



Lemons in Hawai'i

Ken Love¹, Robert E. Paull²

¹Hawaii Tropical Fruit Growers Association, ²Tropical Plant and Soil Sciences

Lemons are just beginning to get the respect they deserve in Hawai'i. We are fortunate enough to have numerous varieties to grow, market, and use for a myriad of culinary creations. Almost 14 million tons of lemons are grown worldwide, with India and Mexico being the largest producers. In Hawai'i, we grow and sell less than 100,000 pounds and still import almost 4 million pounds.

The scientific name of lemon is *Citrus x limon*; the "x" indicates it is a hybrid between different *Citrus* species. The taxonomy and systematics of the *Citrus* genus is complex, and the number of species is much debated. Some have suggested that there are only three valid citrus species: citron (*C. medica* L.), mandarin (*C. reticulata* Blanco), and pummelo (*C. maxima*). The remaining *Citrus*, such as lemon, are from natural hybridization. Lemon is thought to be a hybrid resulting from a cross between citron and sour orange. Sour orange is in turn thought to be hybrid between pummelo and mandarin. Subsequent mutations in lemon have led to the many different types found worldwide. Lemon is known as limone (Italy), zitrone (Germany), limon (Spanish), limao (Portuguese); citron (French), and citroen (Dutch).

Lemon is believed to have originated in northern India and Burma. The Romans were likely acquainted with lemons, sour oranges, and citron, but abandoned



them following the empire's disintegration. Lemon, along with citron and sour orange, again made its way slowly westwards back into Europe between 500 to 1300 AD by way of invaders and travelers, including the Muslim armies, Arab traders, Crusaders, and travelers along trade routes. These early lemons may have been bitter and used as condiments. By the end of the 12th century, lemon had spread throughout the Mediterranean. In 1493, Columbus brought it to Hispaniola, and from there it went with the Spanish to California in 1751. Lemons were reported arriving in Hawai'i with Captain James Cook in 1778 and again with Don Francisco de Paula Marin first in

1813, with other varieties arriving with traders in 1823.

Early territorial reports from 1904 to 1906, including the USDA's "Citrus in Hawaii" and other publications, list 'Eureka', 'Lisbon', 'Villa Franca', and 'Sicily' as some of the varieties available at that time. The rough 'Jambiri' came as a rootstock in the 1920s and started to produce prolifically by 1934. 'Ponderosa' and its seedling 'American Wonder' and a sweet lemon were all mentioned by 1934.

Often called "local lemon," 'Rangpur' and 'Kona' are very sour orange-colored limes. The 'Rangpur' lime came to Hawai'i as a rootstock of a grafted citrus plant, but the grafted variety died and the 'Rangpur' rootstock

proliferated. Over the next 175 years these 'Rangpur' trees evolved into a lime with a puffy orange skin and very thorny branches also known as 'Rangpur'. Its offshoot, with tighter skin and very few thorns, is called the 'Kona' lime. These are in a group called Mandarin Limes.

There is also a tropical subgenus of citrus called *Papedas*, some of which also came to Hawai'i as rootstocks and now produce fruit here. 'Ichang Papeda' is often mistakenly called or sold as 'Japanese Yuzu'. 'Yuzu', however, is another variety this subgenus, along with 'Suidachi', 'Yuko', 'Kabosu', 'Khasi', 'Melanesian', 'Kalpi', and the popular 'Kaffir' lime.

Culinary and Other Uses

The histories of lemons and cooking have been intertwined since the beginning of recorded history. Recipes from ancient Greece, China, Persia, and India show the fruit was in demand, although it was not widely cultivated. Originally used both in sweets, with copious amounts of sugar, and in savorys, the fruit began to be used by early cooks in a number of other popular dishes. It was added to couscous, dried and used in soups and stews, and later in history, made into alcoholic drinks like lemoncillo. Lemon and lime pickles have been popular in India for more than a thousand years. Oil from lemon peel is used in many products, from aromatherapy oils to furniture polish. Other uses include mouthwash, disinfectant, and, mixed with water, heartburn relief. The Romans used it as an insect repellent and to freshen clothes.

Cultivars and Varieties Found in Hawai'i

There are hundreds of lemon varieties around the world; however, many have not made their way to Hawai'i. The most common lemons found in the Island are the following:

'Kalpi' (*Citrus x webberii*)

'Kalpi' is one of the most common lemons in Hawai'i. It is a natural hybrid found in the Philippines that is presumed to have arrived with Filipino immigrants. The name comes from the Bicol region of southern Luzon. These trees are found all over the state and are very prolific. They are often confused with small Italian lemons, very recent imports, and the larger rough-skinned 'Jambiri' lemon. 'Kalpi' is sometimes called Malayan lemon.



'Meyer' (*Citrus x meyeri*)

Frank N. Meyer, who was sent to China by the USDA's David Fairchild, first found this lemon on a fruit-hunting trip. Of the more than 2,500 species of plants Meyer introduced into the U.S., this is the only plant that bears his name. This lemon has dramatically increased in popularity over the past 20 years, in part due to Alice Waters and Martha Stewart featuring them in their cooking and shows. Meyer lemon produces very well in warmer climates like Hawai'i when other lemons may struggle with the heat. The improved 'Meyer' lemon is a selection that was found in the 1950s and released in 1975 as an improved version that is resistant to *Citrus Tristeza Virus*. Ever increasing in popularity, 'Meyer' lemon is sometimes referred to as the sweetheart citrus.

'Sweet Lemon' (*C. x limetta*)

Called sweet lemons or, to a lesser extent, sweet limes, these fruit are found in some areas in Hawai'i. "Sweet" is somewhat of a misnomer, as the fruit is generally insipid, with only a very slight taste. A number of varieties were introduced from India and later Brazil and Mexico, but they never achieved any commercial value. The fruit is not without fans, though, and there are a few named cultivars.

'Jambiri' (*Citrus x jambhiri*)

The rough-skinned lemon, originally from North East India, was commonly used as a rootstock for citrus coming to Hawai'i. Those grafts died off and the tree became a popular backyard tree. Recent molecular markers studies showed that it is a cross



between mandarin and citron. The tree is somewhat resistant to a host of pathogens and extremely resistant to leaf spot but sensitive to *Phytophthora* and waterlogged roots. It is tolerant to both cold and the hot Hawai'i climate. It's unclear if the fruit arrived in Hawai'i with Don Francisco de Paula Marin in the early 1800s or later with the first Portuguese immigrants. The Spaniards are credited with bringing the fruit to Florida and the New World. There are a number of named cultivars, such as 'Estes', 'Milam', 'McKillop', 'Nelspruit 15', and 'Lockyer', although it's not known if these are in Hawai'i. About 98% of the seeds planted are true to type, and the tree is fast growing and early maturing. Some texts list the 'Volkamer' or '*volckameriana*' lemon as being a type of 'Jambiri'. 'Rangpur' and 'Kona' lime are also given the name 'Jambiri' at times.

'Ponderosa' (*Citrus x limon*)

'Ponderosa' and its protégé 'American Wonder' are among the most popular lemons grown in Hawai'i. Elsewhere it is considered an ornamental because of the thick foliage and very large "showy" fruit. It came from a seedling grown in 1887 by George Bowman in Hagerstown, Maryland. It appeared in many nursery catalogs in the early 1900s. Sometimes classed as a citron hybrid, 'Ponderosa' fruit are large. They have been confused with pummelo at some of Hawai'i's farmers' markets, although with one taste, it is obvious that it is a lemon. There are some commercial plantings, and the tree is often used as a rootstock for other lemons.

'Eureka' (*Citrus x limon*)

The first 'Eureka' originated from seed in 1858 in Los Angeles and was propagated in 1877 by Thomas Garey, who called it 'Garey's Eureka'. Popularity rapidly increased, in part due to the tree's being virtually thornless. The University of California lists 14 types of 'Eureka' lemons based on origin. Hawai'i seems to have a few of these 'Eureka' types, including 'Old Line', 'Frost Nucellar', 'Allen-Newman', and the variegated pink-fleshed 'Eureka'. The pink came from a shoot from a regular 'Eureka' prior to 1931 when budwood was distributed. 'Pink Lemonade Eureka' has become very popular in Hawai'i over the past 20 years.

'Lisbon' (*Citrus x limon*)

'Lisbon' is perhaps the most popular commercial lemon next to 'Eureka', although its relationship to Hawai'i has always been marginal as it produces much better in cooler areas. The trees are more cold tolerant and most productive in California. Thick foliage better protects fruit from the sun. The thorns are considerable. Yield is about 25% greater than 'Eureka'. There is some disagreement as to the origin of 'Lisbon'. What is known is that seeds were sent from Portugal to Australia in 1924. (The name 'Lisbon' is not used for the lemon in Portugal.) It was listed in nursery catalogs as early as 1843. It was introduced to California in 1849 and again from Australia in 1874 and 1875. Although 'Lisbon' is continuously imported to Hawai'i, 'Eureka' remains very popular. The University of California lists 12 types of 'Lisbon' lemon.

Environment

The lemon, as with most citrus, prefers well-drained soil. In the Kona district the tree is found from sea level to more than 4,500-foot elevation. It is less tolerant to colder areas than other citrus but should perform well at higher elevations in Hawai'i given sufficient rainfall and nutrition. Spacing is consistent with other citrus; it is usually planted 15 to 20 feet apart, or about 100 trees per acre. When rootbound in large tubs, they will naturally dwarf; this has been observed in areas where there is considerable pahoehoe lava that restricts root growth. Lemons prefer soils with a pH of 5.5 to 6.5 but

have a reputation for tolerating a wide range of poor soils. The tree requires irrigation during periods of extended drought but will not tolerate being waterlogged.

Propagation

Commercial lemons such as 'Lisbon', 'Meyer', 'Eureka', and 'Ponderosa' are grafted but can be air-layered. Large cuttings from a minimum of 2-year-old wood can be rooted in a nursery environment and will usually produce faster than budded or grafted trees. 'Jambiri' or rough lemon is grown from seed and was primarily used as a rootstock but is now finding its way into culinary circles. 'Kalpi' lemon is also grown from seed, but there can be considerable differences in the quality of fruit and the number of thorns on the tree. It is advised to clone better-quality trees by grafting or air-layering.

Culture and Management

Young trees are pruned to establish a shape that facilitates harvesting and increases yields. Annual pruning to maintain a desired height of 6 to 8 feet and to remove dead wood is recommended. Increased yields can be obtained by pruning to open the tree's interior to light and air circulation. Flowering and fruiting occurs on 2-year new growth.

Soil and leaf sampling analysis submitted to and conducted by the University of Hawai'i through the local extension office can suggest the proper fertilizer. Generally no more than 8-8-8 or 6-6-6 is recommended to be applied every four months, while soil analysis will show the need for specific trace elements and lime. The trace elements can be applied as a foliar spray.

Too much potash can increase acidity, and high nitrogen will increase the amount of peel oil. Fertilizing regimens are often dependent on the intended use of the lemon, whether for fresh sales or for processing. Fertilizing frequencies in commercial growing locations vary widely, from one to four times a year. In all cases mulching with organic matter or manure is recommended.

Heavy irrigation can increase yield and fruit size but also susceptibility to infections. In some locations irrigation is withheld in summer until the trees begin to wilt, at which time the fields are irrigated heavily. The trees respond favorably to this method in some locations, but not in others in which there is some summer rain.

Pests and Diseases

There is a plethora of pests and pathogens that plague citrus in Hawai'i. Most of these can be mitigated with good horticultural practices and a modicum of oils such as neem oil, insecticidal soaps like Safer, and alternative sprays like hot pepper. Chemicals for specific issues should be well researched before being applied. Your local extension agent or a specialist at the University of Hawai'i should be able to help identify and determine the best course of action.

Common insect pests and diseases found in Hawai'i include the following:

Fungi

Botryosphaeria sp.

Colletotrichum gloeosporioides

Diaporthe citri, *Phomopsis citri*, *Alternaria citri*,

fungus causing citrus melanose mud cake and tear staining. See <http://www.ctahr.hawaii.edu/oc/freepubs/pdf/PD-59.pdf>

Diplodia natalensis

Glomerella cingulata

Rhizoctonia solani

Septobasidium pseudopedicellatum

Sphaeropsis tumefaciens

Mold

Penicillium digitatum, green mold

Penicillium italicum, blue mold

Penicillium roseum, pink mold

Rot

Fusarium oxysporum, root rot and vascular wilt

Macrophomia phaseolina, root rot

Pythium ultimum, root and stem rot

Phytophthora parasitica, heart rot and wood rot

Other pests

Aonidiella aurantii, armored red scale

Cephaleuros sp., green algae and parasites. See <http://www.ctahr.hawaii.edu/oc/freepubs/pdf/PD-43.pdf>

Cercospora gigantea, leaf spot

Elsinoe fawcetti, citrus scab

Ganoderma sessilis, crinkly leaf and exocortis viruses

As of this writing, the bacterial disease Huanglongbing (HLB), meaning “Yellow Dragon Disease,” also known as Citrus Greening disease, has not been reported in Hawai'i. Bacteria causing this disease are found localized in the plant's phloem, which carries sugars from the leaves to fruit, roots, and new growth. The insect vector, a psyllid that is known to spread the disease, is present in Hawai'i.

Citrus Tristeza Virus is widely present in Hawai'i and affects practically all citrus, especially orange, grapefruit, and lime. Trees decline from death of the vascular tissue (i.e., phloem). The insect vectors are aphids. Rough lemon (*C. x jambhiri*) and Trifoliata orange (*Poncirus trifoliata*) are examples of tolerant rootstocks to tristeza. Lemons are unaffected by the strains of this virus, though the virus may be isolated from the plant (asymptomatic).

Harvesting and Yield

Yields vary widely depending on variety. The rough-skinned ‘Jambiri’ and ‘Kalpi’ lemons bear heavily in locations around the state. For ‘Eureka’, ‘Ponderosa’, and ‘Lisbon’ the yields seem to be very site specific, with often much smaller yields than ‘Meyer’, ‘Jambiri’, and ‘Kalpi’. Yields and quality seem to be better at higher elevations. Yields also vary considerably depending on climatic conditions, nutrition, and the number of trees per acre. In commercial orchards 20 pounds per tree is common during the third year of production. As much as 400 pounds (about 1,000 fruit) may be produced by the time the tree is 10 years old.

Post-Harvest Considerations

Consumers generally look for lemons with a uniform bright yellow color that are firm and, with most varieties, have a smooth skin and are of the right size and shape. Fruit should be free of decay, mechanical injury, shrivel, and discoloration. Ripe lemons should have a pleasant citrus fragrance and a minimum juice content of 28 to 30% by volume.

Fruit can be harvested green or full yellow when they are fully mature and firm. Lemons harvested when they are mature and dark-green have a much longer post-harvest life than those picked yellow. Fruit should be handled gently after harvest as they can be injured, leading to staining of the skin (rind).

Recommended storage temperature is 7 to 12°C (45 to 54°F), with greener fruit held at the higher temperature. Maximum storage time for mature green fruit under ideal conditions is 6 months. The optimum RH is 85 to 95%. Since lemons are chilling sensitive they should not be stored below 10°C (50°F) for prolonged periods, but they can generally be held at 3 to 5°C (37 to 41°F) for two to three weeks.

Packaging, Pricing, and Marketing

Lemons for the large wholesale market are generally packed in 25-pound boxes that are well vented. A few growers have used classic wooden crates when at farmers' markets. A number of varieties of lemons are often

Nutritive Value

Table 1. Food value range per 100 grams of edible portion.

Calories	27–29
Moisture	90.1g
Protein	1.1g
Fat	0.3 g
Cholesterol	0
Carbohydrates	8.2 g–9.32 g
Dietary Fiber	2.8 g
Fiber	0.4 g
Ash	0.3 g
Calcium	26 mg
Phosphorus	16 mg
Iron	0.6 mg
Sodium	2 mg
Potassium	138 mg
Vitamin A	20 I.U.–22 I.U.
Vitamin C	53 mg
Vitamin E	0.15 mg
Thiamine	0.04 mg
Riboflavin	0.02 mg
Niacin	0.1 mg

sold together, with a 2013 average retail price of 50 cents each. At times lemons are sold by size, with small 'Kalpi' lemons selling at 3 for \$1.00 and giant Ponderosas selling for \$1.00 each. Wholesalers will pay from 50¢ to 90¢ a pound depending on quality, variety, and color. Consistent sizing is important for wholesale markets. For more information on pricing lemons and other agriculture commodities, see "Pricing Produce and Products for Fair Profit Based on Cost of Production" <http://www.ctahr.hawaii.edu/oc/freepubs/pdf/ET-13.pdf>.

Cost of Production

As with most citrus, cost of production is fairly similar on all islands but differs in terms of the variety being harvested. For example, there are more 'Meyer' lemons on a tree than 'Eureka', making it easier to harvest larger numbers in a shorter period of time.

The cost of production study in <http://www.ctahr.hawaii.edu/oc/freepubs/pdf/12fruits.pdf> gives examples for 12 fruit, including 'Rangpur', 'Kona' lime, and kumquat. Although based on specific trees, this will give growers the information needed to develop a cost of production analysis for each crop grown on any given farm. CTAHR's publication database at <http://www.ctahr.hawaii.edu/site/Info.aspx> lists a variety of specific cost-of-production studies in Hawai'i, while UC-Davis offers a specific lemon study from California at <http://coststudies.ucdavis.edu/files/lemonvs10.pdf>.

Future

There are hundreds of other lemon varieties around the world that have not made their way to Hawai'i. Since citrus greening disease (HLB) is now found in many locations around the world, it is doubtful that many of these varieties will ever come to Hawai'i unless they are tissue-cultured. Lemons and lemon hybrids like 'Sicily', 'Femminello', 'Genova', 'Monachello', 'Perrine', 'Marrakech', 'Pear', 'Galgal', 'Karna', 'Sanbokan', and 'Snow' should be sourced from HLB-free areas or tissue-cultured and given a chance to thrive in Hawai'i's microclimates. Each of these unusual varieties represents a potential for niche marketing as fresh fruit or in value-added products for Hawai'i's agriculture entrepreneurs.

Additional Resources

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