree health, although heavy pruning may stimulate excessive vegetative growth at the expense of flowering and fruiting.

Irrigation

Irrigation during the flowering and cropping period can greatly increase the number of flowers and the number and size of fruits at harvest.

Fertilizer

As a rule, mangos do not require large amounts of fertilizer. Overfertilization can be detrimental to yield, promoting excessive vegetative vigor at the expense of flowering and fruiting. Mangos are especially sensitive to nitrogen, which not only promotes vigor but also reduces fruit color at harvest and reduces the fruits' tolerance of postharvest disease. Various fertilizer schedules can be found in the publications listed in the bibliography below.

Crop manipulation

Manipulation of flowering to increase fruit set is a common commercial practice. Two popular treatments are the application of potassium nitrate (KNO_3) or paclobutrazol to promote flowering. Potassium nitrate works only on some varieties in some climates. Soil drenches with pa-



Regular annual pruning to maintain an open canopy and control the size of the tree is necessary for commercial production. Pruning by climbing into the canopy is a common method for small growers. PHOTO: C. ELEVITCH

CONTEMPLATING GROWING MANGO COMMERCIALY?

Many issues have to be considered when embarking on commercial mango production. In addition to the obvious production-related issues such as how, where, and what to grow, there are marketing, finance, license, and regulatory issues that need to be considered. A good place to start is by reading a good growing and production handbook and getting advice from an advisory service. Some of these are listed at the end of this publication.

clobutrazol generally increase flowering, encourage early flowering, and reduce vegetative vigor (use of paclobutrazol is subject to registration requirements of the chemical, which may vary with countries). Other techniques that have been used with variable results include cincturing, which involves making a shallow saw cut around the trunk or limb to temporarily ring bark it and restrict the flow of carbohydrates down the limb. Smudging (lighting fires under the trees to smoke the canopy for several weeks) was popular in the Philippines before potassium nitrate became widely used. In some parts of India, root pruning or disruption through cultivation or exposure to the air was used as a flower-inducing treatment.

Harvesting

Fruits are usually harvested by hand or with the help of picking devices. The fruits are handled gently as they are easily damaged by abrasion and sap contamination. Care should be taken to avoid sap contacting the fruit during the harvesting and packing operations, as it is caustic and causes dark, unsightly blemishes on the fruit. Sap can also burn human skin. Mango branches are brittle and can snap without warning. This is a common cause of injury to people climbing trees during harvest.

Postharvest care

To maximize the storage life of mangos, fruits are generally dipped in hot water and fungicides to slow the development of postharvest fungal rots. Controlled cool temperatures are also essential if fruit quality is to be maintained during storage. Temperatures will vary depending on the stage of fruit ripeness and variety. Ethylene gassing is used to trigger even ripening in stored fruit.

Specific detailed information on the various aspects of commercial mango production can be found in the publications listed in the bibliography below.

INTERPLANTING/FARM APPLICATIONS

Mango is often used in a mixed cropping or interpolating situation. When mango trees are young, they can be mixed with smaller crops such as papaya, coffee, and vegetables. As the trees become larger, they cast heavy shade, and their roots out-compete smaller species. Mature mangos can be successfully mixed with other similarly vigorous species such as jackfruit, avocado, breadfruit, coconut, guava, or rambutan.

PUBLIC ASSISTANCE AND AGROFORESTRY EXTENSION

Extension offices for agroforestry and forestry in the Pacific: <<http://www.traditionaltree.org/extension.html>>.

GERMPLASM RESOURCES

Collections of mango varieties and related species are maintained in many tropical and subtropical countries on most continents. Because of the short storage viability of the seed, collections are held as mature growing trees, usually maintained by research organizations involved in mango improvement in the region. In the Pacific, the major collections are held in Hawai'i, Australia, and Fiji as listed below. Collections of *Mangifera* from other parts of the world are listed in the International Plant Genetic Resources Institute (IPGRI) web site <<http://web.ipgri.cgiar.org/germplasm>>.

Locations of major mango collections for the Pacific region

Australia

Queensland Department of Primary Industries
PO Box 1054, Mareeba QLD 4880, Australia
E-mail: ian.bally@dpi.qld.gov.au

Fiji

Botany Section, Koronivia Research Station
PO Box 77, Nausori, Fiji

Philippines

Institute of Plant Breeding, College of Agriculture, UPLB
College, Laguna, Philippines
E-mail: opd@ipb.uplb.edu.ph

United States including Hawai'i

Subtropical Horticultural Research Unit, National
Germplasm Repository—Miami

13601 Old Cutler Road
Miami, FL 33158 USA
E-mail: mia@ars-grin.gov

INTERNET

- Queensland Department of Primary industries mango information: <<http://www.dpi.qld.gov.au/thematiclists/1088.html>>.
- General crop information: <http://www.extento.hawaii.edu/kbase/crop/crops/I_mango.htm and <http://www.crfg.org/pubs/ff/mango.html>>.
- The Mango: Asia's King of Fruits. (Douthett, D.G. 2000. Southern Illinois University Carbondale): <<http://www.siu.edu/~ebl/leaflets/mango.html>>.
- Mango varieties suited for unripe eating: <<http://www.dpi.qld.gov.au/horticulture/5332.html>>.
- Grafting mangos: <<http://www.dpi.qld.gov.au/horticulture/5328.html>>.
- Mango crop production questions and answers: <<http://www.dpi.qld.gov.au/horticulture/5240.html>>.
- Postharvest processing: <<http://www.ba.ars.usda.gov/hb66/contents.html>>.
- Anthraco-nose: <<http://www.dpi.qld.gov.au/business/7318.html>>.
- Fruits in the homegarden: <<http://www.dpi.qld.gov.au/business/8391.html>>.

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Species Profiles for Pacific Island Agroforestry (www.traditionaltree.org)

Mangifera indica (mango)

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