College of Tropical Agriculture and Human Resources
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Finger Limes

At a Glance

This publication covers:

- A potential crop for Hawai'i fruit growers
- Uniqueness of the crop
- How to grow finger limes
- Harvesting and handling
- Uses of the fruit and recipes

Introduction and Origin

Early settlers in Australia consumed finger lime, and while clearing land they retained these trees (Low 1991). This fruit is one of a number of Australian Bush Foods (Bush Tucker) that are undergoing a renaissance, with increased commercial interest. Finger lime fruit are usually yellow-green but can vary widely from yellow and green to pale pink and crimson, with similar variation range in the flesh and seediness. The small translucent vesicles, or "citrus pearls," like caviar, inside the fruit are spherical and almost free, unlike the long, narrow vesicles in other citrus species. These pearls are used as a garnish or added to various recipes. When chewed, the vesicles have an effervescent tangy flavor.

Figure 1. Leaves, thorns, fruit, flower, and halved fruit showing the translucent vesicles.

There a number of commercial finger lime operations in Hawai'i, as well as many single tree plantings. Sales to hotel and restaurants are brisk for special events and in holiday seasons. Sales at farmers' markets are stable, but sales to grocery stores have yet to develop. The tree makes an excellent potted plant or hedge pruned to less than six feet.

Finger lime is native to the sub-tropical rainforests of South-East Queensland from Mount Tambourine to the Richmond River in North-East New South Wales. The Bundjalung people who lived in this area of Australia called finger lime "gulalung." They are currently grown in virtually all tropical and sub-tropical climates. In its natural habitat, this hardy understory shrub or small tree is found below the canopy, which can reach 25 feet in most soils. The plant can tolerate most conditions in Hawai'i, at both extreme upper and lower elevations.

Scientific Name and Description

Finger lime (*Citrus australasica*, F. Muell.) was formerly known as *Microcitrus australasica* (F. Muell.) Swingle. The species is a member of the sub-family *Aurantioideae* in the citrus family *Rutaceae*.

It has a compact or spreading crown with straight thorns (½"long) at the nodes and small narrow leaves (1" by ½")

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that have a slight orange aroma when crushed. Flowers are white to pink with three to five oblong petals 1/3" long on short pedicels, and numerous stamens. Fruit are cylindrical, long and broad, with 5 to 7 locules. They have a peel that ranges from dark green, almost black, to yellow or crimson. The leathery peel is slightly rough, with numerous oil-glands. The translucent flesh has nearly free spherical (ovoid) vesicles that vary from light green to pinkish. Seeds are small, ovoid, usually flattened on one side and about ¼" long with a smooth seed coat.

Taxonomy and Nomenclature

Citrus are thought to have evolved in Southeast Asia, an area influenced by both the east and south Asian monsoons. This area includes the Yunnan province of southwest China, Myanmar, and northeastern India in the Himalayan foothills (Wu et al. 2018). From this region, one branch of the citrus radiation migrated across the Wallace line 4 million years ago when a land bridge existed between Asia and Australia, giving rise to the Australian limes. This Asian radiation includes mandarin and kumquat. The closest relative to the Australian citrus is the genus *Fortunella*, which includes kumquat. The creation of new diverse citrus species in Australia means that they are found in both dry areas and in rainforests in northeastern Australia.

Citrus classification is difficult because of the long period of cultivation and wide-cross-compatibility among species (Mabberley 2004, Bayer et al. 2009). Australian citrus species are divided into five endemic species, with the division based upon leaf and fruit shape (Mabberley 1998), though a number of hybrids have been described. Related Australian limes also have unique textures, flavors, and colors (Hele 2006).

- *Citrus inodora* (Russell River lime) has large leaves and is found, though now rarely, in northern Queensland in high-rainfall lowland rainforests.
- *Citrus australis* (Australian lime) has a globose (spherical) fruit with a green to yellow peel and pale-green pulp. Found in drier open rainforests of southeast Queensland. A natural hybrid with finger lime called "Sydney hybrid" shows extreme vigor and drought tolerance.
- *Citrus glauca* (desert lime) is a weedy and very thorny short shrub less than 10 feet in height found in thick thickets. Some selections are available such as "Outback lime," which has larger fruit (1" diameter) and is thornless. Found from central Queensland into central New South Wales in drier areas subject to cyclonic rains and thunderstorms. Adapted to semiarid areas and saline soils, with a deep root system. Frost tolerant.
- *Citrus garrawayi* (Mount White lime), from rainforests of Cape York in northern Queensland, has shorter, thicker finger-shaped fruit than finger lime.
- *Citrus maideniana* (Maiden's lime) has a similar range and appearance as *Citrus inodora*, with the only distinguishing feature being a sunken apex. Questions are raised as to whether it is a separate species.

Cultivars and Related Species

The wide variation in wild finger limes has given great scope for selection of trees and fruit with desirable horticultural features. Diploid and triploid progeny have been developed (Singh, et al. 2018). Grafting is practiced onto desirable rootstocks with scions from selected trees. Finger limes are sexually compatible with other citrus, which has led to the development of hybrids.

Eight finger limes are registered with the Australian Cultivar Registration Authority [https://www.anbg.gov.au/acra]: 'Alstonville', 'Blunobia Pink Crystal', 'Durham's Emerald', 'Judy's Ever-bearing', 'Rainforest Pearl', 'Pink Ice', 'Byron Sunrise', and 'Jali Red'. D1 is another cultivar growing in popularity; it is large and almost seedless (Table 1). The description of each cultivar can be found at the above site.

Several Citrus hybrids have been developed by crossing the finger lime with standard Citrus species. In Australia, two such hybrids are 'Australian Blood', a cross with

Table 1. Variation in described finger lime varieties (Hardy et al. 2010)

Variety	Description
Alstonville	Tall-growing shrub with dark green-black fruit and a pale-green flesh.
Blunobia Pink Crystal	Compact medium bush with green-brown fruit and a deep-pink flesh
D1	From Eyles Citrus Nursery. Seedless selection with a green-yellow skin and green pulp
Durham's Emerald	Medium open shrub with black fruit and emerald-green pulp.
Judy's Everbearing	Tall bush with green-brown to maroon fruit and green to dark-pink flesh
Pink Ice	Medium height bush with reddish-maroon fruit and clear to pink flesh
Rainforest Pearl	Small open upright tree with green fruit tinged with crimson and a pink flesh.
Ruby	From Eyles Citrus Nursery. Copper peel with a dark-pink pulp.

an acid Rangpur mandarin that has a blood-red rind, flesh, and juice, and 'Australian Sunrise' (*Fortunella* sp. x *Citrus reticulata*) (Sykes 1997, 2002), a cross with a calamondin (which itself is a mandarin crossed with a kumquat) that produces a pear-shaped, orange fruit that makes an excellent marmalade. A hybrid named 'Minnie Finger Lime' was developed by the USDA ARS in Florida; it is a compact tree with light-green to yellow peel at maturity and pale-yellow to pale-green vesicles (Bowman, et al. 2019).

Figure 2. Diversity in fruit vesicle coloration and seed of Hawai'i-grown finger limes.

Flowering, Fruit Growth, and Development

Generally, flowering occurs year round in most parts of Hawai'i. Trees at elevations from 600 to 2,000 ft. may continuously flower and bear fruit. No published data has been found on regulation of flowering or on pollination. It is assumed to be similar to other commercially grown citrus.

The period from flowering to fruit maturity is about five months. Early in fruit development, many young fruit may drop, as with other citrus. Fruit thinning to reduce cluster size leads to larger individual fruit. Fruit can be up to almost 5 inches in length and 1 inch in diameter at full maturity. They will not continue to ripen once harvested.

Propagation

Grafted trees will generally start fruiting within three years, while seedling trees can take up to 15 years to begin to flower (Hardy et al. 2010). The trees do well from cuttings and will produce in 4 to 5 years. Cuttings will root with about 80% success using rooting hormone and are ready to repot in about three months. Once seedling trees produce, they tend to get top worked with selected cultivars, only because the number of thorns increases 10-fold. Though an under-story tree, it can be grown in full sun or dappled light, but not in shaded areas. It is not tolerant of frost or low temperatures.

Windbreaks are critical, for this plant is easily damaged. Fruit rubbing on branches and thorns can cause significant skin damage and lower fruit quality.

Training and Pruning

Production practices for finger limes are similar to those for other citrus species, though the hedge-row system is often used, particularly in Australia. The rows are run north-south to maximize light interception. Planting densities vary with cultivar, with generally 8 to 10 feet between trees and 12 to 15 feet between rows (Hardy, et al. 2010). In Hawai'i, trees can be planted as close as 10 feet in either direction, giving 600 to 800 trees per acre.

The tree can grow to 30 feet; therefore, early pruning is designed to create an open-shaped tree with four to six main branches and a final tree height of less than ten feet. This open shape is desirable for harvesting because of the thorniness of the trees and also to reduce fruit rubbing on branches and marring the fruit peel. Light pruning and removal of dead branches is common. Proactive pruning and shaping of the trees should begin before trees begin to flower and fruit. The thorns can prove daunting, so some growers will maintain an 1/8 of the tree cut out to leave a pie-shaped wedge, allowing for easier access to the center of the tree.

Fertilization

While there is no substitute for a good soil sample to give you the most accurate reading for the proper NPK fertilizer needs, the most commonly used fertilizer on finger limes in Hawai'i is 8-8-8 Complehumus with micronutrients. A handful or ¼ cup added four times a year works well. Any low-numbered citrus fertilizer also will work fine. Frequency will depend on how well the soil drains and on the rainfall. Some tests done in South Kona and on Moloka'i use large amounts of 0-0-50.

In Australia, less fertilizer is used, primarily because the trees have smaller leaves than other citrus and fewer feeder roots centered in the top 1 to 2 feet of soil. The NPK often used by commercial growers in Australia's older soils is 15-4-11. It should be noted that in Australia no fertilizer is used from the time of flowering until the fruit is about 1 inch long, although in Hawai'i, with the trees' constant growth, lower doses can often be very effective. High nitrogen levels have been reported to reduce flowering.

Irrigation and Soil Type

Rainfall in the region where this tree is native ranges from 50 to 67 inches, with well-drained acid soil types (pH 5 to 6.5) The soil types vary from the deep red volcanic clay loams to the yellow and grey podzolic soils of wet sclerophyll forests that are low in nutrients, and basaltic-derived alluvial soils of river flats (Birmingham 1997). Drip irrigation is generally used; care is needed to avoid under- and over watering.

Pests and Diseases

The disease and insect pests of finger limes are similar to those found on other citrus species. A major disease reported in the literature is *Phytophthora* root rot. Budding of finger lime onto *Citrus trifoliata* (Trifoliate orange) rootstock provides protection (Hardy et al. 2010).

Citrus melanose is reported to be a serious disease of finger limes in Australia (Hardy et al. 2010). The disease affects young leaves and fruit of citrus in Hawai'i during rainy and humid weather (Nelson 2008). Citrus melanose is caused by the plant-pathogenic fungus *Diaporthe citri* (anamorph = *Phomopsis citri*). It causes severe fruit rind blemishes without affecting the pulp. On leaves, the disease causes small, black raised lesions often surrounded by yellow halos and can cause leaf distortion (Nelson 2008). Twig or branch dieback occurs, but no disease organism has yet been discovered, though in other citrus a number of causes have been proposed: frost, hot dry or very cold winds, and a lack of soil moisture.

Figure 3 (left to right): fruit with sunburn; deformed fruit, probably from poor pollination; and peel abrasion damage, possibly from thrips feeding on young fruit.

Finger lime is regarded as being tolerant to Huanglongbing (greening disease) caused by proteobacterium (*Candidatus Liberibacter*), which is transmitted by psyllid insects (Chandrika et al. 2016). The Asian citrus psyllid that transmits the proteobacterium in Asia and Americas has been identified in Hawai'i, but the proteobacterium has not been found so far in Hawai'i (Melzer et al. 2017).

Insect pests on citrus in Hawai'i include scale insects, aphids, whitefly, Chinese rose beetle, citrus swallowtail caterpillar, citrus blackfly, and citrus leaf miner. Broad mite is very prevalent and causes leaf curling. Citrus leaf miner causes leaf curl with wavy white lines. Beneficial insects (including parasites and predators) help to control certain insect pests, including the citrus swallowtail caterpillar, aphids, whitefly, scale, and blackfly (Ebesu and Evans 2008).

Harvesting and Yield

Postharvest Considerations

It takes about five months from flowering for the fruit to reach maturity and ripen. Fruit are picked based upon size and color. The fruit does not ripen off the tree and often will drop from the tree if over-ripe. Ripe fruit feel full and are easily detached from the tree. Pickers should wear eye protection and gloves during harvest because of the thorns (McDonald et al. 2006).

Depending upon duration of the flowering period, harvesting might occur every 10 to 14 days for 6 to 8 weeks or more. Yield of 40 to 50 pounds of fruit has been reported for 5- to 6-year-old grafted trees (Rennie 2016). Fruit should be carefully handling to avoid mechanical injury that can lead to peel damage. Avoid direct sun exposure, as the fruit readily develop sunburn.

Current recommendation is to keep the fruit in the shade and not store below 42°F. A postharvest life of 4 to 5 weeks is possible. In Australia, fruit are packed into perforated plastic bags (2 to 4 pounds) then into fiberboard cartons containing 4 to 10 pounds of fruit.

Pulp can be snap-frozen and stored for up to a year at 0°F without loss of flavor or texture of the vesicles. Whole fruit can be held frozen at the same temperature for three months.

Packaging, Pricing, and Marketing

Currently, the major market is in the restaurant trade, though there is considerable potential for marketing in small clamshell trays of 4 to 5 fruit for consumers. Prices in Hawai'i have ranged from $11 to $26 per pound.

Tests in Australia on several finger lime cultivars and color variations and replication of experiments over time and from different orchards showed zero survival of the Queensland fruit fly (*Bactrocera tryoni*). These results led to the recommendation that finger limes be regarded as non-hosts for this fruit fly (Jessup et al. 2006, Jessup 2013). However, this recommendation has not been accepted, and hence finger limes will possibly need to be irradiated before shipment to the mainland US at the recommended dose of 150 Gy for fruit flies (Follett and Weinert 2012).

Figure 4: Examples of finger lime products.

Culinary Uses and Nutritional Composition

The unique quality of the finger lime vesicles or "pearls" is that they can be easily removed with a teaspoon from the peels when the fruit is cut lengthwise (Birmingham 1997). When opening the fruit, avoid getting peel oil onto the vesicles, as that affects flavor. After seeds are removed, the pearls are used as flavoring and coloring, as a garnish on hors d'oeuvres, or with caviar on smoked salmon, with a sour cream dressing. They can be blended into chilled desserts such as mousses and souffles to complement the flavor of the egg. They are also mixed with a fruit salad and added to salad dressings, drinks, or sauces to give a burst of flavor to recipes. The red pearls are added to cold sparkling beverages such as mineral water or lemonade. The juice, which is acidic like that of other limes, can be extracted. The fruit can also be dried and used as a flavoring.

Hawai'i's usage of finger limes grew in part from visiting Australian chefs who featured them and other "bush tucker," aboriginal fruits, at Kona-Kohala Chefs' Association events. Demand for locally grown finger limes increased from there. Local uses include adding them to guacamole, in finger lime salts and sugars, in mixed-fruit dehydrated fruit roll-ups, and as a garnish on soups, meats, and cream cheese. Ceviche with local fish and finger limes is also popular.

The nutrient composition of finger limes is given in Table 2. Like most citrus, it has a relatively high level of ascorbic acid (Vitamin C). Finger limes also contain high levels

Table 2. Nutrient Composition of Finger Lime (Rural Industries Research and Development Corporation, 2012 - Nutritional Data for Australian Native Foods). Vitamin C from McDonald et al. 2006.

Component	Units	Amount
Energy	kj/100g	144-210
Moisture	g/100g	84.4
Fat	g/100g	1
Protein	g/100g	1.6
Ash	g/100g	0.6
Carbohydrates	g/100g	5
Total Sugars	g/100g	1.2
Starch	g/100g	0.1
Total Dietary Fiber	g/100g	7.2
Vitamin C	mg/100g	87.7 ± 5.54
Magnesium	mg/100g	111-140
Zinc	mg/100g	0.28 - 0.85

of antioxidants, though radical scavenger activity is less than that in other Australian native foods such as Kakadu plum, lemon myrtle, and wild lime (Sommano et al. 2013). The antioxidant activity correlates with total phenols, with caffeic and vanillic acids present.

The volatiles released from the peel varies with variety and includes different ratios of limonene, sabinene, citronellal, citronellol, and isomenthone (Delort et al. 2015). Other volatiles frequently found in limes as major consitutents: γ-terpinene, α-pinene, β-pinene, and citral, are low in finger limes.

Recipes

Cutting Finger Limes

Cut off the tips and carefully cut the fruit skin lengthwise on four sides. Peel back the skin and remove the vesicles (pearls) with your thumbs or a small spoon into a bowl. Before you use the pearls in a dish remove any seeds in the bowl.

Guacamole with Finger Limes

Mash one or two Hawaiian grown avocados. Add garlic, salt and hot sauce to taste and mix well. Add the pearls from five finger limes and mix gently.

You can optionally add one cup of corn and one cup of black beans. Pitted olives and capers are also optional. Add the pearls from a few more finger limes on top as a garnish.

Shrimps and Finger Lime

Shrimp, with or without scallop, mixed with sweet red pepper, cilantro and finely diced red onions can be topped with topped with finger lime pearl.

Sashimi Taco with Finger Lime (Alamy)

Oysters with Finger Lime

Use finger lime pearls instead of lemon or lime juice on fresh oysters. Pearls can be gently mixed with rice wine vinegar, minced green onions and freshly ground black pepper before spooning onto the oysters.

Garnish

Replace citrus juice with finger lime pearls on grilled, fried and steamed scallops, lobster and fish. Use as a topping on fried dishes, chicken and steak. It has been recommended on fruit salads, ice cream, and cheesecake and other pies.

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Internet Resources

Tucker Bush
https://tuckerbush.com.au/finger-lime-citrus-australasica

PROSEA
http://proseanet.org/prosea

International Tropical Fruit Network
https://www.itfnet.org/v1

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