

## Passion fruit (*Passiflora edulis* Sims): Passifloraceae

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### Common names

Passion fruit is also known as granadilla, grenadilla, maracuja, granadiglia, passiflora azzurra, fiore della passione, passionaria, pasiflora, passiflore, fleur de la passion, passiflore bleue, blaue passionsblume, pasifloro, passionera, flor de la passió, passionsblomst, grenadilo, flôr di passion, mburukuja, maracujá, fior 'd passion and passionsblomma. General names for both, yellow and purple, in Spanish are granadilla, parcha, parchita, parchita maracuya, or Ceibey (Cuba); in Portuguese, maracuja peroba; in French, grenadille, or couzou. The purple form may be called purple, red, or black granadilla, or, in Hawaii, lilikoi; in Jamaica, mountain sweet cup; in Thailand, linnangkong. The yellow form is widely known as yellow passion fruit; is called yellow lilikoi in Hawaii; golden passion fruit in Australia; parcha amarilla in Venezuela.

In the 16th century, Spanish Christian missionaries stumbled upon the Passion Flower and adopted it as a symbol of the death of Christ due to its unique morphological characteristics. Spanish colonists associated the flowers with the suffering of Christ: the corona refers to the crown of thorns, the three stigmas to the nails at the cross, ... in other words: the common name refers to the passion of Christ. Thus, the English prefix "passion" derives from the passion of Christ suggested by the prominent four-branched style that appears in the flowers.

### General Description

Passion fruit is a woody, perennial vine that bears a delicious fruit and occurs in purple- and yellow-fruited forms (*Passiflora edulis* Sims f. *edulis* and *P. edulis* f. *flavicarpa*) known as purple and yellow passion fruits. The plants have a weak taproot and extensive ivory-colored lateral roots. The stem is usually solitary, up to 7 cm in basal diameter, extends 5 to 10 m or more into the crowns of trees, and is covered by a thin, flaky, light brown bark. The stem-wood is light and brittle. The twigs are yellow-green, turning brown, and support themselves on vegetation by means of tendrils that arise at the leaf axils. The leaves are alternate, green to yellow-green, three-lobed (on mature plants) with serrate edges. The petioles are 3 to 6 cm long and the blades are 5 to 11 cm long by 4 to 10 cm broad. Solitary flowers arise at the leaf axils. The flowers measure 5 to 7 cm across with five greenish-white sepals and five white petals topped with a fringe-like corona of straight purple and white rays. There are five stamens with large anthers and a triple-branched style. The fruit is globose or ovoid, purple or yellow and 4 to 7 cm in diameter. Inside a thick rind are many dark-brown to black seeds enveloped in small sacs filled with aromatic yellow or orange juice. The fruits of the purple passion fruit are smaller but more aromatic than those of the yellow form.

Passion flowers are a large genus of climbing plants with very showy flowers. They display a large range of colors and make an excellent choice of plants to decorate/hide a wall or trellis - because their natural habitats cover a large range in altitudes (up to 3000m) there's always a species that will



be suited for any garden. Some species produce edible fruits and will offer an added value in autumn. The flowers bear 5 vividly-colored tepals and a very large corona consisting of radial filaments which often curl. The plants produce tendrils that embrace and curl around everything they touch. In their habitat they cling onto other plants, they don't grow a sturdy trunk. Some species are known to grow 6 meters in one Summer.

### **Origin and Distribution**

The purple passion fruit is native from southern Brazil through Paraguay to northern Argentina. It has been stated that the yellow form is of unknown origin, or perhaps native to the Amazon region of Brazil, or is a hybrid between *P. edulis* and *P. ligularis* (q.v.). Cytological studies have not borne out the hybrid theory. Speculation as to Australian origin arose through the introduction of seeds from that country into Hawaii and the mainland United States by E.N. Reasoner in 1923. Seeds of a yellow-fruited form were sent from Argentina to the United States Department of Agriculture in 1915 (S.P.I No. 40852) with the explanation that the vine was grown at the Guemes Agricultural Experiment Station from seeds taken from fruits purchased in Convent Garden, London. Some now think the yellow is a chance mutant that occurred in Australia. However, E.P. Killip, in 1983, described *P. edulis* in its natural range as having purple or yellow fruits. Brazil has long had a well-established passion fruit industry with large-scale juice extraction plants. The purple passion fruit is there preferred for consuming fresh; the yellow for juice processing and the making of preserves.

The Australian taste is strongly prejudiced in favor of the purple passion fruit and growers have been reluctant to relinquish it altogether. Only in the last few decades have they begun to adopt hybrids of the purple and yellow which have shown some ability to withstand the serious virus disease called "woodiness".

India, for many years, has enjoyed a moderate harvest of purple passion fruit in the Nilgiris in the South and in various parts of northern India. In many areas, the vine has run wild. The yellow form was unknown in India until just a few decades ago when it was introduced from Ceylon and proved well adapted to low elevations around Madras and Kerala. It was quickly approved as having a more pronounced flavor than the purple and producing within a year of planting heavier and more regular crops.

Passion fruit vines are found wild and cultivated to some extent in many other parts of the Old World- including the highlands of Java, Sumatra, Malaya, Western Samoa, Norfolk Islands, Cook Islands, Solomon Islands, Guam, the Philippines, the Ivory coast, Zimbabwe and Taiwan. From several of these sources, considerable quantities of Yellow passion fruit juice and pulp are exported to Australia. The Yellow passion fruit was introduced into Fiji from Hawaii and became the basis of a small juice-processing industry. Fiji has exported to Australia, New Zealand and Canada as well as to nearby islands.

Since the introduction of the Yellow passion fruit, it has achieved industrial status and National popularity. Much effort is being devoted to improving the yield to better meet the demand for the extracted juice, passion fruit ice cream, and other appealing products such as bottled passion fruit-and-rum cocktail.



## Ecology

Altitude and latitude do not appear to be a constraint other than through the temperatures associated with them. Purple passion fruit grows best in a subtropical climate, and the yellow passion fruit prefers a tropical climate with full-season warm days and nights. However, even yellow passion fruit can survive temperatures down to - 5°C. Generally, annual rainfall should be at least 900 mm. Rainfall in Indian areas that grow passion fruit ranges from 1000 to 2500 mm/year. The species is shallow-rooted but withstands drought by defoliating. Passion fruit tolerates a wide variety of soils and grows best on well-drained sandy loams with a pH of 6.5 to 7.5. Passion fruit is moderately intolerant of shade, requires trees, brush, or fences for support, and benefits from but does not require soil disturbance for reproduction. Wild plants are found in broken forests, stream-bottom galleries, fencerows, abandoned farms, and neglected city lots. Young plants are eaten by livestock, so passion fruit is almost never found in moderate to heavily grazed areas. A large number of insects, nematodes, fungi, and viruses attack the species.

## Types of *Passiflora*

There are about 600 known species of *Passiflora* now found worldwide. Of the 600 species of *Passiflora*, in the family Passifloraceae, only one, *P. edulis* Sims, has the exclusive designation of passion fruit, without qualification. *Passiflora edulis* exists in two distinct types known as *P. edulis*, the purple passion fruit and *P. edulis flavicarpa*, the yellow passion fruit. The purple passion fruit, *P. edulis*, is native to southern Brazil. It bears a dark-purple or nearly black, rounded or egg-shaped fruit about 5 cm long, weighing 30-45 g. The yellow passion fruit, *P. edulis flavicarpa*, evolved from the purple type. Fruit of the yellow passion fruit is deep yellow and similar in shape but slightly longer than the purple passion fruit. Its length is about 6 cm and it weighs about 60-90 g. The yellow form has a more vigorous vine and generally larger fruit than the purple. The yellow form has brown seeds. It has a firm, round, shiny shell. It is sometimes called sweet granadilla and is more common on Pacific islands since it will grow only in the tropics or subtropics. It is lower in acid, so that it may be eaten straight from the shell, whereas most purple passion fruit, for all their fragrance and flavour, cryout for a little touch of sugar.

## Yellow Varieties

Brazilian Golden : Large, golden-yellow fruits, larger than standard forms. Flavor is somewhat tart. Extremely vigorous vine, requiring cross-pollination. Extra large, fragrant flowers, white with a dark center, blooming during mid summer. It Produces one large crop beginning in late August or early September.

Golden Giant: A large Yellow-fruited cultivar that originated in Australia.

## Reproduction

The purple passion fruit blooms in spring and early summer and again for a shorter period in fall and early winter. Yellow passion fruits in Puerto Rico flower from April to September and yield fruits from June to October. In some areas, plants fruit twice each year. Plants usually begin blooming and fruiting in their second year. Yellow passion fruit flowers have both male and female parts but are self-sterile. They rely mainly on carpenter bees (*Xylocopa* spp.) for pollination. Other insects and hummingbirds also visit the flowers. The flowers of purple passion fruit can self-pollinate. Fruits of the naturalized yellow-fruited form range from about 45 to 120 g in Puerto Rico. There is a large variation between plants in size and shape of fruits. Small fruits are sometimes completely devoid of seeds, and large fruits may have over 200 seeds. A collection of seeds from



naturalized plants in Puerto Rico averaged  $0.0251 \pm 0.0004$  g/seed or 40,000 seeds/kg. Passion fruit is usually propagated from seeds but can be started from cuttings, layers, and grafts. Seeds germinate best if allowed to ferment for a few days in the fruit pulp before cleaning and are lightly scarified by clipping or sandpapering. A group of seeds in Puerto Rico were sown without pretreatment in commercial potting mix and began germinating in 14 days and completed germination in 24 days with 61 percent germinated. Plants are grown in beds or pots and transplanted when they reach about 25 cm in height. The seedlings are heavily watered after planting. Seeds are disbursed in the wild by humans, animals especially pigs, and birds, and by vine extension.

### ***In vitro* culture**

Many *in vitro* culture techniques have been described for the *Passiflora* genus including regeneration from hypocotyl, leaves and cotyledons, regeneration from leaf disks and mesophyll and cotyledon-derived protoplasts, regeneration after protoplast fusion, and micropropagation. A mature endosperm culture has been reported for *P. foetida*. Embryo and endosperm culture from seeds of several *Passiflora* species mainly collected in the wild has been attempted in this study.

Seeds of *Passiflora* genus vary greatly in size and shape. However, several common features are apparent, including hard seed coats surrounding a white, well-developed, straight embryo, with large flat cotyledons. A thin layer of endosperm, which can be ruminated, surrounds the embryo.

Endosperm and embryos extracted from seeds were grown in two different media, A and B. The plant growth regulator and sucrose concentration of these media have been reported to induce undifferentiated callus formation (medium A) and to stimulate *in vitro* germination of zygotic embryos (medium B) in rice. Twenty six species responded to either A or B medium with embryo germination or callus formation.

Undifferentiated calli were spontaneously produced especially from embryos grown on medium A. Alternatively, pieces of embryo-derived hypocotyl or root were cut and transferred to high 2.4-D to obtain calli. Different embryos from a single species and even individual embryos produced calli with different characteristics.

### ***Ex-vitro* propagation**

#### **Seed**

Dehydrated seeds of many *Passiflora* species may require from many months up to two years to germinate. *Passiflora* seedcoats are very tough, in nature they're softened by the stomach acids of birds and other animals. This can be mimicked by placing them 24 hours in milk or citrus juice. Rinse the seeds and plant them immediately in an airy general-purpose seedling soil. Cover them with 5 millimeters of the same medium and gently press it down a bit, put them in a bright spot at 20°C. Use a hand sprayer to keep the substrate moist - don't let it dry out. Transplant them to individual pots after they formed a few leaves.



## Cuttings

Start your cuttings from woody sections of the plant - the growing points are too soft, are difficult to root and rot easily. A 2-foot (60cm) branch yields 4 cuttings which have 2 growing points each. Cut the branch diagonally 2 cm above the upper and 3 cm below the bottom growth point. Remove the tendril and leaves from the bottom shoot by swiftly rubbing your fingers down the branch. The upper shoot remains intact but cut away half of the leaf to avoid dehydration. Put the bottom of the cutting in cold water and let them drip off in the fridge, then dab them in rooting hormone powder. Tap off the excess powder and stick them 2/3 in a sandy airy mix. Place them in a bright spot in a humid environment (under clear plastic or in a mini-conservatory), not in direct sunlight. Roots will take a few weeks to appear, don't interfere with them. Water the pot from a tray - watering from the top will collapse the airy soil.

## Biosis

The New-World butterflies of the genus *Heliconius* have developed a special relationship with *Passiflora*. The appearance of both organisms is the result of mutual evolution. The butterfly has specialized in *Passiflora* flowers as food for its caterpillars, which only feed on these plants. Not only does the butterfly lay eggs on the plants for the offspring to feed on, the caterpillar stores the toxic chemicals developed by the plant to ward them off. This makes the caterpillar an unattractive meal for other animals, but the toxins are passed on to the adult stage. After the metamorphosis the butterfly remains poisonous and advertises it with vivid markings on the wings: unfit for consumption.

The caterpillar's appetite can be such a drain on the plant that it is unable to produce flowers or set fruit, in extreme cases they destroy the plant completely. This has led to a battle between the two organisms: not only does the plant produce toxins, it also takes advantage of the insect's weakness. Each *Heliconius* species specializes in one or a few *Passiflora* species and determines the host by looking at the foliage. This has led to *Passiflora* species that produced a large variation in leaf so that the butterfly had difficulty in recognizing them. Other species developed small nodules on the tendril or petiole which mimic the butterfly eggs. The *Heliconius* only lays its eggs on "virgin" plants which haven't been visited by other females, this mechanism fools the butterfly in many cases. A third defense is the production of nectary glands on the leaves and stem which attract ants, wasps and parasites - generally speaking insects which have a strong interest in finding caterpillars on their path.

One species, *Passiflora adenopoda* even grows small hooklike trichomes which have proven to inflict deadly wounds upon the caterpillar. A fourth mechanism has evolved in *Passiflora foetida*: this species has bracts that grow as a mesh with sticky glands around the flower which act as a passive trapping mechanism such as seen in *Drosera* species. These glands obstruct the large-winged *Heliconius* butterflies from landing near the flower.

## Cultivation

Root-pruning should precede transplanting of seedlings by 2 weeks. Transplanting is best done on a cool, overcast day. The soil should be prepared and enriched organically a month in advance if possible. Grafted vines must be planted with the union well above ground, not covered by soil or mulch, otherwise the disease resistance will be lost. Mounding of the rows greatly facilitates fruit collection.



Plant passion fruit vines in full sun except in very hot areas where partial shade is preferable. The vine can be rather rampant, so it is important to plant it next to a chain link fence or install a strong trellis before planting. The plants can also be trained into an attractive arbor.

Regular watering will keep a vine flowering and fruiting almost continuously. Water requirement is high when fruits are approaching maturity. If the soil is dry, fruits may shrivel and fall prematurely.

The passion fruit vine, especially the Yellow, is fast-growing and will begin to bear in 1 to 3 years. Ripening occurs 70 to 80 days after pollination.

### **Growth and Management**

Plants in fertile soil extend their stems about 3 m per year. Each year during the annual dry season, the leaves fall off and the twigs die, leaving the main stem and a few important branches alive to rebuild the crown after the rains begin. Because fruiting takes place on new wood, light pruning does not reduce yield. Plants live from 3 to 8 years and do not resprout. Commercial stands are managed in vineyards, somewhat like grapes. They are planted in trellised rows 4.5 m apart and spaced 4.5 m apart within rows. The orchards are replanted every 4 to 6 years. Alternately, vineyards may be established using small trees or bamboo as standards. Fruiting plants can even be grown in pots under glass. Fruits fall after ripening on the vines and are picked up from the ground at least twice per week. The roots normally form mycorrhizal associations and benefit from inoculation with superior strains of fungi. Wild plants are usually scattered and attempts at management have not been reported.

### **Passion Fruit as an Edible Fruit**

Passion fruits contain numerous small, black wedge-shaped seeds that are individually surrounded by deep orange-colored sacs that contain the juice, the edible part of the fruit. Passion fruit is either eaten fresh or used in commercial juice production. Passion fruit is a high acid food (pH~ 3.2) due to the predominance of two acids, citric (~93-96 % of total) and malic (3-6 % of total) acid. Passion fruit also contains about 14.45 g sugar/100g of edible portion, including fructose, glucose and sucrose, along with seven others in trace amounts. The acids and sugars add to the unique taste and serve as a preservative nature for the tropical fruit.

Both the yellow and purple passion fruits contain ascorbic acid with the purple passion fruit variety containing a slightly higher content of ascorbic acid. Ascorbic acid is an organic acid with good antioxidant properties and is a good source of Vitamin C. The purple passion fruit has a sugar:acid ratio of 5:1. The yellow passion fruit has a sugar:acid ratio of 3:8. The purple passion fruit is generally sweeter than the yellow passion fruit. Passion fruit is high in potassium, vitamin A, vitamin C, niacin and fiber and it is low in sodium, cholesterol and saturated fats.

### **Phytochemicals Present in Passion Fruit**

There are 3 primary groups of active chemicals in passion fruit: alkaloids, glycosides and flavonoids. A large amount of variability is noticed with regards to the incidence and quantity of particular phytochemicals within the same species of passion fruit. There is a lot of evidence that the passion fruit could be a powerful medicinal source but much more research needs to be done to unlock these potentially potent remedies.



## Alkaloids

Harmala alkaloids are a group of  $\beta$ -carboline compounds. Harmala alkaloids present in passion fruit include harmane, harmine, harmaline, harmol, harmalol. The amount of harmala alkaloids present in the purple passion fruit is 0.012% and in the yellow passion fruit 0.700%. Others include Theobromine while Passiflorin is an alkaloid glycoside.

## Flavonoids

The amount of flavonoids present in the purple passion fruit variety is 1.060% and in the yellow passion fruit variety 1.000%. Studies have indicated that in order for the passion fruits sedative effect to exist the glycosides and flavonoids must be combined because individually they produce opposite effects.

Rutin, quercetin and kaempferol belong to the flavonol subgroup of flavonoids.

Catechin and epicatechin belong to the flavan-3-ols subgroup of flavonoids.

Cyanidin-3-glucoside belongs to the anthocyanidin subgroup of flavonoids.

Luteolin and apigenin both belong to the flavone subgroup of flavonoids.

Flavone glycosides present in passion fruit include homoorientin, isoorientin, orientin, isovitexin, vitexin, Iso-schaftoside, schaftoside, saponaretin, saponarin and various other glycosides.

## Carotenoids

The amount of carotenoids present in the purple passion fruit variety is 1.160% and in the yellow passion fruit variety is 0.058%. Carotenoids include  $\beta$ -cryptoxanthin, Prolycopene, *cis*-  $\gamma$  – carotene, *z*-carotene,  $\beta$ -carotene, 13-*cis*-  $\beta$  –carotene, neurosporene and  $\gamma$ -carotene and  $\alpha$  –carotene. In one study,  $\gamma$ -carotene and  $\beta$ -carotene were present in the largest amounts in the yellow passion fruit. In another study, yellow passion fruit was found to be a rich resource of  $\alpha$ -carotene and  $\beta$ -carotene when compared to other tropical fruits but not in comparison to tomatoes and/or carrots.

## Miscellaneous Phytochemicals

Serotonin and Gynocardin are also present in passion fruit. Scopoletin is a phytochemical found in passion fruit and is a hydroxycinnamic acid that belongs to the coumarin group.

## Functional Activity

Passion fruit is proved to have analgesic (pain-reliever), anti-anxiety, anti-inflammatory, antispasmodic, cough suppressant, aphrodisiac, cough suppressant, central nervous system depressant, diuretic, hypotensive (lowers blood pressure) and sedative activities. Besides, it is traditionally reported to possess anticonvulsant, antidepressant, astringent, cardiogenic (tones, balances, strengthens the heart), disinfectant, nervine (balances/calms nerves), neurasthenic (reduces nerve pain), tranquilizer and vermifuge (expels worms) activities. It may have promising and powerful effects on neurological disorders and chronic diseases such as heart disease and cancer. The native American Indians, Aztecs and Mayas used *Passiflora* as a remedy for pains and ailments, a tradition which is still continued today. Local markets offer dried passion flowers which are used to brew a pain-killing tea.



## Uses

Passion fruit is mainly used in jams, jellies, and fruit juices. It is used for medicinal purposes as a sedative, as well as a food source. As an edible fruit, it contains several components such as acids and sugars, nutrients, and non-nutritive phytochemicals that make passion fruit a tasteful and healthy addition to the diet. It is used for mood disorders (depression, anxiety, stress); insomnia and sleep disorders; headaches, migraines and general pain; stomach problems (colic, nervous stomach, indigestion, etc.) and to relieve menstrual cramps and premenstrual syndrome (PMS).

## Other Benefits

By far the greatest benefit of passion fruit to humankind is its fruit and the delicious juice made from it. In addition to being collected by local people in the forests, the fruit is now grown in vineyards in dozens of countries. It is condensed, frozen, and shipped worldwide. The fruit pulp contains 2.2 percent protein, 0.7 percent fat, and 21.2 percent carbohydrates. In addition, the seeds contain 23 percent oil similar to sunflower or soybean oil, and the rind residue is used for cattle feed. The fruits of native and naturalized stands furnish food for numerous species of wild mammals and birds. The whole plant, especially the leaves, contains alkaloids and a number of other phytoactive chemicals. Among these is passiflorine, a known sedative and tranquilizer. Extracts of the leaves have been used for centuries as sedatives by native Brazilians. They prepare a drink from the flower to treat asthma, bronchitis, and whooping cough. The plant is also used as a diuretic to treat urinary infections.

