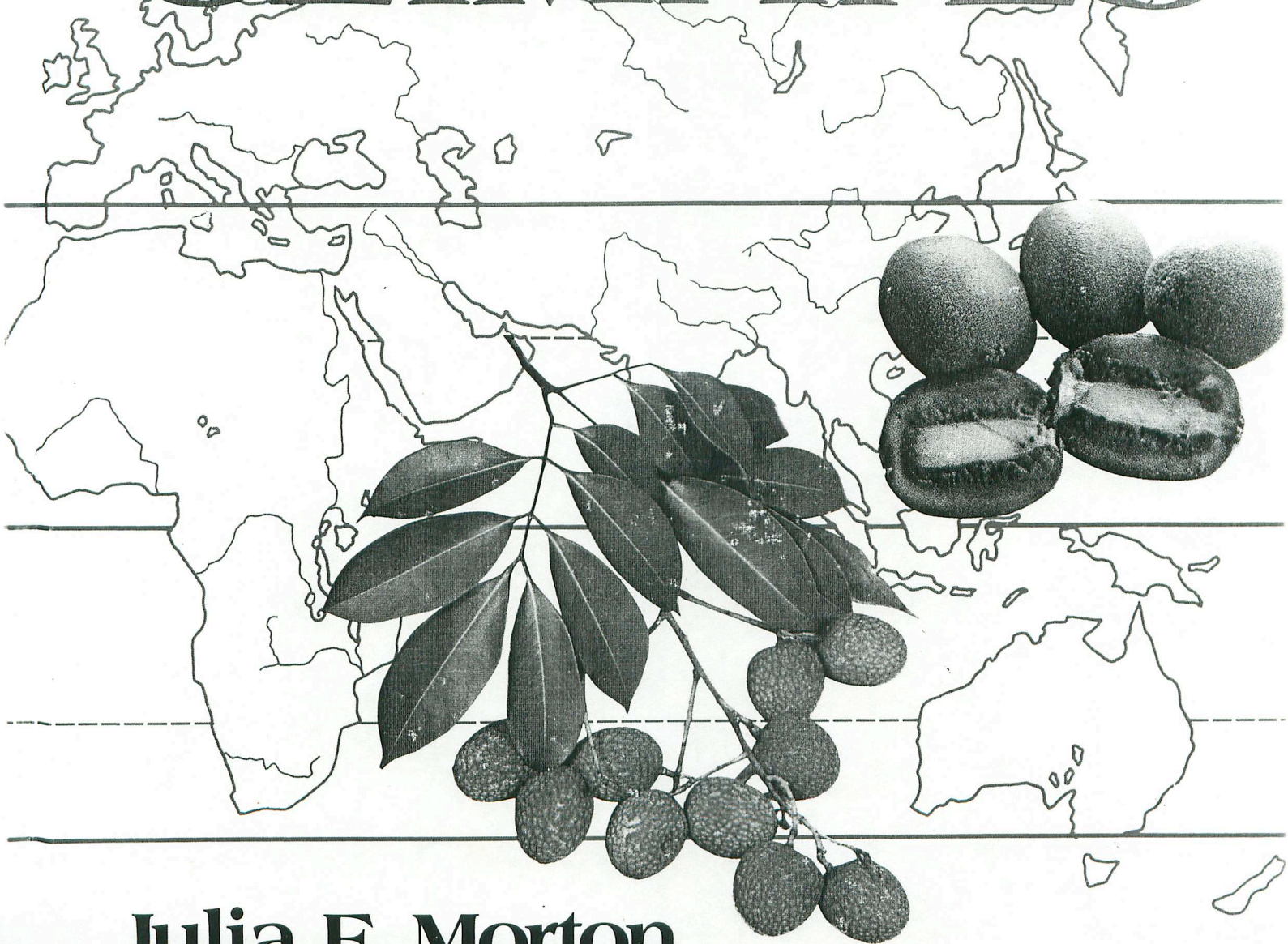
Orange

FRUITS OF WARM CLIMATES



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Orange

One of the most widely favored of the world's fruits, the orange, sweet orange, or round orange, was for many years known as *Citrus aurantium* var. *sinensis* L. and considered to be a form of the sour orange (q.v.). It is still not universally agreed to be a distinct species, *C. sinensis* Osbeck, but it is usually treated as though it were. One of its first recorded regional names was the Persian *narang,* from which were derived the Spanish name, *naranja,* and the Portuguese, *laranja.* In some Caribbean and Latin American areas, the fruit is called *naranja de China, China dulce,* or simply *China* (pronounced *cheena*).

Description

The orange tree, reaching 25 ft (7.5 m) or, with great age, up to 50 ft (15 m), has a rounded crown of slender branches. The twigs are twisted and angled when young and may bear slender, semi-flexible, bluntish spines in the leaf axils. There may be faint or conspicuous wings on the petioles of the aromatic, evergreen, alternate, elliptic to ovate, sometimes faintly toothed "leaves"—technically solitary leaflets of compound leaves. These are 2½ to 6 in (6.5-15 cm) long, 1 to 3¾ in (2.5-9.5 cm) wide. Borne singly or in clusters of 2 to 6, the sweetly fragrant white flowers, about 2 in (5 cm) wide, have a saucer-shaped, 5-pointed calyx and 5 oblong, white petals, and 20 to 25 stamens with conspicuous yellow anthers. The fruit is globose, subglobose, oblate or somewhat oval, 2½ to 3¾ in (6.5-9.5 cm) wide. Dotted with minute glands containing an essential oil, the outer rind (epicarp) is orange or yellow when ripe, the inner rind (mesocarp) is white, spongy and non-aromatic. The pulp (endocarp), yellow, orange or more or less red, consists of tightly packed membranous juice sacs enclosed in 10 to 14 wedge-shaped compartments which are readily separated as individual segments. In each segment there may be 2 to 4 irregular seeds, white externally and internally, though some types of oranges are seedless. The sweet orange differs physically from the sour orange in having a solid center.

Origin and Distribution

The orange is unknown in the wild state; is assumed to have originated in southern China, northeastern India, and perhaps southeastern Asia (formerly Indochina). It was carried to the Mediterranean area possibly by Italian traders after 1450 or by Portuguese navigators around 1500. Up to that era, citrus fruits were valued by Europeans mainly for medicinal purposes, but the orange was quickly adopted as a luscious fruit and wealthy persons grew it in private conservatories, called "orangeries". By 1646 it had been much publicized and was well known.

Spaniards undoubtedly introduced the sweet orange into South America and Mexico in the mid-1500's, and probably the French took it to Louisiana. It was from New Orleans that seeds were obtained and distributed in Florida about 1872 and many orange groves were established by grafting the sweet orange onto sour orange rootstocks. Arizona received the orange tree with the founding of missions between 1707 and 1710. The orange was brought to San Diego, California, by those who built the first mission there in 1769. An orchard was planted at the San Gabriel Mission around 1804. A commercial orchard was established in 1841 on a site that is now a part of Los Angeles. In 1781, a surgeon and naturalist on the ship, "Discovery", collected orange seeds in South Africa, grew seedlings on board and presented them to tribal chiefs in the Hawaiian Islands on arrival in 1792. In time, the orange became commonly grown throughout Hawaii, but was virtually abandoned after the advent of the Mediterranean fruit fly and the fruit is now imported from the United States mainland.

The orange has become the most commonly grown tree fruit in the world. It is an important crop in the Far East, the Union of South Africa, Australia, throughout the Mediterranean area, and subtropical areas of South America and the Caribbean. The United States leads in world production, with Florida, alone, having an annual yield of more than 200 million boxes, except when freezes occur which may reduce the crop by 20 or even 40%. California, Texas and Arizona follow in that order, with much lower production in Louisiana, Mississippi, Alabama and Georgia. Other major producers are Brazil, Spain, Japan, Mexico, Italy, India, Argentina and Egypt. In Brazil, oranges are grown everywhere in the coastal plain and in the highlands but most extensively in the States of Sao Paulo and Rio de Janeiro, where orange culture rose sharply in the years immediately following World War II and is still advancing. Mexico's citrus industry is located largely in the 4 southern states of Nuevo Leon, Tamaulipas, San Luis Potosi and Veracruz. The orange crop is over one million MT and Nuevo Leon has 20 modern packing plants, mostly with fumigation facilities. Large quantities of fresh oranges and orange juice concentrate are exported to the United States and small shipments go to East Germany, Canada and Argentina. However, overproduction has glutted domestic markets and brought down prices and returns to the farmer to such an extent that plantings have declined and growers are switching to grapefruit. Cuba's crop has become nearly ⅓ as large as that of Florida. Lesser quantities are produced in Puerto Rico, Central America (especially

Guatemala), some of the Pacific Islands, New Zealand, and West Africa, where the fruit does not acquire an appealing color but is popular for its quality and sweetness. Many named cultivars have been introduced and grown in the Philippines since 1912, but the fruit is generally of low quality because of the warm climate.

Varieties

Most of the oranges grown in California are of 2 cultivars: the 'Washington Navel' and the 'Valencia'. Florida's commercial cultivars are mainly: (early) 'Hamlin'; (mid-season) 'Pineapple'; (late) 'Valencia'.

The 'Washington Navel' (formerly known as 'Bahia') originated, perhaps as a mutant in Bahia, Brazil, before 1820. It was introduced into Florida in 1835 and several other times prior to 1870. In 1873, budded trees reached California where the fruit matures at the Christmas season. It is large but with a thick, easily removed rind; not very juicy; of excellent flavor, and seedless or nearly so. Ease of peeling and separation of segments makes this the most popular orange in the world for eating out-of-hand or in salads. Limonene content of the juice results in bitterness when pasteurized and therefore this cultivar is undesirable for processing. The tree needs a relatively cool climate and should not be grown below an elevation of 3,300 ft (1,000 m) in tropical countries. Today it is commercially grown, not only in Brazil and California, but also in Paraguay, Spain, South Africa, Australia and Japan.

'Trovita', a non-navel seedling raised in 1914-1915 at the Citrus Experiment Station in California and released in 1935, is milder in flavor and has a few seeds, but may be earlier in season, and it has been considered promising in hot, dry regions unsuitable for 'Washington Navel'. There are several other named variations such as 'Robertson Navel', 'Summer Navel', 'Texas Navel', and the externally attractive 'Thompson Navel' which was grown in California for a time but dropped because of its poor quality. Various mutants, more suitable for warmer climates, have been selected and named in Florida, including 'Dream', 'Pell', 'Summerfield', 'Surprise'—the latter being more productive than 'Washington Navel' in Florida but still not grown to any extent. 'Bahiamina' is a small version of the 'Washington Navel' developed in Brazil in the late 1940's. It follows 'Pera' and 'Natal' sweet oranges in importance in tropical Bahia.

'Valencia', or 'Valencia Late', is the most important cultivar in California, Texas and South Africa. It has been the leader in Florida until recently. In 1984, 40% of the oranges being planted in Florida were 'Valencia', 60% were 'Hamlin'. The 'Valencia' may have originated in China and it was presumably taken to Europe by Portuguese or Spanish voyagers. The well-known English nurseryman, Thomas Rivers, supplied plants from the Azores to Florida in 1870 and to California in 1876. In Florida, it was quickly appreciated and cultivated, at first labeled 'Brown' and later renamed 'Hart's Tardiff', 'Hart' and 'Hart Late' until it was recognized as identical to the 'Valencia' in California. It was not propagated for sale in California until 1916 and was slow to be adopted commercially. It is smaller than the 'Washington Navel', with a thinner, tighter rind; is far juicier and richer in flavor; nearly seedless except in Chile where the dry climate apparently allows better pollination and development of many more seeds - up to 980 in 44 lbs (20 kg). It needs a warm climate. In fact, it is the most satisfactory orange for the tropics, even though it may not develop full color in warm regions. In Colombia, the quality is good from sea level to 5,000 ft (1,600 m). It bears two crops a year, overlapping and giving it the great advantage of a late and long season lasting until midsummer. The fruits on the trees in spring will "regreen", lose their orange color and turn green at the stem end, but the quality is not affected. They were formerly dyed to improve market appearance but since the 1955 Food & Drug Administration ban on the synthetic dyes used on oranges, they have been colored by exposure to ethylene gas in storage. The gas removes the chlorophyll layer, revealing the orange color beneath. "Degreening" does not occur in California where 'Valencia' oranges from one growing area or another are marketed from late spring through fall.

'Lue Gim Gong' was claimed to be a hybrid of 'Valencia' and 'Mediterranean Sweet' made by a Chinese grower in 1886. 'Lue Gim Gong' was awarded the Wilder Silver Medal by the American Pomological Society in 1911 but, later on, his "hybrid" was judged to be a nucellar seedling of 'Valencia'. Propagated and distributed by Glen St. Mary Nurseries in 1912, this cultivar closely resembles 'Valencia', matures and is marketed with its parent without distinction. It is best cited as the 'Lue Gim Gong Strain' of 'Valencia'. 'Mediterranean Sweet' was introduced into Florida from Europe in 1875, was briefly popular, but is no longer grown.

Certain strains of 'Valencia' are classed as summer oranges because the fruits can be left on the trees longer without dehydrating. One is known as 'Pope', 'Pope Summer', or 'Glen Summer'. It was found in a grove of 'Pineapple' oranges near Lakeland about 1916, was propagated in 1935, and trademarked in 1938. On sour orange or sweet orange rootstocks in hammock soils, the fruit matures in April but is still in good condition on the tree in July and August.

'Rhode Red Valencia' was discovered in 1955 in a grove near Sebring, Florida, by Paul Rhode, Sr., of Winter Haven. Some budwood was put on sour orange stock which caused dwarfing and some on rough lemon which produced large, vigorous, productive trees. In 1974, 5 trees were accepted into the Citrus Budwood Registration Program but there was no budwood free of exocortis and xyloporosis viruses. The fruit equals 'Valencia' in soluble solids, excels 'Valencia' in volume of juice, is less acid, has slightly less ascorbic acid, but has a far more colorful juice due to its high content of cryptoxanthin, a precursor of vitamin A which remains nearly stable during processing.

In Cuba, 'Campbell Valencia' (a 1942 seedling similar to 'Valencia'), 'Frost Valencia' (a 1915 nucellar seedling of 'Valencia'), and 'Olinda Valencia' (a virus-free nucellar seedling of 'Valencia' discovered in California in 1939), each on 2 different rootstocks—sour orange and Cleopatra mandarin—were test-planted in 1973 and evaluated in 1982. 'Olinda Valencia' on sour orange excelled in quality and in productivity.

'Hamlin', discovered in 1879 near Glenwood, Florida, in a grove later owned by A.G. Hamlin, is small, smooth, not highly colored, seedless and juicy but the juice is pale. The fruit is of poor-to-medium quality but the tree is high-yielding and cold-tolerant. The fruit is harvested from October to December and this cultivar is now the leading early orange in Florida. On pineland and hammock soil it is budded on sour orange which gives a high solids content. On sand, it does best on rough lemon rootstock.

'Homosassa', a selected Florida seedling named in 1877, is of rich orange color, of medium size, and excellent flavor. It was formerly one of the most valued midseason oranges in Florida but it is too seedy to maintain that position. It is no longer planted except perhaps in Texas and Louisiana.

'Shamouti' ('Jaffa'; 'Khalili'; 'Khalili White')--originated as a limb sport on a 'Beledi' tree near Jaffa, Israel, in 1844; introduced into Florida about 1883; oval, medium-large; peel entirely orange when ripe; leathery, thick, easy to remove; pulp very juicy, of good quality. Constitutes 75% of the Lebanese and Israeli crops; is one of the 2 main cultivars in Syria; was formerly an important, midseason, cold-tolerant, cultivar in Florida and was grown in all other orange-growing regions of the United States. However, the tree tends to alternate-bearing, the fruit does not hold for long on the tree and is subject to the fungus, *Alternaria citri,* and it is no longer planted in this country.

'Parson Brown' was discovered in a grove owned by Parson Brown in Wester, Florida; was purchased, propagated and distributed by J.L. Carney between 1870 and 1878. It is rough-skinned, with pale juice; moderately seedy; of low-to-medium quality. It was formerly popular in Florida because of its earliness and long season (October through December), but has been largely replaced by 'Hamlin'. It is grown in Texas, Arizona and Louisiana but is not profitable in California where it matures at the same time as 'Washington Navel'. It does not develop acceptable quality in the tropics.

'Pineapple' is a seedling found in a grove near Citra, Florida. It was propagated in 1876 or 1877 under the name of 'Hickory'. It is pineapple-scented, smooth, highly colored, especially after cold spells; of rich, appealing flavor, and medium-seedy. It is the favorite midseason orange in Florida, its tendency to preharvest drop having been overcome by nutrition and spray programs. If the crop is allowed to remain too long on the tree, it may induce alternate-bearing. It is grown to some extent in Texas, rarely in California; succeeds on sour orange rootstock in low hammock land, on rough lemon in light sand. Seedless mutants of 'Pineapple' have been produced by seed irradiation. This cultivar does fairly well in tropical climates though not as well as 'Valencia'.

'Queen' is a seedling of unknown origin which was found in a grove near Bartow, Florida. Because it survived the freeze of 1894-95, it was propagated in 1900 under the name 'King' which was later changed to 'Queen'. It is much like 'Pineapple', has fewer seeds, higher soluble solids, persists on the tree better in dry spells; is high-yielding and somewhat more cold-tolerant than 'Pineapple'.

'Blood Oranges' are commonly cultivated in the Mediterranean area, especially in Italy, and also in Pakistan. They are grown very little in Florida where the red coloration rarely develops except during periods of cold weather. In California they are grown only as novelties. Among the well-known cultivars in this group are 'Egyptian', which tends to develop a small navel; 'Maltese', 'Ruby', and 'St. Michael'.

Pollination

Orange blossoms yield very little pollen and orange growers do not practice artificial pollination. However, there is evidence of self-incompatibility and need for cross-pollination in the TANGOR and TANGELO (qq.v.).

Climate

The orange is subtropical, not tropical. During the growing period, the temperature should range from 55° to 100°F (12.78°-37.78°C). In the winter dormancy, the ideal temperature range is 35° to 50°F (1.67°-10°C). Mature, dormant trees have survived 10 hours at temperatures below 25°F (-3.89°C) but fruit is damaged by freezing—30° to 26°F (-1.11°-3.33°C). Young trees may be killed outright by even brief frosts. Hardiness, however, varies with the cultivar and rootstock. Seedling orange trees of bearing age are capable of enduring more cold than budded cultivars. Prolonged cold is more injurious than short periods of freezing temperatures. In Florida, many efforts have been made to protect orange trees from winter cold, which is most damaging if preceded or accompanied by drought.

In the early days, slatted shadehouses were erected over young groves. Windbreaks have been planted on the northeast exposure. Old automobile tires have been burned in piles throughout groves. A commercially produced heater has been fueled and lit in the coldest predawn hours. Helicopters have been flown back and forth to cause movement of air, and, more recently, wind machines have been installed. Most recent, and most effective are overhead sprinklers which give maximum protection from cold damage.

Favorable annual precipitation varies from 5 to 20 in (12.5-50 cm), though oranges are frequently grown in areas receiving 40 to 60 in (100-150 cm) of rain. Benthall says that in the damp climate of Lower Bengal, the fruits lack juice and are usually very sour. California's generally dry climate contributes to more intense color in the orange peel than is seen in humid areas. Success in orange culture depends a great deal on the selection of cultivars tolerant of the weather conditions where they are to be grown.

Soil

The best soil for orange-growing in Florida is known as "Lakeland fine sand," well-drained, and often identified as high hammock or high pineland soil. There must be adequate depth for good root development. Shallow soils of high water-holding ability are avoided. In Egypt, it has been found that where the water table is too high—30 in (78 cm) or less below the surface of the soil—root growth, vegetative vigor and fruit yield of orange trees are greatly reduced. In the alkaline soil of South Florida, neglected orange trees develop chlorosis and gradually decline. Many old groves planted in the southern part of the state to avoid cold have been totally lost. In California, the best soils for orange groves are deep loams. It is important to select the appropriate rootstock for particular soil conditions.

Propagation

While the orange will often come true from seed because of nucellar embryos, the common means of assuring the reproduction of cultivars of known quality is by budding onto appropriate rootstocks. It is believed that budding was practiced by Europeans during the 16th and 17th Centuries, but, with the realization that seedling trees were more vigorous and productive, Italian and Spanish orange growers went back to planting seeds. Fortunately, budded orange trees from Europe had been imported into Florida in 1824 and budwood from these and of others later brought in from England was utilized in topworking existing sour and sweet orange seedlings. It was soon apparent that the budded trees came into bearing earlier than seedlings, were less thorny, and matured

uniformly. The sweet orange lost popularity as a rootstock because of its susceptibility to foot rot. Sour orange, resistant to foot rot, became the preferred rootstock in low hammock and flatwoods soils with high water table until the discovery of the virus disease, tristeza, in Florida orange groves in 1952. This caused many to switch from the susceptible sour orange to 'Cleopatra mandarin'. Unfortunately, trees on 'Cleopatra' stock are reduced in size, they have lower yields than those on sour orange, and acidity of the fruit is elevated.

As citrus-growing stretched southward into high pineland, rough lemon (*Citrus jambhiri*) rootstock gained favor and was found to induce more rapid and vigorous growth and earlier bearing, counterbalancing its sensitivity to cold and tendency toward foot rot. Rough lemon became the dominant rootstock in Florida until it was found to be extremely susceptible to blight and was abandoned. Sour orange has been reinstated in recent years because tristeza has been more or less dormant since the 1940's and sour orange is now the prevailing stock for 50% of the orange and grapefruit trees in the state. In second place is the 'Carrizo citrange', resistant to tristeza but subject to exocortis and also to blight though less so than rough lemon. 'Carrizo' is somewhat resistant to the burrowing nematode and gives a little higher yield than the similar rootstocks. Growers are advised to quickly replace blight-affected orange trees on rough lemon with new plants on 'Carrizo' held ready for this purpose. Because exocortis can now be detected quickly, it has become possible to utilize 'Carrizo' as a rootstock for hundreds of thousands of orange trees in Florida.

About 90% of commercial orange groves in Queensland are on rough lemon rootstock, as are 90% of the citrus trees in Jamaica. In Egypt, rough lemon rootstock has been found short-lived on heavy soils. In that country, early budding was done on citron (*Citrus medica* L.) but that stock was abandoned when sour orange was found much more desirable on the prevailing loamy-clay. Second to the sour orange rootstock is the Egyptian lime, locally considered "native" and used mainly on lighter soils.

In the tropical citrus-growing region of Bahia, Brazil, Rangpur lime (*C.* X *limonia* Osbeck) has been the dominant rootstock—95% in orchards and 100% in nurseries—but experiments in the past few years have shown that rough lemon and Cleopatra mandarin give better results. Also, 'Cleopatra' has good resistance to "citrus decline", whereas Rangpur is susceptible to Phytophthora root rot and exocortis.

Some oranges are budded onto the so-called "trifoliate orange" (*Poncirus trifoliata* Raf.) which tends to reduce the growth but is cold-tolerant and able to flourish on low, wet soils. It does poorly in light sand. Rootstocks capable of dwarfing orange trees may become necessary if close spacing is to be considered more advantageous. Trifoliate orange cultivar 'English Small' has successfully dwarfed 'Valencia'. 'Rusk' and 'Carrizo' ('Troyer') citranges (*P. trifoliata* X *C. sinensis*) show promise for semi-dwarfing of 'Valencia'. However, all of these are very susceptible to the exocortis virus. Alternative rootstocks include 'Swingle citrumelo' (*P. trifoliata* X *C. paradisi*)—cold-hardy, resistant to tristeza, exocortis, xyloporosis, and the citrus nematode but not the burrowing nematode—and the 'Volkamer lemon' (*C. volkameriana*) which behaves much like rough lemon but gives very high yields of fruit of slightly better quality.

In India, the sweet lime (*C. limettioides* Tanaka) was found to be the best rootstock for their 'Mosambi' orange in wet zones with high maximum temperatures.

Cuban horticulturists are currently experimenting with various *Citrus* species as potential rootstocks to replace sour orange.

In Florida, nurseries of seedling rootstocks must be approved by the Department of Agriculture, Division of Plant Industry. The seeds must not be more than 3 to 4 weeks old unless they have been washed, dried, then mixed with sand and kept in a cool place, or put into a plastic bag and refrigerated for a few weeks at about 40°F (4.4°C). Seeds of *P. trifoliata* are planted in the fall but sour orange and 'Cleopatra mandarin' are planted in spring. Seeds are set in rows 3 to 4 ft (0.9-1.2 m) apart and will germinate in 3 weeks. When the stems reach ½ in (1.25 cm) in diameter, the seedlings are ready for budding. The budding technique most commonly used in Florida is shield-budding by the inverted "T" method, inserting the bud 2 to 3 in (5-7.5 cm) above ground level. California propagators favor the upright "T". Usually the trees are ready for transplanting after one growing season. Mature trees that have been frozen back, or that are to be converted to more suitable cultivars, may be top-worked by cleft-grafting, crown grafting, or budding of the sprouts that arise after the tree is cut off close to the ground.

It must be kept in mind that the rootstock influences not only the rate of growth, disease resistance and productivity of the cultivar but also the physical and chemical attributes of the crop. For example, 'Valencia' oranges on sour orange stock have been found to have more dry matter in the peel, pulp and juice than those on rough lemon. 'Washington Navel' oranges on rough lemon stock have had low levels of potassium in the peel, pulp and juice; and, on 'Cleopatra mandarin' stock, even lower in the pulp and juice. Trifoliate orange rootstock produces high levels of potassium throughout the fruit. In southeastern Queensland, Australia, nearly half of the oranges for processing are grown in the Near North Coast area. There, trials of 'Valencia' on rough lemon revealed that fruit quality was inferior to that in Florida; there was bitterness in the juice and only a small percentage of the fruits met the minimum standards for processing as frozen orange juice concentrate. General quality, flavor and ascorbic acid content were considerably higher on sweet orange rootstock. Trifoliate orange gave second-best results. Rootstocks affect the chemistry of the peel oil, especially the aldehyde content, and the oil content of the peel is influenced by selection of budwood. Dr. Walter T. Swingle, one of the early and renowned plant explorers of the United States Department of Agriculture, was an authority on *Citrus* and vitally interested in rootstocks. He was convinced that they were the key to the successful future of the citrus industry.

Culture

A spacing of 25 x 25 ft (7.5x7.5 m) was standard in the past. However, many orange groves today are being close-planted and "hedged" to facilitate both manual and mechanical harvesting, and between-row alleys must be wide enough to accommodate mobile machinery for fertilizing, spraying, pruning and harvesting. There are arguments against close-spacing; mainly that, as the trees grow and become more crowded, productivity declines; also that close-spacing requires expensive pruning. However, data gathered on yields of the 'Pineapple' orange on rough lemon rootstock at Lake Alfred, Florida, over an 11-year trial, showed total yields for the period as: 2,380 boxes per acre (5,880/ha) at 25 x 20 ft (7.5x6 m)—87 trees per acre (215/ha); 3,496 boxes per acre (8,639/ha) at 20 x 15 ft (6x4.5 m)—145 trees per acre (358/ha); 4,484 boxes per acre (11,079/ha) at 15 x 10 ft (4.5-3 m)—290 trees per acre (716/ha). Other examples are given under **"Yield"**.

The young trees must be carefully tended and kept weed-free for the first 2 or 3 years in the field. Citrus trees have special nutritional requirements. The soil should be tested to determine the best balance of major and minor elements to be added. In general, orange trees need to be fertilized with N P K very soon after harvesting. The balance of major nutrients has to be considered in relation to the ultimate use of the crop. For example, extra nitrogen increases the peel oil content of oranges, while extra potassium decreases it. In California, 1 lb (0.45 kg) of nitrogen per tree per year has been found sufficient to maintain high productivity. Indian scientists, after a 4-year study, concluded that sweet oranges of the best quality were produced by applications of nitrogen at the rate of 2 lbs (0.9 kg) per year for 8-year-old trees. Orange trees are watched for signs of deficiencies which may be counteracted by foliar spraying. Leaf analysis reveals what is lacking or being applied in excess.

Efforts in northern India to control spring fruit drop with growth regulators have not been successful but pre-harvest drop has been greatly reduced. Gibberellic acid at 100 to 1,000 ppm, whether applied at full bloom or small fruit stage, has significantly increased the number of 'Washington Navel' fruits harvested.

Irrigation: Irrigation of orange trees is carefully managed. Ordinarily, it is omitted in the fall in order to avoid the production of tender new growth that would be damaged in winter cold spells. It may be very desirable in the spring dry season to prevent wilting. Excessive irrigation lowers the solids content of the fruit. The deeper the soil, the better the root system and the greater the ability to withstand drought. Soils at least 4 ft (1.2 m) deep can be given 1½ in (6.25 cm) of water as needed, whereas soils only 1½ ft (45 cm) deep should receive no more than 1 in (2.5 cm) of water at a time but more frequently.

Pruning: Orange trees are self-forming and do not need to be shaped by early pruning. Removal of water sprouts from young and older trees is important. Branches that are lower than 1 ft (30 cm) from the ground should be taken off. Deadwood from any cause—adverse soil conditions, pests or diseases, nutritional deficiencies, or cold injury—should be cut out and cut surfaces over 1 in (2.5 cm) in diameter should be sealed with pruning compound. Orange trees that are close-planted and "hedged" are being mechanically pruned by special equipment. Cuban experimenters claim that this procedure is beneficial in increasing the number of new shoots and that it decreases pest and disease problems.

In Israel, the old practice of girdling has been revived. If done in winter, it will enhance the sprouting of buds in the spring. Summer girdling increases the size of the fruits.

Harvesting

In the early days of the orange industry, harvesters climbed ladders and pulled the fruits off by hand, putting them into pails or shoulder-sacks which they later emptied into 90-lb (40.8 kg) field boxes. From 1900 to 1940, they used clippers. With the erstwhile shortage and increased cost of field labor, various changes and improvements have been made in harvesting methods. Pulling is again practiced, especially with fruits destined for processing. In the United States, Federal regulations and the individual state Department of Agriculture and state Citrus Commission control the stage of maturity at which the fruits may be picked and the grading of the fruits for marketing and shipping.

In anticipation of drastic increases in the cost of conventional harvesting, various methods of wholly or partly mechanized harvesting have been explored, including limb and tree shakers and air jets. Devices developed are not being widely utilized as yet because of the investments necessary for their acquisition and the current availability of manual labor. Manual picking is less laborious now that oranges for processing can be allowed to fall on the ground instead of being placed in sacks which have to be carried down ladders. The efficiency of hand-harvesting has been enhanced also by the use of fiberglass ladders and abscission agents which make it possible to pluck the fruit with less force and consequently greater speed. Good workers who have harvested oranges at the rate of 6.5 boxes per hour are now able to pick 9.1 boxes per hour. The effectiveness of the abscission agent depends largely on the lapsed time after spray-application and the prevailing temperature and relative humidity during that period.

Yield

On the average, a 'Washington Navel' orange tree may bear approximately 100 fruits in a season. Horticulturists at the University of Puerto Rico have selected Navel orange clones and budded them onto orange seedlings for test plantings. Of 5 that were numbered 4, 5, 6, 7 and 8, numbers 5 and 7 surpassed the others in productivity, number 7 yielding 293 fruits per tree. These two clones are considered worthy of propagation and naming. It is said that very old, large orange trees in the Mediterranean area may bear 3,000 to 5,000 oranges each year.

Growers everywhere are testing high-density as a means of gaining higher yields. In Australia, 'Valencia' orange

trees 6 years old, planted 1,011 to 2,023 trees per acre (2,500-5,000/ha), yielded 24 tons/acre (60 tons/ha). 'St. Ives Valencia' trees on *P. trifoliata* rootstock and inoculated in the nursery with mildly dwarfing exocortis, were planted in 1973 at densities ranging from 270 to 2,023 trees per acre (667-5,000 trees/ha). Those at 506 trees/acre (1,250/ha) yielded 55 tons/acre (135 tons/ha). Those at 1,214 to 2,023 trees/acre (3,000-5,000/ha) yielded 105 tons/acre (260 tons/ha) until after the 4th crop, when productivity began to decline.

Keeping Quality

Oranges can be stored for 3 months at 52°F (11.11°C); up to 5 months at 36° to 39°F (2.22°-3.89°C). Deterioration in market quality is primarily due to transpiration—loss of moisture in the peel and pulp. After 2 months of storage at 68°F (20°C) and relative humidity of 60 to 80%, 'Valencia' oranges have been found to have lost 9.5% of the moisture in the peel but only 2.1% of that in the pulp. The peel becomes 50% thinner, the pulp 10%. Later, the peel is very thin, dry and brittle while the pulp is still juicy. Coating the fruits with a polyethylene/wax emulsion doubles the storage life.

Pests

Oranges and other citrus fruits are commonly affected by citrus rust mites causing external blemishing and, in extreme infestations, smaller fruits, pre-mature falling and even shedding of leaves. Citrus red mites (purple mites) and Texas citrus mites, common in summer, disfigure the surface of the fruit and the foliage mainly in the winter and during droughts. Parasitic fungi (*Hirsutella thompsonii* and *Triplosporium floridana*) help to eradicate rust mites and the Texas citrus mite.

Several scale insects prey on citrus trees. The most harmful enemy is citrus snow scale infesting the woody portions of the tree. Purple scale and glover scale suck sap from the branches, twigs, leaves and fruit. Florida red scale and yellow scale induce shedding of fruit and foliage. Chaff scale may be found on the fruit, foliage and bark and produces green spots on the fruit. Cottony cushion scale often infests young trees. Maintaining populations of the Vedalia lady beetle in nurseries and groves is a fairly effective means of controlling this scale. Parasitic wasps (*Aphytis* spp.) are able to control Citrus snow scale, purple scale and Florida red scale.

California red scale (*Aonidiella aurantii*) is fairly well controlled by insect parasites in desert orchards but chemical treatment is necessary in the San Joaquin Valley when pheromone trapping of males reveals infestations. Pheromone trapping has virtually eliminated this scale in commercial groves in Arizona.

Mealybugs, prevalent in spring and early summer, form white masses underneath and between fruits in the early stages of development and may cause shedding, and their excretion of honeydew provides a base for the fungal manifestation termed sooty mold. The whitefly in its immature stage congregates on the lower side of the leaves, sucking the sap, and also excreting honeydew leading to sooty mold. Immature whiteflies are preyed upon by the parasitic fungi, *Aschersonia* spp. and *Aegerita* sp., which are frequently mistaken for harmful pests. The citrus blackfly, *Aleurocanthus woglumi,* deposits eggs in spiral formations on the underside of the leaves. It is a serious pest in many of the citrus regions of the world. In January 1976, an inspection program was launched in Florida with the expectation that spraying could eventually be replaced with biological control utilizing the blackfly parasites, *Amitus hesperidum* and *Prospaltella opulenta.* By 1978, the parasites were credited with a 97% reduction in the blackfly population.

Aphids (plant lice) cause leaves to curl and become crinkled. The brown citrus aphid, *Toxoptera citricidus,* is the main vector of the tristeza virus. The orange dog is a large brown-and-white caterpillar, the larva of a black-and-yellow, swallowtailed butterfly. These pests damage the trees in summer and autumn.

In 1953, it was discovered that the burrowing nematode, *Radopholus similis,* was the cause of "spreading decline" in Florida and extraordinary measures costing over 21 million dollars in the next 22 years were taken to remove infested trees, treat the soil and create buffer zones to prevent spread into other groves.

Fruit flies are a constant threat to oranges and massive steps have been taken against the spread of the Mediterranean fruit fly whenever it has appeared in Florida or California. The Caribbean fruit fly is common in Florida and oranges from this state were, until 1980, fumigated with ethylene dibromide before export. When this chemical was reported to have caused cancer in experimental animals, it was banned for export or domestic use. Instead, cold treatment for 17 days at 34°F (1.1°C) has been required. Quality of 'Valencia' oranges has remained stable for only 1 week at 40°F (4.4°C) following cold treatment; has deteriorated in a further 2 weeks at 70°F (21.1°C).

Diseases

Orange and other citrus trees are subject to a great number of fungal diseases affecting the roots, the trunk and branches, the foliage and the fruits. Greasy spot, caused by *Cercospora citri-grisea,* is seen, 2 to 9 months after severe infection, as yellow-brown, blistery, oily, brown or black spots on the foliage. Severe defoliation may follow. The fungus, *Diaporthe citri,* is responsible for gummosis, melanose, dieback and stem-end rot. The fungus, *Elsinoe australis,* causes sweet orange scab which is frequently seen on oranges in South America and in Sicily and New Caledonia. *Phytophthora megasperma, P. palmivora* and *P. parasitica* are common causes of foot rot.

There are also viruses and viroids usually named for the syndromes they cause—crinkly leaf; gummy bark; exocortis (scaly butt) transmitted by budwood and by tools; psorosis, xyloporosis (cachexia), transmitted only by budwood. Tristeza has been a major problem in Florida in the past and still is in Brazil. Since 1953, Florida has maintained a Citrus Budwood Registration program for the production of virus-tested citrus trees. Under this

program, the Etrog citron was adopted as a test plant for identifying exocortis virus in one year's time, and techniques have been developed for identifying tristeza in a few hours instead of months.

In 1984, an outbreak of citrus canker (*Xanthomonas campestris* pr. *citri* or *Phytomonas citri*) in four wholesale citrus nurseries in Florida caused widespread alarm and forced the burning of thousands of nursery plants and a search for plants that had been sold by those nurseries, in efforts to prevent the spread of this menace. The virus causes lesions on fruits, stems, and, unlike other diseases, on both sides of the leaves; induces leaf fall and premature fruit drop and, in severe cases, the death of the tree. Canker is common in various countries including India, the Philippines, the Middle East, parts of Africa and in Brazil and Argentina. The highly virulent "Oriental Strain A" was introduced into Florida in 1910 and was eradicated in Florida and the Gulf States by 1933. In anticipation of reintroduction, pathologists have gone abroad to study the disease. By January 1986, "Strain E" had been reported in 17 nurseries and over 15 million young trees had been destroyed. Eradication programs were intensified when "Oriental Strain A" reappeared on Florida's west coast in midsummer, and 5 million more trees had to be burned.

Blight, or young tree decline (YTD), is the leading cause of losses of orange trees—up to a half-million per year—in Florida, especially 'Valencia' on rough lemon, but any cultivars on any rootstocks. Sour orange rootstock seems somewhat more resistant than the others. Blight was thought to be the result of nutritional deficiencies or physiological or soil problems. But root-grafting of healthy trees onto affected trees has shown the disease to be infectious.

Experiments at Lake Alfred have shown that substantial recovery from YTD can be achieved by early treatment of an affected tree with 20 gals (76 liters) of a 1½% solution of sodium erythorbate or erythorbic acid applied to the soil, and 10 gals (38 liters) applied as a foliar spray, plus soil application of 5 to 7½ lbs (2.2-3.3 kg) of calcium chloride or calcium nitrate—about 6 ft (1.8 m) out from the base of the trunk. Foliar sprays of urea—5 lbs (2.2 kg) per 100 gals (380 liters)—with a wetter-sticker are given to encourage new growth.

Californian scientists have traced decline of the 'Navel' orange to incompatibility with trifoliate orange rootstock (especially 'Rubidoux'; rarely 'Rich 16-6'). Malformation at the union, evident in about 20 years, fully developed in 25, takes two forms—"tongue-and-groove", and "shelf-and-shoulder" distortions.

Often, abnormal aspects of leaves, occasioned by mineral deficiencies, may be mistaken for signs of disease, Exanthema is the result of copper deficiency. Mottle-leaf indicates zinc deficiency. Yellow spot signals lack of molybdenum. On the other hand, star melanose is brought about by late copper spraying. Inspection by trained entomologists and/or plant pathologists is usually necessary to determine the actual cause, or causes, of disfigurations or decline. Citrus quarantine laws are very strict with a view to preventing the introduction and spread of pests and diseases, and failure to comply with these laws can have disastrous consequences.

Food Uses

In the past, oranges were primarily eaten fresh, out-of-hand, and many are so consumed in warm climates. In Cuba, oranges are peeled by an old-fashioned apple peeler mounted on the pushcart of fruit vendors. Today, pre-peeled oranges in plastic bags are sold to motorists by Latin American street vendors in Miami. The hand-labor of peeling oranges has limited the production of sliced oranges for use by restaurants and orange-salad packers. However, a peeling machine developed by John Webb in Clearwater, Florida, is peeling 80 oranges a minute and this device, together with his successful sectioning machine, is expected to greatly expand the commercial use of fresh oranges.

In the home, oranges are commonly peeled, segmented and utilized in fruit cups, salads, gelatins and numerous other desserts, and as garnishes on cakes, meats and poultry dishes. They were also squeezed daily in the kitchen for juice but housewives are becoming less and less inclined to do this. In South America, a dozen whole, peeled oranges are boiled in 3 pints (1.41 liters) of slightly sweetened water for 20 minutes and then strained and the liquid is poured over small squares of toast and slices of lemon and served as soup.

In the past few decades, the commercial extraction of orange juice and its marketing in waxed cartons or cans has become a major industry, though now surpassed on a grand scale by the production of frozen orange concentrate to be diluted with water and served as juice. Dehydrated orange juice (orange juice powder), developed in 1963, is sold for use in food manufacturing, adding flavor, color and nutritive elements to bakery goods and many other products. Whole oranges are sliced, dried and pulverized, and the powder is added to baked goods as flavoring.

Orange slices and orange peel are candied as confections. Grated peel is much used as a flavoring and the essential oil, expressed from the outer layer of the peel, is employed commercially as a food, soft-drink and candy flavor and for other purposes. Pectin for use in fruit preserves and otherwise, is derived from the white inner layer of the peel. Finisher pulp, consisting mostly of the juice sacs after the extraction of orange juice, has become a major by-product. Dried to a moisture content of less than 10%, it has many uses as an emulsifier and binder in the food and beverage industries.

Orange wine was at one time made in Florida from fruits too affected by cold spells to be marketed. It is presently produced on a small scale in South Africa. Orange wine and brandy are made in Brazil from fruits which have been processed for peel oil and then crushed.

Food Value

The chemistry of the orange is affected by many factors. On the average, 'Valencia', 'Washington Navel', and other commercial oranges have been found to possess the values shown on the next page.

Food Value Per 100 g of Edible Portion						
	Fruit (fresh)	*Juice (fresh)**	*Juice (canned, unsweetened, undiluted)*	*Frozen concentrate (unsweetened, undiluted)*	*Juice (dehydrated)*	*Orange Peel (raw)***
Calories	47-51	40-48	223	158	380	
Moisture	86.0 g	87.2-89.6 g	42.0 g	58.2 g	1.0 g	72.5%
Protein	0.7-1.3 g	0.5-1.0 g	4.1 g	2.3 g	5.0 g	1.5 g
Fat	0.1-0.3 g	0.1-0.3 g	1.3 g	0.2 g	1.7 g	0.2 g
Carbohydrates	12.0-12.7 g	9.3-11.3 g	50.7 g	38.0 g	88.9 g	25.0 g
Fiber	0.5 g	0.1 g	0.5 g	0.2 g	0.8 g	
Ash	0.5-0.7 g	0.4 g	1.9 g	1.3 g	3.4 g	0.8 mg
Calcium	40-43 mg	10-11 mg	51 mg	33 mg	84 mg	161 mg
Phosphorus	17-22 mg	15-19 mg	86 mg	55 mg	134 mg	21 mg
Iron	0.2-0.8 mg	0.2-0.3 mg	1.3 mg	0.4 mg	1.7 mg	0.8 mg
Sodium	1.0 mg	1.0 mg	5 mg	2 mg	8.0 mg	3.0 mg
Potassium	190-200 mg	190-208 mg	942 mg	657 mg	1,728 mg	212 mg
Vitamin A	200 I.U.	200 I.U.	960 I.U.	710 I.U.	1,680 I.U.	420 I.U.
Thiamine	0.10 mg	0.09 mg	0.39 mg	0.30 mg	0.67 mg	0.12 mg
Riboflavin	0.04 mg	0.03 mg	0.12 mg	0.05 mg	0.21 mg	0.09 mg
Niacin	0.4 mg	0.4 mg	1.7 mg	1.2 mg	2.9 mg	0.9 mg
Ascorbic Acid	45-61 mg	37-61 mg	229 mg	158 mg	359 mg	136 mg

*Volatile properties include: ethyl, *iso*amyl and phenylethyl alcohols; acetone; acetaldehyde; formic acid; esters of formic, acetic and caprylic acids; geraniol and terpineol. The juice also contains β-sitosteryl-*D*-glucoside and β-sitosterol.
***Orange Peel Oil:* *d*-limonene (90%); citral; citranellal; methyl ester of anthranilic acid; decyclic aldehyde; linalool; *d*-*l*-terpineol; nonyl alcohol; methyl anthranilate; and traces of caprilic acid esters.

Toxicity

Persons in close proximity to orange trees in bloom may have adverse respiratory reactions. Sawdust of the wood of orange trees, formerly used for polishing jewelry, has caused asthma. Excessive contact with the volatile oils in orange peel can produce dermatitis. People who suck oranges often suffer skin irritation around the mouth. Those who peel quantities of oranges may have rash and blisters between the fingers. If they touch their faces, they are apt to have facial symptoms as well. In southern Florida, a young woman shook an orange tree in order to cause the fruit to fall. An hour later, she broke out in hives, presumably from exposure to a spray of citrus oils from the ruptured peduncles, stem-end peel, and broken leaf petioles. A similar reaction has occurred from shaking down the fruits of a lime tree in Miami. Sensitive individuals may have respiratory reactions in proximity to the volatile emanations from broken orange peel.

Other Uses

Pulp: Citrus pulp (¾ being a by-product of orange juice extraction) is highly valued as pelleted stockfeed with a protein content of 6.58 to 7.03%, and it is also being marketed as cat litter. It is a source of edible yeast, non-potable alcohol, ascorbic acid, and hesperidin.

Peel: In addition to its food uses, orange peel oil is a prized scent in perfume and soaps. Because of its 90-95% limonene content, it has a lethal effect on houseflies, fleas and fireants. Its potential as an insecticide is under investigation. It is being used in engine cleaners and in waterless hand-cleaners in heavy machinery repair shops. It is commercially produced mainly in California and Florida, followed distantly by Italy, Israel, Jamaica, South Africa, Brazil and Greece, in that order. Terpenes extracted from the outer layer of the peel are important in resins and in formulating paints for ships. Australians have reported that a shipment of platypuses sent to the United States in the 1950s was fed mass-produced worms raised on orange peel.

Seeds: Oil derived from orange and other citrus seeds is employed as a cooking oil and in soap and plastics. The high-protein seed residue is suitable for human food and an ingredient in cattlefeed, and the hulls enter into fertilizer mixtures.

Flowers and foliage: The essential oils distilled from orange flowers and foliage are important in perfume manufacturing. Some Petitgrain oil is distilled from the leaves, flowers, twigs, and small, whole, unripe fruits.

Nectar: The nectar flow is more abundant than that from any other source in the United States and is actually a nuisance to grove workers in California, more moderate in Florida. It is eagerly sought by honeybees and the delicious, light-colored honey is widely favored, though it darkens and granulates within a few months. Citrus honey constitutes 25% of all honey produced in California each year. There are efforts to time pest-control spraying to

avoid adverse effects on honeybees during the period of nectar-gathering.

Wood: The wood is yellowish, close-grained and hard but prone to attack by drywood termites. It has been valued for furniture, cabinetwork, turnery and engraver's blocks. Branches are fashioned into walking-sticks. Orange wood is the source of "orange sticks" used by manicurists to push back the cuticle.

Medicinal Uses: Oranges are eaten to allay fever and catarrh. The roasted pulp is prepared as a poultice for skin diseases. The fresh peel is rubbed on acne. In the mid-1950s, the health benefits of eating peeled, whole oranges was much publicized because of its protopectin, bioflavonoids and inositol (related to vitamin B). The orange contains a significant amount of the vitamin-like glucoside, hesperidin, 75-80% of it in the albedo, rag and pulp. This principle, also rutin, and other bioflavonoids were for a while much advocated for treating capillary fragility, hemorrhages and other physiological problems, but they are no longer approved for such use in the United States.

An infusion of the immature fruit is taken to relieve stomach and intestinal complaints. The flowers are employed medicinally by the Chinese people living in Malaya. Orange flower water, made in Italy and France as a cologne, is bitter and considered antispasmodic and sedative. A decoction of the dried leaves and flowers is given in Italy as an antispasmodic, cardiac sedative, antiemetic, digestive and remedy for flatulence. The inner bark, macerated and infused in wine, is taken as a tonic and carminative. A vinous decoction of husked orange seeds is prescribed for urinary ailments in China and the juice of fresh orange leaves or a decoction of the dried leaves may be taken as a carminative or emmenagogue or applied on sores and ulcers. An orange seed extract is given as a treatment for malaria in Ecuador but it is known to cause respiratory depression and a strong contraction of the spleen.