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Citrus (citrus) and *Fortunella* (kumquat)

Rutaceae (rue family)

C. aurantifolia	lime	*C. limon*	lemon	*C. paradisi*	grapefruit
C. aurantium	sour orange	*C. macroptera*	wild orange	*C. reticulata*	mandarin
C. grandis	pummelo	*C. medica*	citron	*C. sinensis*	sweet orange
C. hystrix	Kaffir lime	*C. mitis*	calamondin	*Fortunella* spp.	kumquat

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IN BRIEF

Distribution Widely distributed and cultivated worldwide including throughout Oceania.

Size Depending on species and cultivar, trees reach heights of 3–15 m (10–50 ft).

Habitat In the subtropics 0–750 m (0–2450 ft); in the tropics 0–1600 m (0–5250 ft); without irrigation, rainfall of 900–3000 mm (35–120 in) is needed.

Vegetation Associated with a wide range of cultivated tropical and subtropical species.

Soils Tolerates a wide range of soils; however, does not stand waterlogged soil, and grow best in freely draining soils; pH 5–8.

Growth rate 0.1–0.3 m/yr (4–12 in) in height.

Main agroforestry uses Homegardens, bee forage (excellent honey), animal fodder, craft and fuel wood.

Main uses Fruit, medicine, cosmetics.

Yields Vary greatly depending on variety and growing conditions; mature trees of oranges and grapefruit can bear 125–204 kg/tree (275–450 lb/tree) in commercial situations.

Intercropping Can be intercropped with a wide variety of species in homegardens and mixed farm systems.

Invasive potential Citrus species are not considered to be invasive.

Citrus is a favorite fruit in Pacific island homegardens and has commercial potential in local markets.

INTRODUCTION

Citrus species are small to medium-size shrubs or trees that are cultivated throughout the tropics and subtropics. They are native to parts of India, China, northern Australia, and New Caledonia. All species are aboriginal, early European, or modern introductions throughout Oceania. Most species have been given names in many native languages of the Pacific, attesting to how citrus has been embraced by native cultures. Citrus is adaptable to many subtropical and tropical environments and soils and has traditionally been cultivated in homegardens together with other important species such as coconut, breadfruit, papaya, and numerous others. One could say citrus is an essential component of any Pacific island (and subtropical or tropical) homegarden.

Citrus is primarily valued for the fruit, which is either eaten alone (sweet orange, tangerine, grapefruit, etc.) as fresh fruit, processed into juice, or added to dishes and beverages (lemon, lime, etc.). All species have traditional medicinal value. Citrus has many other uses including animal fodder and craft and fuel wood. Although commercial production for export markets has not been significant in Oceania, there is potential for small farmers to supply local markets with fresh fruit and unique varieties.

DISTRIBUTION

Native range

The genus *Citrus* is native to the tropical and subtropical regions of India and southern China to northern Australia and New Caledonia. The cultivation of oranges and pummelo dates back to 2400 BC in China.

Current distribution

Some species can still be found in a wild state, but most species are today known only in cultivation. Citrus has been distributed widely and cultivated worldwide for fruit and juice. All species are present in Oceania today as aboriginal, early European, or recent introductions.

BOTANICAL DESCRIPTION

Genus

Citrus L.

Family

Rutaceae (rue family)

Subfamily

Aurantoideae

Subgenera

The genus *Citrus* is further subdivided into subgenera: *Citrus* and *Papeda*, with the difference being the presence of acrid oil droplets in the pulp vesicles of *Papeda*. Of the species covered here, most belong to the subgenus *Citrus*, with *C. hystrix* and *C. macroptera* belonging to *Papeda* (Stone 1985).

Species origins and Pacific island introductions

Species	Common name	Native origin	**Time of Pacific island introduction** (Thaman and Whistler 1996)
C. aurantifolia	lime	Malesia	early European introduction to Pacific islands, including atolls
C. aurantium	sour orange	S. China and Indochina	early European introduction to Pacific islands
C. grandis	pummelo	Malesia	aboriginal introduction to Fiji, western Polynesia, and Tonga; early European introduction to other Pacific islands
C. hystrix	Kaffir lime	Malesia	early European introduction to many Pacific islands; recent introduction to Kiribati and Tuvalu
C. limon	lemon	SE Asia	early European introduction to Pacific islands
C. macroptera	wild orange	Malesia, Melanesia	Polynesian introduction Vanuatu, New Caledonia, and Polynesia (Walter and Sam 2002)
C. medica	citron	India	early European introduction to Pacific islands
C. mitis	calamondin	China	recent introduction to many Pacific islands
C. paradisi	grapefruit	West Indies	recent introduction to many Pacific islands
C. reticulata	mandarin	SE Asia	recent introduction to many Pacific islands
C. sinensis	sweet orange	S. China, Indochina	recent introduction to many Pacific islands

Preferred and non-preferred scientific names

C. aurantifolia (Cristm.) Swingle (lime)

Non-preferred names
Limona aurantifolia Cristm.
Citrus lima Lunan
Citrus acida Rsxb.
Citrus hystrix var. *acida* (Roxb.) Engler
Citrus medica var. *acida* (Roxb.) Hook. F.
Citrus medica sensu Catala, Guillaumin, non L.

C. aurantium L. (sour orange)

Non-preferred names
Citrus vulgaris Risso

C. grandis L. (pummelo)

Non-preferred names
Citrus aurantium var. *grandis* L.
Citrus aurantium var. *decumana* L.
Citrus maxima (Burm.) Merr.
Citrus decumana (L.) Murr.

C. hystrix DC (Kaffir lime)

Non-preferred names
C. bergamia (Duhamel) Risso

C. limon (L.) Burm. f. (lemon)

Non-preferred names
C. medica var. *limon* L.
C. limonum Risso
C. limonia Osbeck

C. macroptera Montrouzier (wild orange)

Non-preferred names
C. aurantium spp. *sapnacea* Saff.

C. medica L. (citron)

Non-preferred names
C. medica var. *genuina* sensu Bryan
C. aurantium L. var. *medica* Wight & Arnott
C. crassa Hasskarl

C. mitis Blanco (calamondin)

C. paradisi Macf. (grapefruit)

C. reticulata Blanco (mandarin)

Non-preferred names
C. nobilis sensu auct. Micr. Non Lour.
C. nobilis Andrews
C. deliciosa Tenore
C. chrysocarpa Lushington

C. sinensis Osbeck (sweet orange)

Non-preferred names
C. aurantium var. *sinensis* L.
C. aurantium ssp. *sinensis* (L.) Engl.

EXAMPLE OF EARLY PACIFIC ISLAND INTRODUCTION

Commenting on the citrus species on Niue, Smith (1902) wrote: "The orange (*Moli*) grows well and bears fine sweet fruit, but the natives here have not planted it to any extent. It bears the same name in Fiji, Samoa, Tonga, Futuna, Rarotonga, and Tahiti. The lemon, lime, citron and shaddock also flourish very well in Niue, particularly the lemon (*Tipolu*)."

Size

Citrus are shrubs to medium-size trees up to about 6 m (20 ft) in height, although some species can reach 15 m (50 ft). Rootstocks can greatly affect the height of grafted trees. Trees have thin, smooth, and gray-brown to greenish bark. Most species are single-trunked with very hard wood. Canopy widths range from slender to broad, depending on species. Many cultivated species are pruned so that the canopy is as wide as the tree is tall.

Species	common name	Size and spines
C. aurantifolia	lime	shrub/small tree to 4 m (13 ft), spiny
C. aurantium	sour orange	tree to 10 m (33 ft), short spines
C. grandis	pummelo	tree to 12 m (40 ft), spiny
C. hystrix	Kaffir lime	tree to 5 m (16 ft), short spines
C. limon	lemon	tree to 6 m (20 ft), stout spines
C. macroptera	wild orange	tree to 5 m (16 ft), spiny
C. medica	citron	shrub to 3 m (10 ft)
C. mitis	calamondin	tree to 12 m (40 ft), spiny
C. paradisi	grapefruit	tree to 15 m (50 ft)
C. reticulata	mandarin	tree to 9 m (30 ft), usually spiny
C. sinensis	sweet orange	tree to 12 m (40 ft), often spiny stems

Form

Tree growth and form varies depending on the genetic background and whether the tree was established by seed or grafting. Some lemon varieties can produce vigorous canopies (e.g., 'Bearss'), while other varieties are spreading in nature. Generally, limes have a low-growing habit and long branches that arch outward. The typical form of sweet orange tends to be a conical shape, narrowing to-

Common Names

C. aurantifolia (lime)

Yap: *remong*
Marshall Islands: *laim*
Nauru: *deraim, derem*
Guam: *limon*
English: lime, Tahiti lime, key lime, W. Indian lime, acid lime
French: *citronnier*
Kiribati: *te raim*
Tonga: *laimi, moli laimi*
Palau: *malchianged*
Pohnpei: *karer*
Kosrae: *laim*
Chuuk: *laimes, nayimis*
Fiji: *moli laimi, laimi*
Tahiti: *taporo*
Marquesas: *ihitoro, hitoto*
New Caledonia: *le limier*
Samoa: *moli tipolo, tipolo, tipolo lamolemole*

C. aurantium (sour orange)

Fiji: *moli jamu*
Guam: *kahet*
English: sour orange, Seville orange
Hawai'i: *'alani*
Tubuai: *anani, bigarade*
Swains Island: *moli*
New Caledonia*: l'oranger*
Samoa: *moli 'aina*
Tonga: *kola*
Futuna: *moli kai*

C. grandis (pummelo)

Fiji: *moli kana*
Palau: *jabong*
Guam: *kahet magas, lalangha*
English: pummelo, shaddock, jabon (Hawai'i)
French: *pamplemoussier*
New Caledonia: *le pamplemoussier*
Fiji: *moli kana*
Tonga: *moli Tonga*
Samoa: *moli Tonga, moli meleke, moli 'ai suka, moli suka*

C. hystrix (Kaffir lime)

Guam: *limon admelo*
English: Kaffir lime, Mauritius papeda, rough lemon, wart lime
Palau: *debechel*
Yap: *gurgur gurgumimarech*
Samoa: *tipolo patupatu*
Tonga: *lemani, moli lemani*
Kiribati: *te remen*
Tuvalu: *laim*

C. limon (lemon)

Palau: *debechel*
Hawai'i: *lemi*
Kiribati: *te remen, te remon*
Tonga: *moli lemani, lemani*
Fiji: *moli karokaro, moli sosoriatia, moli ni vavalagi*
Guam: *limon real*
English: lemon
Pitcairn: *rough-skinned lemon*
Hawai'i: *lemi, kukane*
Samoa: *moli tipolo, moli*
Niue: *tipolu*
Cook Islands: *tiporo*
New Caledonia: *le citronnier*

C. macroptera (wild orange)

Guam: *kahet*
English: wild orange, melanesian papeda
Tonga: *moli uku*
Samoa: *moli u'u*
Fiji: *moli kau*
Vanuatu: ghost lime (eng.), *moli* (Ambae, Malo), *mol* (Efate, Pentacost, Santos), *ngoli* (Maewo), *na-moli* (Tongoa)

C. medica (citron)

Guam: *setlas*
English: citron
Swains Island: *tipolo*
Samoa: *tīpolo, tīpolo patupatu*

C. mitis (calamondin)

Palau: *kingkang*
Samoa: *tipolo Iapani*
Hawai'i: *'alani'awa'awa*
English: calamondin, calamondin orange

C. paradisi (grapefruit)

English: grapefruit, pomelo
Fiji: grapefruit
Pitcairn: grapefruit

C. reticulata (mandarin)

Fiji: *moli madarini, madarini, narangi*
Palau: *kerekur*
Yap: *goligao*
Guam: *kahe na kikiki, lalanghita*
English: mandarin, tangerine, dancy tangerine, kid glove orange, clementine, satsuma orange
Hawai'i: *alani-pake, tacibana*
Kosrae: *muhsrisrik*
New Caledonia: *le mandarinnier*
Samoa: *moli saina*
Tonga: *moli peli*

C. sinensis (sweet orange)

RMI: *woan*
Yap: *gurgur*
Palau: *meradel*
Kiribati: *te aoranti*
Fiji: *moli unumi, moli ni taiti, molidawa, molilecau, molitaiti, mitha nimbu*
Guam: *kahet*
English: sweet orange, common orange, china orange, navel orange
French: *oranger doux*
Kosrae: *muhluhlahp*
Pitcairn: tree-orange
Samoa: *moli 'aina, moli 'aiga*
Tonga: *moli kai, moli inu*
Futu: *moli*
Nuie: *moli*
Cook Islands: *anani*
Rapa: *anani*
Society Islands: *arani*
Hawai'i: *alani Hawai'i*, Ka'u orange, Waialua orange
New Caledonia: *l'oranger*

ward the top of the tree, with upright medium to large, compact horizontal branches. Grapefruit produces large trunks (0.5–0.75 m [1.5–2.5 ft] in diameter) and a large conical head. Trees produced from seed tend to have more thorns and upright branch growth than trees produced from grafting.

Flowering

Flowers are 2–4 cm (0.8–1.6 in) in diameter, axillary, fragrant, single, few or cymose, and often perfect (having both functional stamens and pistils) or staminate. The calyx is 4–5 lobed and there are usually five petals with oil glands. Stamens number between 20 and 40. Petal colors range from white to pinkish in Kaffir lime to pinkish to purplish externally in citron and reddish in lemon varieties. The subglobose ovary is superior, with 8–18 locules (cavities), with 4–8 ovules per locule in two rows.

All citrus flowers are fragrant (pummelo flowers pictured). PHOTO: C. ELEVITCH

Leaves and branches

Leaves are entire, 4 to 8 cm (1.6–3.2 in) in length, unifoliate, fairly thick, with winged petioles. Leaves are ovate, oval or elliptical, with acute to obtuse tips, and glands containing oils in glands, which are released when crushed. Young twigs are angled in cross-section, green, and axillary single-spined, while older twigs and branches are circular in cross-section and spineless.

Fruit

The fruit is a hesperidium, a fleshy, indehiscent berry that ranges widely in size, color, shape, and juice quality. Citrus fruit range in size from 4 cm (1.6 in) for lime to over 25 cm (10 in) in diameter for pummelo. Fruits are globose to ovoid in shape (for more details see Appendix A). The fleshy endocarp is divided into 10–14 sections containing the stalked pulp and separated by thin septa. Each section contains pulp (juice vesicles) that contains a sour or sweetish watery juice. A whitish "rag" or mesocarp (also known as the albedo) covers the endocarp. In turn, the thin outer section of the leathery peel or exocarp containing many oil glands is known as the flavedo (Purseglove 1974).

Seeds

Seeds are pale whitish to greenish, flattened, and angular. The seeds are usually polyembryonic, meaning they have multiple embryos that can germinate. The embryos are either "zygotic" or "nucellar." The zygotic embryos are derived from pollination of the ovary, i.e., sexual reproduction, and therefore are not always similar in horticultural qualities to the parent tree. The nucellar embryos are derived wholly from the mother plant and display very similar characteristics to the parent plant.

Rooting habit

Over 70% of citrus tree roots are in the top meter (3.3 ft) of soil. Citrus trees produce a taproot that can extend 2 m (6.6 ft) below the surface. Fibrous roots commonly extend well beyond the canopy.

Look-a-like species

All citrus species have dark green, waxy leaves with a characteristic citrus odor, and sweet-smelling flowers. Most species are easy to differentiate by their fruit. Kaffir lime and wild orange are often mistaken for each other. According to Walter and Sam (2002), Stone (1970) distinguished the two from each other on the basis of the fruit and the

WATER TENNYSON SWINGLE

Walter Tennyson Swingle (1871–1952) conducted much of the pioneer research that forms the foundation of our present knowledge about *Citrus* and *Fortunella* species. He described many of the citrus species, varieties and relatives he collected on extensive world travels, conducted research on citrus diseases, and conducted hybridization studies that led to new groups such as the Minneola tangelos and citranges. Dr. Swingle's work with nucellar (true to type) seedlings of citrus led to the clones of commercial varieties now planted throughout the citrus-growing regions of the world. After retiring, Dr. Swingle's publication *The Botany of Citrus and its Wild Relatives of the Orange Subfamily* represented the culmination of 50 years of taxonomic botany on this important cultivated species.

Popular citrus fruits include (clockwise from upper left): calamondin, navel orange, pummelo, grapefruit, and tangerine.
PHOTOS: C. ELEVITCH

From top to bottom: New varieties of mandarins, Valencia oranges, and grapefruit. photos: CITRUS RESEARCH AND EDUCATION CENTER

petiole shape. Wild orange fruit has a smooth skin, and the petiole wings are entire. Kaffir lime fruit has bumpy skin, and the petiole wings are crenulate (toothed). The leaves of sour orange have a petiole that is much larger than that of sweet orange (about the size of grapefruit petiole). See Appendix A for more detail about fruit and leaf characteristics.

GENETICS

Variability of species

Citrus species are highly variable. Also, members of the group can hybridize readily and are generally graft- and cross-compatible. For example, some "tangerine hybrids" are tangelos (tangerine × grapefruit), tangors (tangerine × orange), and tantangelos (tangerine × tangelo).

Varietal selections are usually propagated by grafting to produce trees that are identical to the parent material. Some variation can sometimes occur even in grafted trees from natural mutations in buds ("bud sports").

Known varieties

There are many, many varieties. For example, sweet orange alone contains four groups of cultivars. These groups and their cultivars are:

- Common or round oranges (e.g., 'Valencia', 'Hamlin', 'Parson Brown', 'Pineapple')
- Blood oranges (e.g., 'Tarocco', 'Moro')
- Navel Oranges (e.g., 'Washington')
- Acidless oranges (e.g., 'Succari', 'Lima')

For more information on varieties, see Variety Table, Appendix B.

ASSOCIATED PLANT SPECIES

In general, the flora of the native habitats of citrus consists of tropical to subtropical species in humid to subhumid environments. Most citrus species are associated with the Indomalayan flora. One exception is wild orange, which is also native to Melanesia and is therefore associated with the Melanesian floristic region.

Species commonly associated as aboriginal introduction in Pacific islands

In the Pacific, most citrus species are found in cultivated areas, orchards, and homegardens. A typical high island backyard garden may have two to three species or cultivars of citrus (e.g., pummelo, mandarin, lime, etc.), coconut,

A large orange tree planted in an agroforest by Palauan migrants to Guam. This agroforest is located on the sloping area to the Agana Swamp which is being used for cultivation of swamp taro, true taro, breadnut, bananas, cassava, yams, coconuts, and other species. PHOTO: H. MANNER

mango (*Mangifera indica*), guava (*Psidium cattleianum* and *Psidium guajava*), lychee (*Litchi chinensis*), fig (*Ficus carica*), papaya (*Carica papaya*), cassava (*Hibiscus manihot*), breadfruit (*Artocarpus altilis*), and jackfruit (*A. heterophyllus*), to name a few. On atolls, citrus is less frequently found, but when present it is found in association with coconuts, breadfruit (either *A. altilis* or *A. mariannensis*, or both), papaya, and mango.

ENVIRONMENTAL PREFERENCES AND TOLERANCES

Climate

Suitable climates for citrus are the tropical and subtropical humid regions of the world. The fruit is said to achieve its highest flesh quality in subtropical humid climates or the drier regions (i.e., Mediterranean climates) with irrigation (Rieger 2002). Limes seem to be the citrus best adapted to atoll environments (Thaman and Whistler 1996). Kaffir lime is also well suited to atolls and is one of the most important sources for disease-free rootstocks for atolls.

Elevation

In the subtropics, citrus grows between sea level and 750 m (2450 ft) above sea level. In the tropics, citrus does well below 1600 m (5250 ft).

Mean annual rainfall

900–3000 mm (35–120 in). Without irrigation, 900 mm (35 in) per annum is typically needed for any significant fruit production.

Rainfall pattern

Species grow in climates with summer, winter, bimodal, or uniform rainfall.

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

1–3 months. (The dry season in Mediterranean climates where citrus is often grown is up to 4 months.)

Mean maximum temperature of hottest month

31–32°C (88–90°F) in Florida. Optimum daytime temperatures are 25–30°C (77–86°F), but temperatures can reach 43°C (110°F) in Southern California and other citrus-growing regions.

Mean minimum temperature of coldest month

8–14°C (47–57°F) in Florida. Low temperatures typically limit the range in which citrus can be grown. Citrus becomes quiescent at temperatures below 13°C (55°F).

Minimum temperature tolerated

The fruit is killed by 30 minutes of temperatures at –3––2°C (26–28°F). Stems and leaves can be killed by a few minutes at –7––3°C (20–26°F) (Rieger 2002). This is dependent on previous climatic conditions and age of fruit, leaves and branches.

Soils

Citrus tolerates a wide range of soils, from almost pure sands to organic mucks to heavy clay soils (Rieger 2002). The trees do not stand waterlogged soils but grow well in freely draining soils. They are sensitive to excessive boron, sodium carbonate, and sodium chloride (Purseglove 1968).

Soil texture

Citrus grows in a wide range of light, medium, and heavy soils (sands, sandy loams, loams, sandy clay loams, clays, clay loams, and sandy clays).

Soil drainage

Performs better on freely draining soils compared with poorly drained soils, and does not tolerate waterlogging.

Soil acidity

Citrus grows in acid to neutral soils with pH 5–8; however, their growth is greatest at pH 6–7. Trees on Swingle rootstock will grow in pH 5–7.5 and do not perform well on soils with high pH as a result of high calcium content.

Special soil tolerances

Growing on appropriate rootstocks, citrus can tolerate soils that are too dry to be productive for other crops (soybean, cotton, wheat, sugarcane, etc.).

Tolerances

Drought

Growth in Mediterranean climates where the rainfall averages less than 250 mm/yr (10 in/yr) or less and summers are dry is only possible with irrigation. Citrus can generally tolerate 3–4 months of minimal rainfall. Drought tolerance depends on temperatures, soils, wind, and the desired level of fruit production. Citrus loses productivity in drought and requires irrigation during the summer months, e.g., in Florida and Central and Southern California, to sustain intense fruit production.

Full sun

It is well adapted to high sunlight as evidenced by the presence of citrus groves in Mediterranean climates and even more arid (high net radiation) desert climates with irrigation.

Shade

Citrus can tolerate minimal shading. Shading or low light levels will affect the fruit bearing of trees (Jiffon and Syvertsen 2002). Grapefruit is more susceptible to shading than oranges. Fruit productivity may be reduced by up to 50% by shading for more than 6 months.

Fire

Trees can handle minimal amounts of smoke and heat from fires. Fires that raise the internal tree temperatures above 54°C (130°F) will damage the trees.

Frost

The species do not tolerate frost well. Previous environmental conditions dictate the trees' level of cold tolerance. When trees experience consistently cooler temperatures with little rainfall before a freeze, they can demonstrate greater tolerance of the subfreezing conditions than trees that have been actively growing. In Florida and other subtropical climates where citrus is grown commercially, smudge pots are used to maintain air circulation during frost events. When available, micro-sprinkler irrigation is the preferred method of cold protection. Irrigation water is applied prior to the arrival of freezing temperatures to warm the soil, and then again during the freezing events to provide heat to the trees that is released during the formation of ice crystals.

Waterlogging

Citrus does not tolerate waterlogging. When temperatures are over 24°C (75°F), fibrous root death from lack of oxygen (anoxia) can begin within 7–14 days. As citrus roots die, trees develop water stress symptoms such as leaf wilting, yellowing, and drop. How quickly water stress develops depends on water movement, soil pH, and the amount of hydrogen sulfide present. Hot weather will speed up the development of visible symptoms. Moving water delays the development of anoxic symptoms, so it is important to start drainage operations as soon as possible. If drainage reduces water levels 10–15 cm (4–6 in) per day, root loss can be avoided. Even circulating water within a block is better than allowing water to stagnate. Hydrogen sulfide (H_2S) minerals produced by anaerobic bacteria have an odor of rotten eggs (in acid soils but not in all cases), which is an indication that fibrous roots are dying. This process can be slower at higher soil pH. Swingle and Carrizo rootstocks tend to tolerate flooding better than sour orange and Cleo.

Salt

Citrus does not tolerate salinity well. For this reason, most citrus grows poorly in coastal and atoll environments. High levels of salt in water will increase the osmotic pressure and reduce the ease of water uptake by trees (Boman and Stover 2002). Citrus species are differentially sensitive to salt depending on the type of salt (Mass 1992).

Wind

Citrus trees are susceptible to leaf, branch, and fruit damage in strong winds.

GROWTH AND DEVELOPMENT

During the first year after planting, tree growth is usually minimal. Assuming adequate moisture and nutrients, trees will greatly increase in height and diameter between the second and fourth year after planting. For grafted trees, during the first 3–4 years after planting, the tree undergoes primarily vegetative growth, but fruit may occasionally be produced. Vegetative growth flushes occur during the spring and summer months. While citrus is an evergreen, there are annual periods of necessary quiescence, which normally occur during the winter months when lower temperatures are experienced. Once trees enter into regular fruit bearing, vegetative growth and the annual increase in tree height and diameter will slow. The desired tree size is typically achieved between ten and fourteen years after planting. Fruiting typically declines from its peak after 20–25 years, but trees are known to survive and bear fruit for 250 years (Hume 1938).

Growth rate

Growth rates are highly variable based on climate, cultural practices, tree spacing, scion, and rootstock (Wheaton et al. 1999). Younger trees (approximately 5–10 years old) tend to have greater growth rates in relation to beginning tree size. In a California study, trees grew 10 cm/yr (4 in) in height between 3 and 6 years. Comparatively, trees between 6 and 12 years grew at a rate of 30 cm/yr (12 in) in height. Trunk cross-sectional areas can increase from 5 to 33 cm^2 (0.8–5.1 in^2) each year. Roots of citrus trees less than 5 years old were found to extend between 2 and 5 mm/day (0.08–0.2 in/day) depending on the soil moisture levels.

Flowering

Flowering can occur within the second year after planting, but regular flowering occurs 4 years after planting. Seasonal flowering occurs after the winter months when trees have experienced a period of quiescence. Over 300 hours of temperature below 20°C (68°F) followed by warm temperatures will induce flowering. Multiple blooms each year can be experienced on trees growing in tropical conditions. Only a small percentage of flowers produce fruits; large numbers of flowers drop after opening, and large numbers of fruits drop 10–12 weeks after pollination. Fruits take 7–14 months to mature (Purseglove 1974).

Reaction to competition

Citrus trees have demonstrated resiliency to competition from some annual broadleaf weeds. In the first year after planting, trunk and canopy growth of citrus trees were affected by Spanish needle (*Bidens bipinnata*). The canopy is more affected by competition than the trunk growth (Buker 2005). Between 5 and 8 years after planting, trees are still susceptible to competition with annual grasses. Season-long competition reduced fruit yields 30% (Carvalho et al. 2003). The greatest reported impact by weeds on citrus yields was from a perennial grass; Bermuda grass (*Cynodon dactylon*) reduced yields 50% after season-long competition (Jordan 1981).

PROPAGATION

Citrus can be propagated by many methods including seeds, cuttings, air-layering, grafting by many methods, and tissue culture. Although some cultivars can be reproduced by seed, this method is considered inferior. Varieties that are reproduced by seed require more time to produce fruit, are more susceptible to diseases, are more difficult to keep true to type, and tend to produce more thorns than grafted varieties. Their fruit is also harder to pick as a result of the upright and thorny growth. In commercial practice, citrus is commonly propagated by grafting an individual bud of a selected variety onto a rootstock seedling.

Vegetative propagation known as "T-budding"

Budding uses a bud cut from the parent tree (scion) that is grafted onto a seedling rootstock. Once the bud is in place, the foliage of the rootstock above it is cut off or tied down to "force" the bud growth. There are several horticultural advantages to budding. A major advantage is the known success in reproducing the characteristics of the parent tree (for more information, see Williamson and Jackson 1994). Producing trees through budding allows the selection of rootstocks that can impart disease tolerance and allow production in soils not suited for the scion.

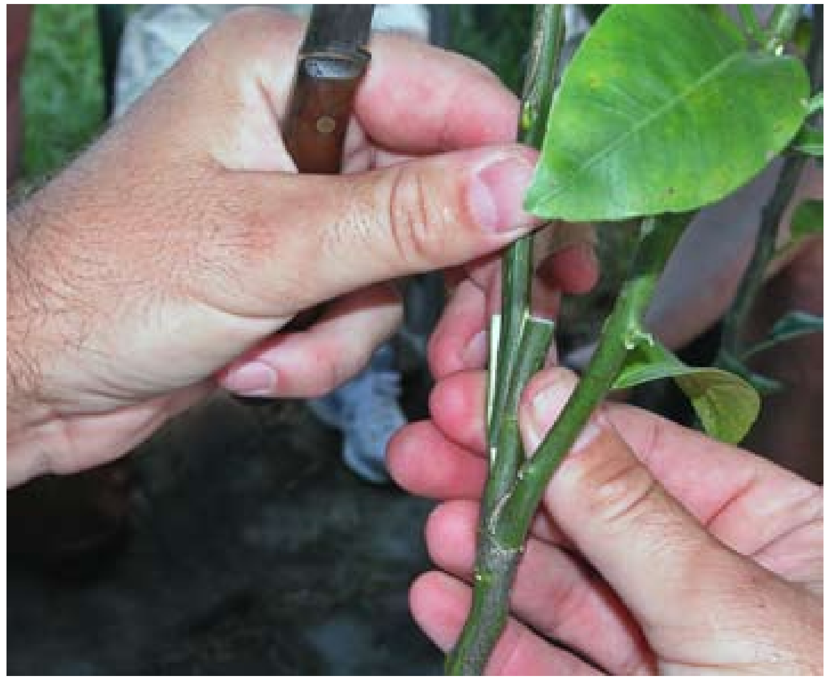
Budwood collection

Select branches that are mature, vigorous, round (rather than angular), and close to or smaller than the diameter of the rootstock in which the bud will be grafted. Adequate maturity can often be identified by formation of lignified tissue in the green bark (lines of wood formation). Branches earmarked for budwood production should be regularly inspected and treated to keep them free of pathogens and

PATHOGEN WARNING

Before any propagation effort is attempted, thorough efforts should be made to determine local and international regulations.

Devastating pathogens can be inadvertently spread through propagation of seeds and vegetative material used for grafting. Before propagating a tree, the local regional (county, state, etc.) agricultural authorities should be contacted regarding the presence of pathogens in the area. Most countries have strict regulations about the import of citrus, and government agricultural quarantine departments must be consulted prior to import. When buying commercial citrus plants, make sure the nursery has followed applicable regulations for disease-free propagation.



Left: A recent bud graft, showing callous formation around the edge. PHOTO: J. WILLIAMSON **Right: Grafting scion wood to the top of a seedling (wedge or cleft grafting) is also a common method of propagating citrus varieties.** PHOTO: C. ELEVITCH

insects.

Cut the selected limbs from the parent tree so that 20–25 cm (8–10 in) of desirable buds will remain after removing the new flush and all leaves. When removing the leaves, a small portion of the petiole that is adjacent to the bud should remain attached to the bud as a handle until the budding process is completed (Williamson and Jackson 1994).

Bud preparation

Budding can be achieved with very little equipment. A sharp knife is needed to cut buds from the parent tree. In addition, polyethylene wrap is needed to keep the bud secured to the rootstock and to seal in moisture and seal out rain or irrigation water.

Budwood storage

Budwood cut from the parent tree is best used shortly after cutting. However, if stored moist in a sealed plastic bag in a cool place, budwood can survive for 2–3 months after cutting from the parent plant. Once individual buds are cut from the budwood, they should be used immediately for best grafting success, although individual buds may remain viable for a few hours when stored cool and moist.

Pre-grafting treatments

No pretreatments are necessary for successful budding of healthy scions.

Propagation area

Survival of budded plants is greater in protected environments. If available, shade houses or greenhouses with adequate water are advisable.

Early growth

Buds that are successfully growing will be green and have callus forming around the edges 14–21 days after cutting. Wraps can be removed at this time.

Rootstock propagation

Seed removed from the fruit and cleaned and dried can be stored for a year in a cool, dry atmosphere (Williamson and Jackson 1994). Rootstock seedlings should germinate within days of planting, and are ready to bud to as soon as they have a stem about 6 mm (0.15 in) in diameter. Growth media should have good drainage and moderate water-holding capacity. Poly bags have been used successfully as pots if they have drain holes at the bottom. Media that are high in organic material (>50%) can create problems and should be avoided if possible.

Time to outplanting

Trees may be ready to plant 6–12 months after budding, however, the longer they remain in a protected environment, the greater the chance of survival. Larger plants grown in larger containers bear fruit sooner after outplanting than smaller plants.

Approximate size at outplanting

Trunk diameter and tree height vary with variety. Trees are normally 0.5 m (20 in) in height and trunk diameter is usually 1–2 cm (0.4–0.8 in).

Guidelines for outplanting

If replanting into a site that had citrus trees, soil fumigation prior to planting is advised. Nematodes, *Phytophthora*, and blight risk are reduced by fumigation. Regrowth of previous rootstocks can be expected if they are not completely removed or destroyed. Survival rate of newly planted trees when properly cared for is 95% or higher.

Other comments on propagation

Cuttings, especially from young branches, root well. This method can be used to preserve varieties until suitable rootstock is available.

DISADVANTAGES

Genetic variation in cultivation is limited, as vegetative propagation is the primary method of producing new plants. The limited genetic variation renders citrus plants susceptible to pathological and entomological pressures. Skin irritants contained in the peel may cause dermatitis or other chronic skin conditions in people who have constant contact with citrus oil or skin.

Potential for invasiveness

Although some species have naturalized on some Pacific islands, this is rarely considered a problem. Most species grown in the Pacific islands are restricted to cultivated areas.

Pests

Citrus is affected by numerous species of insects, mites, and disease pathogens that infest the leaves, flowers, bark, fruit, and branches of citrus.

Insects and mites

Mites

Several species of mites are pests of citrus, most notably the citrus rust mite, *Phyllocoptruta oleivora*, which causes minimal damage to foliage but extensive damage to fruit. They move from the leaves to the young fruit when it sets and extract the cell contents from the skin. The damage is generally minor in regard to production but causes a russetting of the fruit, making it unmarketable. Other mite pests are the citrus bud mite, *Eriophyes sheldoni*, the red spider mite, *Panonychus citri*, and the broad mite, *Polyphagotarsonemus latus.*

Scales, mealybugs, and whiteflies

This group of related insects is very common, and they feed on the foliage, fruit, and roots of citrus. Generally, they pierce plant cells with their needle-like mouthparts and suck out the liquid; many then secrete honeydew. Ants, such as the longlegged ant, *Anoplolepis longipes,* feed on the honeydew and protect the pest insects from predators. Sooty mold (a fungus) also grows on the honeydew and reduces light penetration to the leaf (and thereby photosynthesis) but does not infect the leaf.

There are numerous pest species of these insects, but among the ones causing the most damage are the California red scale, *Aonidiella aurantii*, which attacks fruit, foliage and twigs; black scale, *Saissetia* species; the citrus mealybug, *Planococcus citri*; the citrus whitefly, *Dialeurodes citri*; the citrus blackfly, *Aleurocanthus woglumi*; and the woolly whitefly, *Aleurothyrixus floccosus*.

Aphids, psyllids, and sharpshooters

This group of insects causes similar damage to that caused by the group above but is notable due to their ability to transmit diseases agents such as viruses and bacteria. They usually feed on new leaves and stems and can cause significant damage; however, the diseases vectored are usually more serious than the feeding damage. Many species of aphid affect citrus; one of the most widespread is the brown citrus aphid, *Toxoptera citricida*, which is known to carry citrus tristeza virus. *Diaphorina citri*, the Asian citrus psyllid, is a carrier of the pathogen causing greening disease. The glassy winged sharpshooter, *Homalodisca coagulata*, is also a pest of citrus.

Fruit flies

The Oriental fruit fly, *Bactrocera dorsalis,* and the Mediterranean fruit fly, *Ceratitis capitata*, are the main fruit fly pests of citrus. The major problem they pose is that they deposit their eggs in the fruit as soon as there is any color break, and the larvae burrow into the fruit and feed. This makes the fruit unpalatable as well as having the potential to introduce these pests, which cause serious damage to numerous agricultural products, into new areas.

Other insect pests

The citrus leafminer, *Phyllocnistis citrella*, Chinese rose beetle, *Adoretus sinicus*, thrips such as *Scirtothrips citri*, and other insects feed on citrus causing varying levels of damage.

Clockwise from top left: Mites on lemons showing fruit bronzing symptom; mealybugs; nutrient deficiency leaf symptoms, probably iron; leaf miner. PHOTOS: S. C. NELSON

Diseases and disorders

Physiological disorders (not caused by pathogens)

Fruit splitting

This disorder is common on fruits with thin peels such as navel oranges (Washington navels are particularly prone to this) and tangerines. Although its specific cause is unknown, no pathogen has been associated with it, and it is likely due in part to uneven growth caused by weather or by erratic irrigation and fertilization. Addition of potassium fertilizer (foliar spray) will reduce splitting in some years (Tucker et al. 1994).

Root rot

There are many possible causes of root rot, but one common cause is watering too frequently. Root rot can be a direct result of the lack of oxygen in the root zone due to over-irrigation or an indirect result when over-irrigation predisposes the roots to infection by a root rotting pathogen.

Nutrient deficiencies

Nutrient deficiencies can be caused by leaching due to excessive irrigation or rain, by naturally low soil nutrient levels, by soil nutrient imbalances, improper pH, or insufficient or incorrect fertilizer application. Nitrogen, zinc, magnesium and iron deficiencies are common and correctable.

Diseases caused by pathogens

Citrus is prone to many diseases of the leaves, roots, wood and fruit; some of the more common ones are listed below.

Root rot and Phytophthora gummosis

There are many pathogenic species of the *Phytophthora* fungus causing root rots that prevent the plant from taking up sufficient water and nutrients. The leaves will turn yellow, wilt, and may drop; the tree slowly declines, and often will die.

Gummosis, another disease caused by *Phytophthora* spp., affects the base of the trunk and lower limbs from which a clear gum is secreted. The bark dries upward, hardens, and cracks; the lesions spread and often girdle the branch or trunk. Most scion wood is very susceptible to this disease; be sure the graft union is well above the soil level at planting.

Melanose

Melanose is widespread but is a problem only when inoculum levels are high and there is extended rainfall during early fruit development. The symptoms begin as small, brown, sunken spots, which become raised as they develop, on the leaves and fruit. On the fruit the spots may combine and expand to become relatively large diseased areas, depending on the stage of fruit development when they are infected.

Greasy spot

Greasy spot, a common disease in hot, humid areas, is caused by the fungus *Mycosphaerella citri*. It produces brown to black lesions on the undersides of leaves, which appear as grease-soaked spots, and very small lesions on the skin of the fruit. If severe, the disease causes defoliation leading to a significant reduction in yield.

Scab

Citrus scab, caused by *Elsinoe fawcetti*, is the most widespread of three scab diseases. Infection causes a small bulge on one side of the leaf and a corresponding depression on the other side. Raised, brown pustules form on the fruit rind, becoming corky as they develop. The symptoms resemble scaring from wind; scab and wind scar may occur together where a leaf is in contact with the fruit.

Top: Scab symptoms on fruit. Bottom: Canker symptoms on leaves and fruit. PHOTOS: S. C. NELSON

Black spot

Black spot infects leaves and fruit but is only a problem as a disease of the fruit. Leaves infected by *Guignardia citricarpa* may develop small necrotic spots with a gray center but most often do not show symptoms. On fruit, the black spots may take various forms, making the disease difficult to identify. The spots make the fruit unmarketable as fresh fruit but they can be used for processing. When the infection is severe, fruit may drop prematurely.

Citrus canker

All the previously discussed diseases are caused by fungi; citrus canker is caused by a bacterium, *Xanthomonas axonopodis* pv. *citri*. Symptoms of canker are lesions on young fruit and leaves from which bacterial ooze is exuded under humid conditions. On leaves the lesions begin as circular, pinpoint-size spots which enlarge and become irregularly shaped pustules surrounded by a characteristic yellow halo. An even more reliable symptom is a water-soaked edge that develops around the lesion. The size of the leaf spots can vary with cultivar and time of infection but will be approximately the same on each leaf. On fruits the lesion size varies but will be otherwise similar to the leaf lesions.

Greening

Greening, one of the most devastating citrus diseases, is caused by a bacterium which grows in the bark, leaves, and veins of infected trees. It had previously been thought to be caused by a virus, but the pathogen has now been identified as *Liberobacter* species. Affected fruit do not color properly or remain green, consequently the name, greening. Other names for the disease, yellow dragon and yellow shoot, may be more descriptive, because newly infected trees produce shoots that are yellow. Leaf symptoms on chronically infected trees may resemble nutrient deficiencies. Trees will die back and decline severely.

Tristeza

Tristeza virus is one of the most serious pathogens of citrus and is widespread throughout citrus-growing areas. Symptoms are highly variable among citrus species and cultivars and are affected by the strain of the virus and the environmental conditions. Stunting, stem pitting, vein clearing, leaf cupping, yellowing, and reduced fruit size are common symptoms. Vein clearing (disappearance of green color in or along the leaf veins, visible when the leaf is held up to light) and stem pitting (small holes in the stem underneath the bark) can often be used to diagnose this disease. Tristeza is often severe, resulting in significantly reduced yields and often tree death.

Psorosis-ringspot

Psorosis-ringspot, a widespread problem particularly in old-line trees, is a complex of several diseases. Although not fully understood, the disease is believed to be caused by a virus or virus-like pathogen. Bark scaling and flaking on trunks and limbs of sweet orange, grapefruit, and occasionally mandarins is a classic symptom of one form of the disease. Young leaves may show various symptoms including yellow flecks, leaf mottling, or distinct light green patterns, and young shoots may die back. Mature leaves may have raised ring-spots (a yellowish ring with green tissue in the center) or large, irregular yellowish or light green patterns; fruits may also show ring-spots.

Nematodes

Several nematode species infect citrus and cause mild to serious damage depending on the species of nematode and citrus, the age of the plants at infection, and the environmental conditions. The only species that is found worldwide is the citrus nematode, *Tylenchulus semipenetrans*, which is most damaging in dry areas with moderate temperatures. Due to the low rate of population growth of the citrus nematode and the slow development of symptoms, the disease it causes is called citrus slow decline. Other nematodes that are pathogens of citrus are the burrowing nematode, *Radopholus* species, causing spreading decline; the lesion nematode, *Pratylenchus* species, causing citrus slump; and the root-knot nematode, *Meloidogyne* species, causing rootknot. Because these nematodes infest the roots of the plant, they interfere with the uptake of water and nutrients, causing symptoms such as reduced leaf and fruit size, wilting, canopy thinning, and a general, slow decline.

Postharvest diseases

Some common postharvest fungus diseases of citrus are stem-end rot (*Lasiodiplodia theobromae* or *Diaporthe citri*), green mold (*Penicillium digitatum*), sour rot (*Galactomyces citri-aurantii*), anthracnose (*Colletotrichum gloeosporioides*), *Alternaria* stem-end rot (*Alternaria citri*), and brown rot (*Phytophthora palmivora* and *P. nicotianae*).

AGROFORESTRY/ENVIRONMENTAL PRACTICES

Homegardens

Citrus trees are very common in homegardens, where three to four species are often found for fruit, juice, flavorings, and as ornamentals.

Living fences

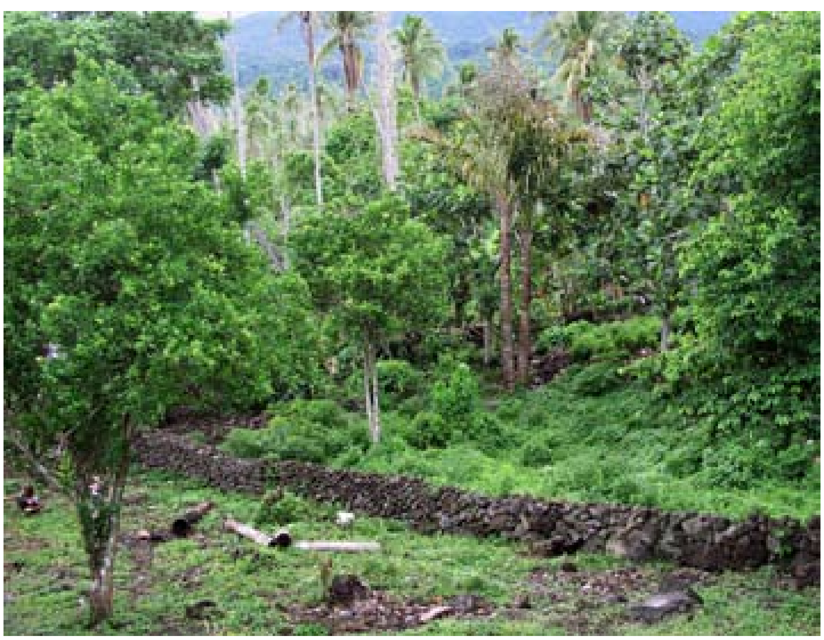
Thorny types may be useful for living fences, especially when hedged.

Bee forage

Many citrus species including lime, sour orange, Kaffir lime, and calamondin are known to be good forage plants for bees (Thaman et al. 2000).

Ornamental

Most citrus species have an ornamental appearance and serve this purpose in Pacific island mixed homegardens.



Top: Sweet orange growing over coffee in Kona, Hawai'i. PHOTO: C. ELEVITCH
Bottom: Citrus growing among other tree crops including sago palm and coconut in Aopo Village, Savai'i, Samoa. PHOTO: H. MANNER

USES AND PRODUCTS

Fruit

All species are extremely important for their fruit, which is eaten fresh or processed in numerous ways.

Nut/seed

An industrial extract of grapefruit seeds and pulp is used to produce a potent topical antibacterial and fungicidal agent.

Beverage/drink/tea

Fruit juices of all species can be used in beverages. Lemon and sweet orange leaves are boiled to make tea. In Egypt and elsewhere, sour orange juice has been fermented to make wine.

Medicinal

Citrus species are important in traditional Pacific island medicine. In Samoa, a leaf infusion made from sweet orange is used against mouth sores in infants (Goethesson 1997). Citron leaves are used together with other plant parts to make infusions for treating stomach and skin ailments (Whistler 1996). Also in Samoa, a sweet orange bark infusion is used to treat postpartum sickness, serious flu, and internal injuries (Whistler 1996). In Tonga, an infusion of sweet orange leaves, usually together with leaves of mango, *Glochidion ramiflorum*, *Diospyros major*, and/or the bark of breadfruit, is used as a potion to treat "relapse sickness," mostly affecting postpartum women (Whistler 1992). In Tahiti, citrus leaves are used for internal ailments and fractures. In Fiji, the scraped root of pummelo is used to treat hemorrhoids. In the United States, citrus is suggested as part of a healthy diet because of its high vitamin C content and its lycopene and flavonoids, which are known to reduce prostate and breast cancer risk, reduce viral effects and inflammation, and improve capillary activity and cholesterol levels.

Flavoring/spice

Most species have value as flavorings. For example, lime and lemon are commonly used to marinate raw fish and to flavor food. Whole limes are also pickled as a relish (achar) for curry. Sour orange skin and flesh is used to make marmalade. Kaffir lime leaves are used as a flavoring in cooked sauces.

Honey

Citrus is one of the most important honey plants in many parts of the world. In California, for example, citrus has been said to constitute 25% of honey production (Morton 1987).

Animal fodder

The pulp and other by-products from juice production are used as cattle feed. The seeds and peels are dried, then physically pressed and cooked into pellet-shaped feed for cattle in the United States. Birds are known to feed on varieties with seedy fruit.

Beautiful/fragrant flowers

All species have fragrant flowers, which are very pleasant in a homegarden.

Timber

Pummelo and sweet orange wood is used in light construction (Clarke and Thaman 1993). Sour orange wood is hard, fine grained, and valued for cabinetry and turnery (bowls, etc.). In Cuba, sour orange is made into baseball bats (Morton 1987).

Fuelwood

Citrus as fuelwood is generally of minor importance in the Pacific islands. Pummelo wood is considered a good firewood.

Craft wood/tools

Wood of wild orange was used for axe handles and canes in Samoa (Walter and Sam 2002). Lemon wood is used for tool handles (Clarke and Thaman 1993). Wild orange wood is used as the anvil in tapa pounding in Samoa (Whistler 2000). Wood of Kaffir lime and pummelo has been noted as having importance for craft wood (Thaman et al. 2000).

Body ornamentation/garlands

Sweet orange and Kaffir lime flowers are sometimes used in garlands in the Pacific islands (Thaman et al. 2000 and Clarke and Thaman 1993).

Toxin/insecticide/fish poison

Kaffir lime has been noted as having potential in this regard (Thaman et al. 2000).

Cosmetic/soap/perfume

The macerated pulp and leaves of wild orange were used as a shampoo in Guam, Samoa, and Fiji (Walter and Sam 2002). In Guam, Stone (1970) noted that the pulp was used for washing clothes and hair. Stone (1970) also wrote that Kaffir lime has the same uses as wild orange and sour orange.

In Chuuk, the pounded roots of a citrus species known locally as kurukur, are mixed with the leaves, bark, and fruit of other plants to make a perfumed precipitate (called soonen ayis) for scenting necklaces, headbands, hair, and body (Merlin and Juvik 1996).

Oil/lubricant

Oils in the peel, leaf, and flower are used in cosmetics and as medicinals. The flowers of sour orange yield neroli oil, which is very important in the perfume industry (Morton 1987). Solvents extracted from citrus peels, particularly oranges, are used in general-purpose cleaners, hand cleaners, furniture polishes, soaps, and pet shampoo. Orange oil is also used for fragrance in air fresheners, candles, and aromatherapy.

Other

The whole fruits of pummelo are used for toys (wheels, etc.). In Samoa, the fruits of sour orange are used in a game called te ‘aga, wrapped with a piece of beach hibiscus (*Hibiscus tiliaceus*) bark fiber (Whistler 2000).

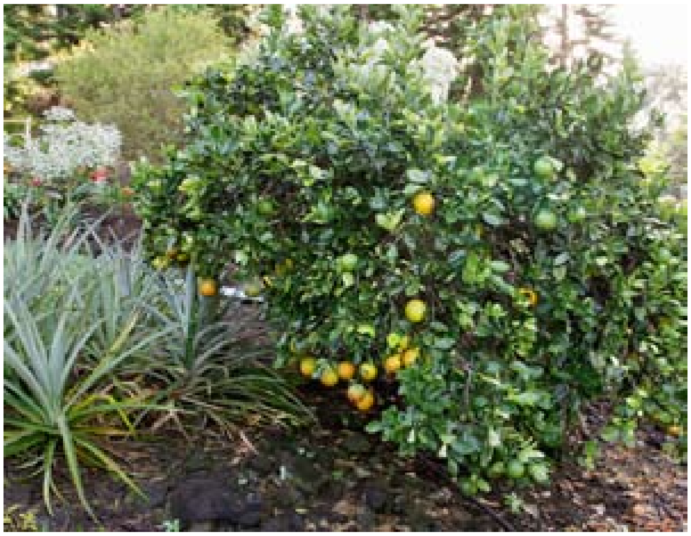
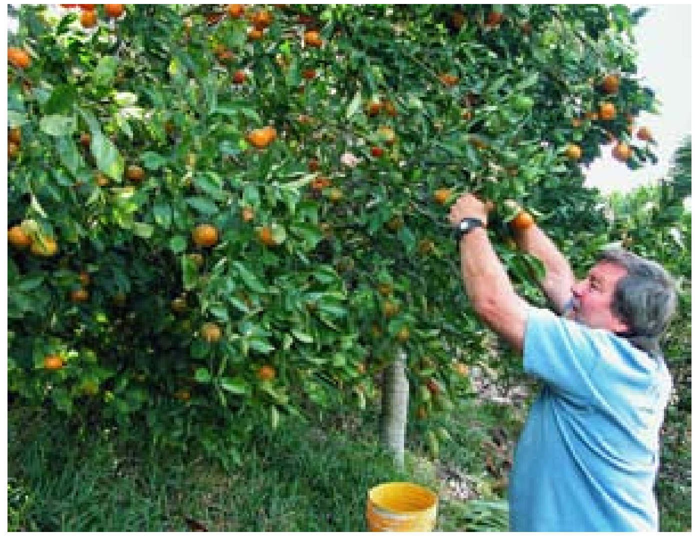
URBAN AND COMMUNITY FORESTRY

Citrus can be an excellent option for urban planting. Final tree height is not excessive, and the root systems are not disruptive to permanent structures or other trees. Citrus is sensitive to ozone affects and has some basic requirements for air quality. Trees thrive in locations with drainage that does not allow water to stand for more than a week. Citrus is highly suitable for use in a homegarden for fruit and juice. Its abundant, fragrant flowers are a visually and aromatically pleasing addition to the landscape, especially when situated along paths, near lanais, or outside windows.

If planting is desired in temperate climates, then careful site selection can allow citrus to be grown outside of its natural range. Citrus trees should be planted where natural or structural windbreaks will prevent prevailing cold winds from chilling trees during freeze events and where walls can reflect heat back onto the trees.

Size

Size varies with species and variety. Generally, annual pruning is used to maintain tree size and shape, while stimulating fruit production. Another method of maintaining a small size is to plant varieties that are grafted to dwarfing rootstocks, or, if space is very limited, by growing the trees

Left: Grafted trees in cultivation, such as this navel orange, are usually pruned to a size and shape that facilitates picking. Right: Picking an abundant crop of tangerines in a homegarden. PHOTOS: C. ELEVITCH

in large containers (Wheaton et al. 1999).

Rate of growth in a landscape

Depending on climate, soils, and care, tree growth during the early years can reach 30 cm/yr (10 in/yr), slowing to 10 cm/yr (4 in/yr) as the tree attains its mature size.

Roots

The majority of citrus roots are found within the top 1 m (3.3 ft) of soil. Their rooting systems are extensive enough to strongly compete with other plants in the area. The individual roots of citrus are not as large as some trees, and they typically do not disrupt man-made structures. It is unlikely that citrus roots interfere with pipes, as underground irrigation has been used extensively for citrus worldwide.

Products commonly used in a household

Fruit for eating or juicing is the main product from citrus grown in a landscape. Other products include leaves for cooking (e.g., Kaffir lime leaves in Thai food) and cut flowers for fragrant flower arrangements.

Light requirements

Most citrus species require full sunlight to grow well and produce fruit. Shading greatly decreases plant vigor and productivity.

Water/soil requirements

Adequate soil moisture is very important for quality fruit production. Dry conditions can mean smaller fruit, premature fruit drop, and dry and grainy fruit. Consistent, but not too frequent, irrigation may be necessary for optimal health and productivity. Mulching can help keep the soil moist by reducing evaporation of soil moisture. Most rootstocks generally do poorly on soils excessively high in organic matter (Histosols).

In areas with shallow, poorly drained soils, good site preparation can allow citrus to be successfully grown. Use of either drain tiles under the tree that lead to a holding pond or bedding (mounding of surrounding soil on top of existing soil where tree is to be planted) can allow trees to grow.

Life span

Trees growing on favorable soils that are well maintained (watered and fertilized regularly) can last 30 years before they lose some of the full beauty of the foliage.

Varieties favored for use in a homegardens or for street trees

Sweet Orange: 'Navel', 'Parson Brown', 'Pineapple', 'Sunstar', 'Gardner', 'Midsweet', 'Valencia'.

Grapefruit: 'Duncan', 'Marsh', 'Redblush', 'Thompson', 'Flame', 'Ray Ruby'.

Specialty: 'Satsuma', 'Robinson', 'Fallglo', 'Sunburst', 'Orlando', 'Dancy', 'Minneola', 'Temple', 'Murcott', 'Kumquat'.

Seasonality of leaf flush, flowering, fruiting

In tropical climates, flowering and fruiting can occur nearly year round. A main flowering tends to occur in the spring.

Use as living fence, hedge, or visual/noise barrier

Citrus can be used as a barrier hedge when trees are planted close together. Many varieties are spiny, which can enhance the effect of a hedge as a barrier. However, when hedged it takes time for trees to regrow full foliage, and if the trees do not receive ample sunlight, the regrowth occurs primarily in the tops, leaving the trunks exposed.

Bird/bee/wildlife

Citrus supports bees, which produce honey. Birds often build nests within the canopy, and some will feed on the seeds, fruit, or the insects that feed on tree foliage. Snakes, where present, are commonly found within the canopies.

Maintenance requirements

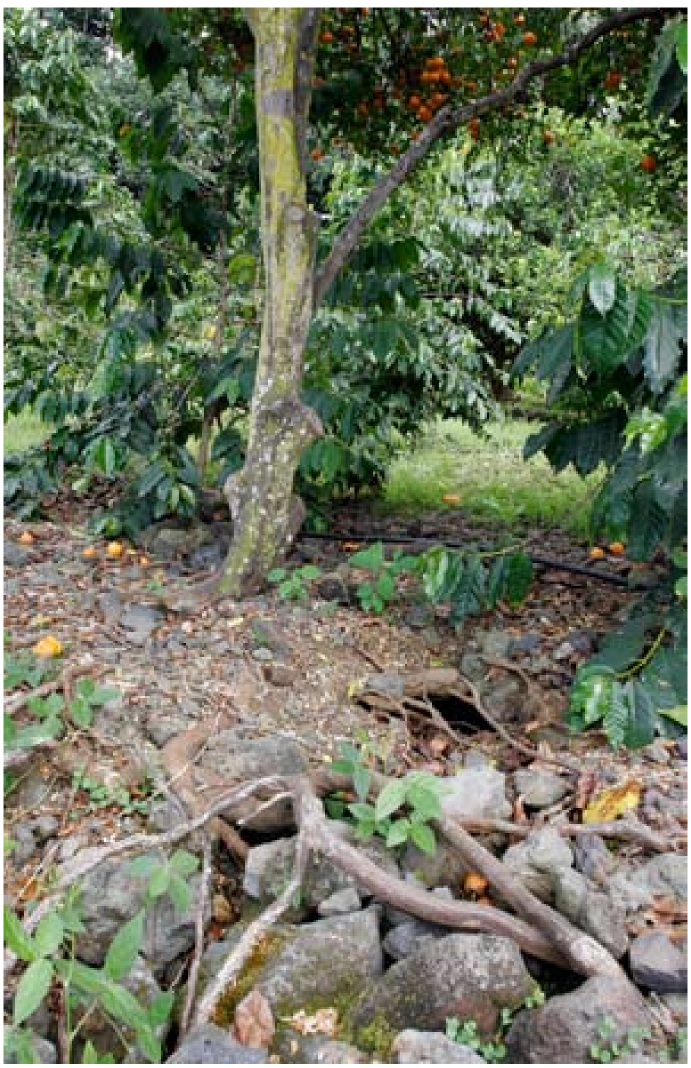
Once the tree has reached the desired height, annual pruning may be required to maintain the height, thin the growth, and promote prolific fruiting. Most fruit is set on wood that is less than 2 years old. Pruning is least damaging to tree yields when done on a regular basis to wood (branches) on the outside of the canopy. Wood can and should be removed if the section has died or has begun to decay.

Special considerations regarding leaf, branch and fruit drop

If the fruit is not harvested, it will fall off the tree, rot, attract fruit flies, and produce slightly offensive odors. Trees with heavy fruit crops are susceptible to breakage in high winds. Tangerines are particularly susceptible to breakage and splitting in windstorms.

Nuisance issues: Poisonous parts, thorns/spines, foul smell

Some species (e.g., limes) have many thorns. Sweet orange trees produced from seed will have fewer thorns as they



Left: Citrus' surface roots can easily be exposed by erosion, especially on rocky soils. Right: Fallen fruit should be removed to avoid attracting and fostering pests. PHOTOS: C. ELEVITCH

WHEN TO HARVEST FRUIT

Although it is commonly thought that citrus should be picked after turning color, this is not necessarily true, especially in tropical climates. Many types of citrus fruits, such as grapefruits and mandarins, do not fully turn color when ripe, and commercial producers use special treatments to induce full color break to make the fruit more appealing to consumers. In other words, skin color is a poor indicator of ripeness. Also, waiting for the skin to fully turn color also can greatly increase fruit fly damage. The best way to check for ripeness is by tasting a fruit or two that appear to be fully developed.

mature.

Common pest problems

Climates that receive moderate to high rainfall, temperatures, and humidity will experience more insect, weed, and disease pressure. Regardless of the pest management program (IPM, organic, or conventional) the success of the program will be greatly influenced by selecting the proper variety (Inserra et al. 2003).

As with any plant, keeping citrus healthy and vigorous will reduce the effects of insects and diseases in two ways, making them less likely to be infested as well as more able to withstand the pest. This includes

- Fertilize plants on a regular schedule
- Keep weeds under control
- Prune to maintain vigor
- Increase air and light penetration
- Remove any diseased wood
- Provide an adequate and consistent supply of water
- Do not irrigate too frequently to avoid disease infestation
- Observe trees for signs of insects, disease, or other problems

Several species of mites, scales, aphids, mealybugs, and fruit flies are common pests of citrus. Diseases of citrus that are often found are root rot, gummosis, melanose, greasy spot, scab, black spot, and citrus canker. Nematodes and viruses also cause several diseases of citrus.

See “Susceptibility to pests/pathogens” above for more information.

COMMERCIAL PRODUCTS

The fruits and juice of all citrus are a local cash crop on all Pacific islands. Lime, lemon, grapefruit, mandarin, and sweet orange have been export crops for a number of Pacific islands.

Spacing for commercial production

Tree spacing for areas with greater soil depth will be wider than for areas with shallow soil depth. Likewise, trees with more vigorous rootstocks should be spaced further apart than trees with less vigorous rootstocks. A common range for tree spacing is 6–7.5 m (20–25 ft) between rows and 3–4.5 m (10–15 ft) within rows. Use wider spacing for more vigorous trees (see, e.g., Tucker et al. 1994b).

Management objectives

Pruning should be done when trees are young to establish the basic shape and continued as trees mature. In commercial orchards, pruning facilitates normal daily operations and increases yields. Where trees have outgrown their allotted space, pruning can increase the bearing surface. Trees that grow too close together will shade out the lower canopy portions and in return decrease fruit set. When pruned to allow light to reach the top and lower sides of tree, the increased bearing surface results in greater fruit set. Any sprouts arising from the rootstock (i.e., from below the graft union) should be removed. Pruning of the scion of young trees will only delay growth and extend the juvenility.

Pruning is conducted to either encourage growth (thinning) or reduce tree size (heading back). Thinning of bearing trees encourages vegetative growth, and removal of interior branches can encourage the outward growth into the allotted area planned for the mature tree to occupy. Heading back reduces the outward canopy growth through top-

There is no shortage of exciting citrus varieties to try. Here, Tahitian pompelmous is displayed as a new commercial crop in Kona, Hawai‘i. PHOTO: C. ELEVITCH ping and hedging of branches.

Pruning can have negative effects on bearing. When wood is removed, carbohydrates and nitrogen are removed from the tree, upsetting the natural balance. Withholding fertilization before pruning can reduce excessive flushing by ensuring that more carbohydrates are present in the tree than nitrogen. Pruning deadwood is not the same as pruning viable shoots, as there are no carbohydrates or nitrogen available in deadwood. Thus, it is not necessary to withhold fertilizer when deadwood pruning is planned. Further information should be sought before conducting pruning (see, e.g., Tucker et al. 1994a).

Fertilizers containing N and K are best applied in small applications several times over the course of the year rather than all at once and best placed in holes dug around the drip line of the canopy of the trees. If feasible, monthly foliar applications of micronutrients is helpful. Overuse of high-nitrogen fertilizers will encourage a proliferation of piercing-sucking insects, including aphids, scales, and mealybugs, and will foster sooty mold. The most effective fertilization strategy is developed by first testing the soil of the planting site.

Alternately or in addition to inorganic fertilizers, well composted manures or other organic fertilizers can be added to the planting hole and spread around the base of the tree occasionally. Citrus responds very well to additions of organic matter. Compost, composted manures (such as composted steer manure mixed in the planting hole with the soil at planting) combined with regular irrigation during the first 3 months will ensure vigorous plant growth in the first year.

Trees benefit greatly from mulching, which slowly adds organic matter to the soil, helps retain soil moisture, and suppresses weeds. However, deep mulch should be kept from directly contacting the trunk.

Design considerations

The desired eating quality of fruits must be considered when planting. For example some varieties (‘Nova’, ‘Clementine’, ‘Aflourer’, etc.) must be planted in solid blocks of one variety to produce seedless fruit. If other citrus is nearby, cross pollination will occur and produce seedy

Top: Selecting the proper tree spacing and rootstock to match the environmental conditions can reduce pruning requirements and fruit yield fluctuations. PHOTO: R. BUKER **Bottom: Deadwood such as at the top of this grapefruit tree should be removed.** PHOTO: C. ELEVITCH fruit.

Estimated yields

In any given year, yields of well fertilized and watered mature trees are typically between 41 and 184 kg (90–400 lb) per tree. As trees increase in age, the typical yield should also increase. Once the canopy is fully developed, yields stabilize. In Florida, typical commercial yields for early and mid-season maturing varieties ('Hamlin', 'Parson Brown', 'Pineapple', 'Early Gold', etc.) are 182 kg/tree (400 lb/tree), Navel and Valencia oranges 125 kg/tree (275 lb/tree), white grapefruit 204 kg/tree (450 lb/tree), and red grapefruit 185 kg/tree (410 lb/tree). These yields represent collective averages over the 4 years 2000–2004 in Florida.

On-farm processing

The best method of preventing fruit decay is to selectively harvest and pack fruit. Once decaying fruit has been removed, water can be used to sanitize the fruit. Water above 71°C (160°F) or an approved sanitizing agent (e.g., chlorine, peroxyacetic acid, etc.) can be used to treat equipment that is used to store fruit. Cleaned fruit should be kept in a very cool (not freezing) location until utilized.

Citrus exports from the Pacific islands

In contrast to the mainland United States and other countries, the Pacific islands are small producers and exporters of citrus fruit and products. Consequently, statistical data on the export of citrus and citrus products from the Pacific islands are often unavailable, non-existent, or highly variable from one year to the next, and from one database to the next. Appendix C is a compilation of recent citrus fruit and products export for some Pacific islands.

INTERPLANTING/FARM APPLICATIONS

Example system

Location

Kona, Hawai'i

Description

Small-scale farmers growing coffee frequently interplant fields with citrus, banana, avocado, mango, and other fruit trees. The fruit trees are usually grown along boundaries and in marginal areas where coffee picking and tree maintenance are inconvenient. Citrus trees grown include pummelo, tangerine, sweet orange, lemon, lime, and calamondin.

Yields/Benefits

The citrus trees provide fruit for households, without reducing coffee yields significantly.

Crop/tree interactions

The citrus trees provide heavy shade in their immediate vicinity, but because there are few trees per unit area, coffee yields are not greatly affected. In hotter, drier areas, the citrus may even benefit the coffee by moderating temperatures.

Spacing

There is no fixed spacing, but there may be 5–10 citrus trees per farm, mostly planted along boundaries and near homes.

Citrus trees such as this calamondin are commonly interplanted with coffee in Kona, Hawai'i. PHOTO: C. ELEVITCH

Fortunella species (kumquat)

Kumquat (*Fortunella* spp.) is an evergreen shrub or small tree. The fruits are eaten out of hand, used as decorations, or preserved in syrups and marmalades. The trees thrive in the subtropics, but can tolerate freezing and subfreezing periods, remaining dormant for some time following the cold shock. Resembling tiny oranges, kumquat fruits are distinguished from *Citrus* spp. primarily by their soft, thin, edible peel and by their small number of segments, usually three to five. The peel is sweet, and the flesh is sour; the combined flavors provide a pleasant dessert at meal's end.

Distribution

Native range

Native to South East China and tropical Malaysia, the kumquat (kam kwat in Cantonese) was honored by royalty and peasants alike.

Current distribution

Kumquat was included in the genus *Citrus* until about 1915, when Dr. Walter Swingle reclassified six species to the genus *Fortunella*. This new genus honored Robert Fortune, who journeyed extensively in China and introduced over 120 species of plants to western gardens (see bio for Fortune below). The kumquat was also described on a list of plants in Japan in 1712, noted in Europe and North America since the mid 19th century, and in Hawai'i before the 1880s. It is also cultivated in Central and South America, South Africa, South India, and Australia.

Botanical description

Genus *Fortunella* (Swingle)
Family Rutaceae
Subfamily Aurantoideae

Preferred scientific names/varietal names

F. hindsii (Swingle)

'Hong Kong Wild', 'Golden Orange', 'Golden Bean', chin chu (Mandarin), shan chin can, chin tou, kam quat (Cantonese)

'Hong Kong' grows wild in Hong Kong, Kwantung, and Chekiang provinces of China, fruiting during the winter months. The small fruits are the size of a pea, 2 cm (½–¾ in), bright or scarlet orange, nearly round, with pulp in 3–4 segments. The flowers are white, short and broad, and do not open as widely as others in the genus. The tree has oval leaves with winged petioles, and the profuse thorns on the branches are longer than the fruit itself.

Flowers of *F. crassifolia*, variety 'Meiwa'. PHOTO: D. WARD

F. japonica (Thunb.) Swingle (syn. *Citrus japonica* Thunb., *C. madurensis* Lour.)

'Marumi'

'Marumi' is a round, golden-yellow fruit about 2.5 cm (1 in) in diameter, with thin waxy skin, aromatic and spicy, with large oil glands. The fruits have acid-sweet, juicy flesh, with pulp in 4–7 segments, and 1–3 seeds. The trees are slightly thorny and cold-tolerant.

F. crassifolia (Lour.) Swingle (syn. *Citrus margarita* Lour.)

'Meiwa'

'Meiwa' has the largest and sweetest fruits of the kumquats. Oblong to round, 3.2 cm (1.75 in) long, the fruits are sometimes seedless or with few seeds, and little juice, while the peel is orange-yellow, sweet, tender, fleshy, and edible. Some have postulated that 'Meiwa' is a cross between *F. margarita* and *F. japonica.*

F. margarita (Swingle)

'Nagami'

'Nagami' is widely grown as an ornamental tree. The prolific fruit are 4 cm (1.6 in) long and 2 cm (0.8 in) in diameter, with an orange-colored rind when ripe, slightly sweet peel with a bitter aftertaste, and juicy acid pulp.

***F. polyandra* (Ridl.) Tanaka**

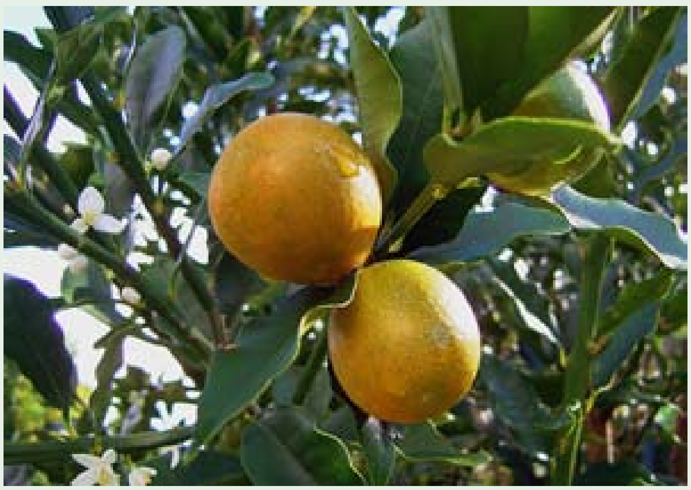
limau pagar, hedge lime grown in Malaysia

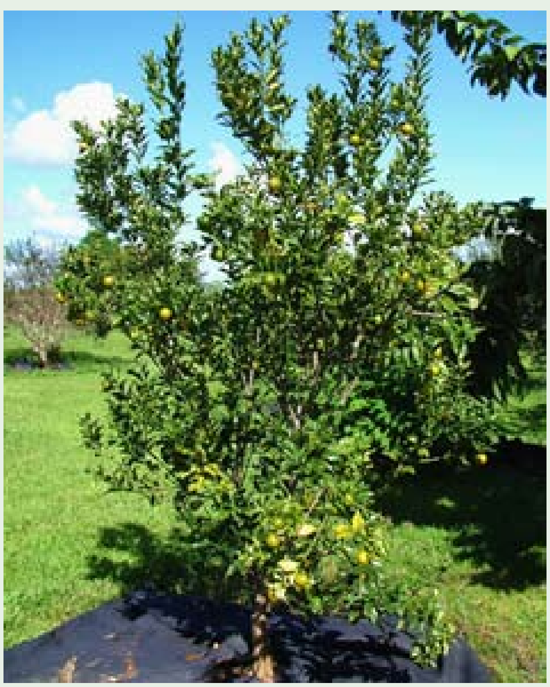
Limau pagar is native to tropical Malaysia and southern China, is larger than other kumquats, and may in fact be a limequat. It has a deep golden-orange peel, which is extremely sour, and flame-colored, seedy flesh.

Description

Kumquats are slow-growing, shrubby, compact evergreen trees, 2.5–4.5 m (8–15 ft) tall, and rarely exceeding 3 m (10 ft) in height. The kumquat scion wood is grafted to rootstock such as *Poncirus trifoliata*, citrange C-35, or citrange 'Carrizo'; the ultimate size of the tree is largely dependent on the rootstock selected. The flowers are white, fragrant, five-parted, and borne one to five in leaf axils. The branches are light-green, angled, thorny, thornless or with a few spines, depending on cultivar. Leaves are simple, alternate, lanceolate, pointed at tips, 3.3–8.6 cm (1.3–3.4 in) long, finely toothed from the apex to the middle, dark green above, lighter green below, petioles sometimes winged.

The fruit is round or oval-oblong, 1.6–4 cm (0.6–1.6 in) wide, and ripens slowly on the tree, changing from green






Left: 'Meiwa' fruit and tree. Right: 'Nagami' fruit and tree. PHOTOS: D. WARD to brilliant orange, yellow, or scarlet, depending on the cultivar. The peel is golden-yellow to reddish-orange, with large, conspicuous oil glands; rinds are thin to thick, waxy, edible, and acid to sweet in taste. The pulp is acid to subacid with three to eight segments and up to eight seeds and is more tart than the skin.

Climate

The kumquat is the most cold-resistant of the citruses and becomes dormant when temperatures fall below freezing, remaining dormant without shoots or blossoms for some time after warmer weather returns. Many cultivars are hardy to –7°C (20°F), but all grow faster and bear more fruit in warm climates. 'Nagami' requires a hot summer, (27–38°C [80–100°F]), but can withstand frost down to –8––6°C (18–21°F) without injury. In warm climates, trees may produce several crops during the year, but most fruiting occurs from fall to spring.

Propagation

Rootstock

The trees are rarely grown from seed. In China, Japan, northern Florida and California ~~are~~ they are grafted onto the trifoliate orange (*Poncirus trifoliata*). In southern Florida, scion is grafted onto sour orange and grapefruit. In Hawai'i, kumquats are grafted onto 'Carrizo' (a Washington navel × trifoliate orange hybrid) or onto citrange hybrid C–35 (Ruby orange × trifoliate orange) because of their resistance to citrus nematode, *Phytophthora* spp. and the tristeza virus.

Culture

Set out 2.4–3.6 m (8–12 ft) apart, or spaced at 1.5 m (5 ft) in hedged rows 3.6 m (12 ft) apart. The tree is frequently grown in a container, such as a 15-gallon pot, as a specimen plant. In colder climates, the container is brought indoors when temperatures drop below freezing.

Harvesting

Fruits are harvested when they reach full color (either orange or green-orange, depending on the variety) with two or three leaves attached to the stem to enhance keeping quality.

Pests and diseases

Kumquat is highly resistant to citrus canker, but several diseases have been observed, such as scab, algal leaf spot, greasy spot, anthracnose, fruit rot, stem-end rot and gummosis. Insect pests include fruit fly, citrus swallowtail larvae, aphid, and mealybug. Because the trees are susceptible to tristeza virus, they are grown on virus-resistant rootstock.

Food uses

The fruit is eaten out-of-hand whole when ripe (especially 'Meiwa'), preserved whole in sugar syrup, canned, candied, or sugared. The fruit is also made into marmalade by itself or mixed half-and-half with calamondins, and it is pickled or incorporated into sauces.

Urban and community forestry

Kumquat cultivars have long been a favorite in the urban environment. They are small, compact trees without competitive roots systems and are tolerant of hot, humid summers and cold winters. Full sun is best for growth and vigor, but they can tolerate semi-shade. They can be pruned into a hedge, and the brightly colored fruits are highly attractive in the landscape. They also can do very well when grown in pots. If not harvested, fruits will drop and require removal to reduce infestation by fruit fly. Cultivars 'Nagami' and 'Meiwa' are preferred, as they are the most ornamental in the landscape.

ROBERT FORTUNE

Robert Fortune (1812–1880) was a Scotsman sent by the British Horticultural Society to collect an assortment of curiosities in China. He became proficient in the Mandarin language and managed to disguise himself as peasant "Sing Wah" so well that he was able to travel to forbidden places unchallenged. Master of industrial espionage, Fortune made four trips to China and one to Japan and smuggled China's highly coveted tea cultivars and growing techniques to the Indian Himalayas, thereby diminishing China's lucrative monopoly. He kept careful journals of his collections and observations and is credited with introducing the art of bonsai to the Western world. His successful use of terraria led to the successful introduction of 120 species, including kumquat, to England in 1846. Introduced to Florida in 1855, the genus of thin, edible-rinded fruits was named *Fortunella* by Dr. Walter Swingle in 1915, to recognize the exploits and contributions of the intrepid plant explorer.

PUBLIC ASSISTANCE AND AGROFORESTRY EXTENSION

College of Tropical Agriculture and Human Resources
University of Hawai'i at Mānoa
Cooperative Extension Service
3050 Maile Way, Gilmore 203
Honolulu, Hawaii 96822
Tel: 808-956-8139; Fax: 808-956-9105
E-mail: extension@ctahr.hawaii.edu
Web: <http://www.ctahr.hawaii.edu/ctahr2001/Extension>.

University of Florida
Citrus Research and Education Center
700 Experiment Station Road
Lake Alfred FL, 33850
Tel: 863-956-1151; Fax: 863-956-4631

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

GENETIC RESOURCES

Bureau of Citrus Budwood Registration
Division of Plant Industry
3027 Lake Alfred Road
Winter Haven, Florida 33881
Tel: 863-298-7712; Fax: 863-298-7738
Web: <http://www.doacs.state.fl.us/budwood>

USDA-ARS National Clonal Germplasm Repository for Citrus and Dates
1060 Martin Luther King Blvd.
Riverside, CA 92507
Tel: 951-827-4399; Fax: 951-827-4398
Web: <http://www.ars-grin.gov/ars/PacWest/Riverside/homepg1.htm>

INTERNET

Electronic Data Information Source of the University of Florida, Institute of Food and Agricultural Sciences (UF/IFAS) <http://edis.ifas.ufl.edu>.

Citrus Nutrition and Fertilization (University of Florida) <http://edis.ifas.ufl.edu/TOPIC_Citrus_Nutrition_and_Fertilization>.

Citrus Research & Education Center's Florida Citrus Pest Management Guide <http://www.crec.ifas.ufl.edu/CRECHOME/groweraids.htm>.

Google directory of citrus fruits <http://directory.google.com/Top/Science/Agriculture/Horticulture/Fruits/Citrus_Fruits/>.

University of Georgia Horticulture <http://www.uga.edu/fruit/citrus.htm>.

Questions and Answers to Citrus Management, 3rd Edition <http://ucce.ucdavis.edu/counties/ceriverside/newsletterfiles/Questions_and_Answers_to_Citrus_Management2489.pdf>.

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Appendix A. Selected fruit and leaf characteristics of *Citrus* spp. (Castle and Gmitter 1999)

Fruit

Species	Size (diam)	Shape	Peel color and other	Pulp Color	Juice
C. aurantifolia (lime)	4–6 cm (1.6–2.4 in)	Globose to ovoid	Green, greenish yellow	Green	Very sour
C. aurantium (sour orange)	5 cm (2 in)	Subglobose, sl. oblate	Greenish yellow to scarlet red	Orange	Very sour
C. grandis (pummelo)	9–25 cm (3.5–10 in)	Subglobose, globose, oblate-globose to pyriform	Pale green to pale yellow	Pale green to pinkish	Scanty, mildly acid to mildly sweet or insipid
C. hystrix (Kaffir lime)	7 cm (2.8 in)	Subglobose to oblate-globose or ellipsoid	Green to yellow, very bumpy, glandular, bitter	Greenish	Acid, bitter
C. limon (lemon)	4–7 cm (1.6–2.8 in)	Ovoid, mammillate	Light to deeply yellow	Pale greenish to yellowish	Sour
C. macroptera (wild orange)	6–7 cm (2.4–2.8 in)	Subglobose, somewhat contracted at base	Pale dull yellow, fairly smooth, moderately thick pericarp	Greenish yellow, dry	Acid and bitter
C. medica (citron)	8–10 cm (3.1–4 in)	Ovoid to oblong	Yellow to green, rough tuberculate, thick	Pale, greenish	Acid to mildly acid
C. paradisi (grapefruit)	15 cm (5 in)	Globose or oblate	Yellow	Pale yellow green	Copious, acidic to faintly bitter
C. reticulata (mandarin)	6 cm (2.4 in)	Oblate-globose to depressed-subconcave globose	Orange, greenish orange, thin	Pale to rich orange	Mild to sweet
C. sinensis (sweet orange)	8–10 cm (3.1–4 in)	Subglobose to sl. oblate	Greenish yellow to bright orange	Orange	Mildly sweet to sweet

Leaf

Species	Size (length)	Shape	Petiole
C. aurantifolia (lime)	5–7.5 cm (2–3 in)	Elliptic to oblong ovate	Spatulate, narrowly winged
C. aurantium (sour orange)	10 cm (4 in)	Ovate, apex obtusely acute, base cuneaaate to rounded, margins sl. undulate to subcrenate	2–3 cm long, wing spathulate, 5–15 mm broad
C. grandis (pummelo)	11–13 cm (4.3–5.1 in)	Ovate to elliptic,	Broad, obcordately winged, with wings ¼ to ⅓ the length of the leaf
C. hystrix (Kaffir lime)	4–5 cm (1.6–2 in)	Broadly ovate to ovate-oblong	Broadly winged and the same size as the blade
C. limon (lemon)	7–9 cm (2.8–3.5 in)	Ovate , narrow, margin subserrate to serrate-crenulate	Narrowly winged to merely marginate
C. macroptera (wild orange)	10 cm (4 in)	Broadly ovate–lancelolate	Winged obovate to broadly subspathulate, as large as the blade
C. medica (citron)	6–7 cm (2.4–2.8 in)	Elliptic-ovate to ovate-lanceolate, obtuse to rounded, serrate-crenate margins	Short, wingless, not clearly articulated
C. paradisi (grapefruit)	9–18 cm (3.5–7 in)	Ovate to elliptic, smaller than *C. grandis*	Obovate-oblanceolate, narrower petiole wing
C. reticulata (mandarin)	8 cm (3.1 in)	Rhombic, acute, lanceolate to broadly lanceolate, margins irregularly crenate or crenulate	Short, wingless to sl. marginate.
C. sinensis (sweet orange)	10 cm (4 in)	Elliptic to ovate, margins undulate to crenate	Short, 1/5 the length of the leaf blade

APPENDIX B. Attributes of selected citrus scion cultivars and cultivar groups
(key: F–fresh fruit use, P–pulp use, E–early season, M–mid-season, L–late season)

Variety	Production areas	Use	Season	Advantages	Disadvantages
Sweet oranges					
Navel oranges Washington (Bahia), Bahianinha, Navelate, Navelina, Newhall, Leng, Lane Late, and others	Argentina, Australia, Morocco, South Africa, Spain, U.S. (California), Uruguay	F	E–L	Large fruit; seedless; fairly easy to peel; season of maturity of various clones ranges from early to late	Low yield; specific climatic conditions required for best quality; processed juice is bitter from limonin content
Common oranges					
Ambersweet	U.S. (Florida)	P, F	E	Excellent color; early maturity; easy to peel	Poor performance as young trees; demanding cultural requirements
Hamlin	U.S. (Florida), Brazil	P	E	Productive tree; early maturity; few seeds	Poor color; fair flavor
Jincheng	China	F, P	M	Good yield, color, and quality; stores well	Oval shape creates problems for mechanized grading
Natal	Brazil	P	L	The latest-maturing cultivar in Brazil	Freeze damage to fruit in colder regions
Pera	Brazil	P	M	Productive tree (in Brazil)	Fair quality; seedy; prone to set multiple crops
Pineapple	U.S. (Florida)	P	M	Productive tree; good color and flavor	Alternate bearing; seedy; cold-sensitive when heavily cropped
Shamouti	Israel, Cyprus, Turkey	F	M	Easy to peel; seedless; distinctive flavor; good storage capability	Thick rind of coarse appearance; low juice content; juice is bitter from limonin
Valencia	U.S. (California, Florida), Australia, Argentina, Brazil, Morocco, South Africa, Uruguay	P, F	L	Excellent color and juice quality; few seeds; late maturity	Lower yield potential; freeze damage to fruit in colder regions
Xuegan	China	F, P	M	Large fruit with good quality; stores well	Thick peel
Acidless oranges Succari, Lima, Anliucheng, and others	North Africa, Middle East, Brazil, China	F	E–M	Acceptable fruit for consumers intolerant of acid.	Unsuitable for processing
Blood oranges Doble Fina, Maltaise Sanguine, Sanguinelli, Moro, Tarocco, and others	Mediterranean region	F, P	M–L	Unique flavor and appearance	Specific climatic conditions required for optimum quality

Variety	Production areas	Use	Season	Advantages	Disadvantages
Grapefruit					
White grapefruit					
Duncan	U.S. (Florida)	P	M–L	Productive, vigorous tree; large fruit; excellent quality	Excessively seedy
Marsh	U.S. (Florida), Cuba, South Africa	F, P	E–L	Productive, vigorous tree; nearly seedless; good quality	Flavor less intense than that of Duncan
Oroblanco (Sweetie)	Israel, U.S. (California)	F	E–M	Seedless; high sugar content and low acidity allow production of good-quality fruit in cool areas and allow earlier harvest	Thick rind and open core, atypical of grapefruit; yields lower than yields of Marsh have been reported
Pigmented grapefruit					
Flame	U.S. (Florida)	F	E–M	Good flesh color in early and mid-season; good flavor and texture; nearly seedless	Color fades in late season; little commercial experience
Redblush (Ruby Red)	U.S. (Florida), Cuba, South Africa	F	E–M	Healthy, productive tree; nearly seedless; good quality; attractive peel blush	Less colorful flesh than more recently released cultivars
Rio Red	U.S. (Texas)	F	E–M	Good flesh color; healthy, productive tree; nearly seedless	Little commercial experience
Star Ruby	U.S. (Texas, Florida), South Africa	F	E–M	Most intensely pigmented flesh and rind; seedless; retains color late in the season; thin rind	Weak, unthrifty trees; great susceptibility to *Phytophthora*, herbicide injury, storage rots, and cold
Mandarins and their hybrids					
Clementine (Oroval, Fina, Nules, and many other clones)	Spain, Morocco	F	E–M	Easy to peel; seedless when grown in isolated blocks; good flavor	Small fruit, seedy with cross-pollination
Dancy	U.S. (Florida)	F	M	Vigorous tree; good color and flavor; easy to peel	Alternate bearing; seedy; difficult to harvest; susceptible to *Alternaria*
Ellendale	Australia, Argentina, Uruguay	F	M	Large fruit with good color and flavor; easy to peel; nearly seedless in solid blocks	Prone to splitting of fruit and tree; high acidity; seedy with cross-pollination
Fairchild	U.S. (California, Arizona)	F	E	Attractive appearance; adaptable to arid production areas	Small fruit; seedy; rind is oily and difficult to remove
Fortune	Spain	F	L	Productive tree; attractive fruit, with good color and flavor; later maturity than most mandarins	Rind prone to pitting; susceptible to *Alternaria*; seedy with cross-pollination; high acidity
Imperial	Australia	F	E	Very early maturity; easy to peel	Alternate bearing; fair flavor
Kinnow	Pakistan, India	F, P	L	Very high sugar content; juicy; vigorous tree	Seedy; alternate bearing
Mediterranean (Willowleaf, Baladi, Avana, and others)	Italy, Portugal	F	M–L	Easy to peel, unique flavor and aroma; cold-tolerant	Small fruit with seeds; poor storage and shipping capability; alternate bearing

Variety	Production areas	Use	Season	Advantages	Disadvantages
Minneola	U.S. (Florida), Israel, South Africa, Argentina	F	M	Large fruit with distinctive shape, excellent color, and rich flavor; vigorous, productive tree	Susceptible to *Alternaria*; seedy with cross-pollination
Murcott (Smith, Honey tangerine)	U.S. (Florida), Brazil, Israel, Australia	F, P	M–L	Excellent flavor and flesh color; productive, cold-hardy tree	Seedy; alternate bearing; susceptible to scab and *Alternaria*; terminal bearing habit
Orlando	U.S. (Florida)	F, P	M	Vigorous tree; cold-hardy	Difficult to peel; pale flesh and juice; low acidity; seedy
Ortanique	Jamaica, Israel, South Africa, Australia, Cyprus	F	L	Large, attractive fruit with good color and flavor; stores well; juicy; very late maturity; productive tree	Rind is oily and difficult to remove; seedy with cross-pollination
Ponkan (Nagpur suntara, Batangas, Warnurco)	China, India, Japan, Philippines, Brazil	F	M	Large fruit; very easy to peel; crisp flesh texture; productive tree	Rind becomes puffy; difficult to harvest, ship, and store; seedy; alternate bearing
Robinson	U.S. (Florida)	F	E	Very early maturity; good color; cold-hardy tree	Seedy; difficult to peel; susceptible to twig and limb dieback
Satsuma (Owari, Miyagawa, Okitsu, Clausellina, and many other clones)	China, Japan, Spain, Turkey, Korea, Argentina, Uruguay, U.S. (California), South Africa	F, P	E–M	The most cold-hardy tree among the edible citrus cultivars; easy to peel; seedless; tolerant of citrus canker	Poor fruit quality in humid subtropics; rind puffiness shortly after maturity
Sunburst	U.S. (Florida)	F	M	Very attractive fruit with excellent color	Susceptible to mite damage; seedy; difficult to peel
Temple	U.S. (Florida)	F, P	M–L	Unique flavor; attractive external color and appearance	Susceptible to cold and citrus scab; seedy; fruit acidity

APPENDIX C. Kumquat varieties and hybrids

Kumquat varieties

Botanical name	Variety	Other names	Locale	Fruit size	Ripe color	Skin/Peel
F. hindsii (Champ) Swingle	'Hong Kong Wild'	chin chu, shan chin can, chin tou (Mandarin), kam quat (Cantonese), Golden Bean, Golden Orange	Hong Kong, Kwantung, Chekiang Provinces	nearly round, 2 cm (0.8 in)	orange to scarlet	thin, not fleshy
F. japonica (Thunb.) Swingle (syn *Citrus japonica* Thunb., *C. madurensis*, Lour.)	'Marumi'		introduced to USA from Japan	round, 2.5 cm (1 in)	golden-yellow	smooth, large oil glands, thin, aromatic and spicy
F. crassifolia Swingle	'Meiwa'	ninpo, neiha kinkan, kinkit (Japan)	Chekiang province, China, and Fukuoka province, Japan	short-oblong to round, 4 cm (1.6 in)	orange-yellow	very thick, sweet
F. margarita (Lour.) Swingle	'Nagami'	too kin kan (Japan)	China	4.5 cm (1.8 in) long and 3 cm (1.2 in) wide	yellow to bright orange	thin, slightly sweet
F. polyandra (Ridl.) Tanaka	'Limau pagar'	Malayan kumquat, hedge lime	southern China, tropical Malaysia	large compared to other kumquats	deep golden-orange	extremely sour
F. swinglei Tanaka	'Swingle's kumquat'					
F. obovata hort ex. Tanaka	'Chang Shou'	longevity kumquat				

Fortunella × (Kumquat hybrids)

Botanical name	Common name	Varietal name	Fruit size	Ripe color	Skin/Peel	Pulp
× *Citrofortunella* spp. or F × *Citrus aurantifolia* (Christm.) Swingle	limequat	Mexican lime × kumquat hybrids		light yellow	resembles lime when immature	sweet, juicy
× *C. floridana* J. Ingram & H.E. Moore	limequat	'Eustis'	oval or round 2.8–4 cm (1.1–1.6 in) wide	pale yellow	smooth, glossy, prominent oil glands, thin, edible	light green, tender, juicy, very acid
× *C. floridana* J. Ingram & H.E. Moore (different seed)	limequat	'Lakeland'	oval 4.5–7 cm (1.8–2.8 in) wide	bright yellow	smooth, thin	juicy, pleasantly acid
× *C.* Swinglei J. Ingram & H.E. Moore	limequat	'Tavares'	obovate to oval 3.2–4.75 cm 1.3–1.9 in) wide	pale orange-yellow	smooth, thin, tender edible	buff-yellow, juicy, very acid
× *C. reticulata* or *C. unshiu* (Mak.) Marc. × (*F. japonica* × *F. margarita* 'Meiwa')	orangequat		larger than kumquats	deep orange		juicy, deep orange
× *C. limon* (L.) Burm.	lemonquat					
Citrus × 'Meyer' × *F. margarita* 'Nagami'	lemonquat					
× citrange	citrangequat	'Thomasville'	resembles oval kumquat		edible	very juicy, acid
× *Poncirus trifoliata* (L.) Raf.	citrumquat					
Limequat × *F. hindsii* (Champ.) Swing.	procimequat					
× *Citrus reticulata*	kumandarin					
Citrus × yuzu × *F. margarita* 'Nagami'	yuzuquat				edible	very acid
F. margarita sic (*crassifolia*) 'Nagami' × *F. margarita* 'Meiwa'	nameiwa, ten-degree kumquat					

Pulp	Segments	Seed	Tree /Shrub	Thorns	Leaves	Climate	Comments
	3–4	plump seeds	tender shrub, grown in West as ornamental pot plant	very thorny		bring indoors below 0°C (32°F)	
scant, acid	4–7	1–3 small seeds	reaches 2.75 m (9 ft), very cold tolerant	slightly thorny	small leaves, upright open habit	more cold-tolerant than Nagami; if acclimated, hardy to –7°C (20°F)	
sweet or subacid	7	seedless or few seeds	dwarf or small tree, ornamental form has variegated fruits	frequently thornless or with short, stout spines	very thick, rigid, partly folded, pitted with oil glands	if acclimated, hardy to –7°C (20°F)	best for eating out of hand, introduced to USA from Japan, possibly a 'Nagami' and 'Marumi' cross
acidic, little juice, acidic aftertaste	4–5	2–5 seeds	vigorous tree, reaches 4.5 m (15 ft)		small dark green leaves, fine branches	cold tolerant; if acclimated, hardy to –7°C (20°F)	most popular variety in Florida
flame colored flesh		up to 8 seeds	tender shrub, resembles lime			resembles lime, more cold tolerant, indoors below 0°C (32°F)	could be a limequat
			tender shrub			bring indoors below 0°C (32°F)	
			shrub			cold tolerant; hardy to –7°C (20°F)	

Segments	Seed	Tree	Thorns	Leaves	Flowers	Climate
		small compact tree		single leaflets, petioles narrowly wingled		more cold tolerant than lime, but not as cold hardy as kumquat, very resistant to withertip
6–9	5–12 small	everbearing, fall to winter	small spines		pure white, prolific	cold tolerant; if acclimated, hardy to –7°C (20°F)
5–8	2–9 large		nearly spineless		white with pink streaks	
7–8	6–11 large	vigorous	short spines		pink flower buds	
						if acclimated, hardy to –12°C (10°F)
	seedy	shrub, vigorous, erect, very ornamental	thorny or thornless	trifoliate		highly cold-resistant, if acclimated hardy to –9°C (15°F)
		shrub				if acclimated, hardy to –12°C (10°F)
		shrub		dark, glossy leaves with undulating margin		extremely cold-hardy; if acclimated, hardy to –12°C (10°F)

APPENDIX C. **Major pacific island exports of citrus fruit and citrus products for 2003 (unless otherwise specified).**

	Fiji		French Polynesia		New Caledonia		Samoa		Vanuatu (1990)	
Commodity (UN Code)	**Value (1000)**	**Kg (1000)**	**Value (1000)**	**Kg (1000)**	**Value (1000)**	**Kg (1000)**	**Value (1000)**	**Kg (1000)**	**Value (1000)**	**Kg (1000)**
Citrus fruit, fresh or dried (0805)	$72	585	$1,187[6]	60[6]	$31,829	21,565	$320,313	132,235		
Oranges, fresh or dried (080510)	$2,491[4]	2,701[4]					$671	546		
Mandarin, clementine & citrus hybrids, fresh or dried (080520)	$10[6]	21[6]			$28	0				
Grapefruit, fresh or dried (080540)			$651[3]	109[3]	$18	1			$115[2]	40[2]
Lemons and limes, fresh or dried (080530)	$3	488			$31,783	21,534	$40[5]	109[5]		
Citrus fruits, otherwise prepared or preserved (200830)	$5	3								
Orange juice, frozen (200911)	$19,343	21,000					$1,010			
Orange juice (0591)									$137[1]	117[1]
Orange juice, not frozen, fermented, or spirited (2 00919)	$35,367	17,922	$38,100	21,316		20,919	$334	50		
Grapefruit juice, not fermented or spirited (200920)	$68	85	$12,061	6,772			$12,330[6]	9,812[6]		
Citrus juice nes (one fruit) not fermented or spirited (200930)	$19,840	3,792					$1,634,130	179,945		
Essential oils of bergamot (330111)	$587[4]	41[4]					$1,168	13		
Essential oils of citrus fruits (330119)	$2,474	425					$501	1		
Citrus based jams jellies marmalade, etc. (200791)	$580	56	$191	60	$1,243[6]	0[6]	$1,252	716		
Citrus fruits, otherwise prepared or preserved (200830)	$5	3					$4,209[6]	1,460[6]		

[1] Data for 1990; [2] Data for 1993; [3] Data for 1997; [4] Data for 2000; [5] Data for 2001; [6] Data for 2001.

Source: UN Commodity Trade Statistics Database (UN Comtrade). <http://unstats.un.org/unsd/comtrade/>.

Citrus species (citrus)

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