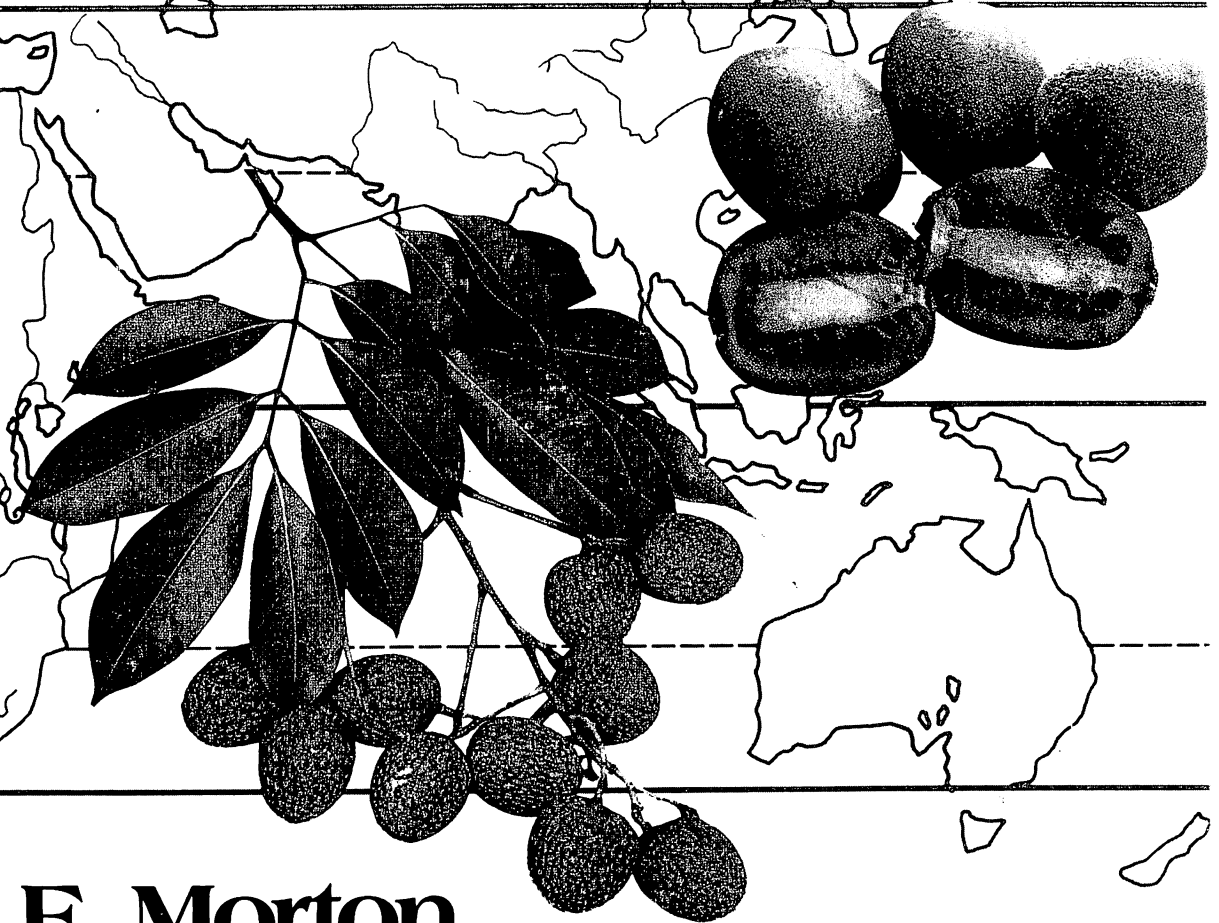


FRUITS OF WARM CLIMATES



Julia F. Morton

PASSIFLORACEAE

Passionfruit (Plates XLIII and XLIV)

Of the estimated 500 species of *Passiflora*, in the family Passifloraceae, only one, *P. edulis* Sims, has the exclusive designation of passionfruit, without qualification. Within this species, there are two distinct forms, the standard purple, and the yellow, distinguished as *P. edulis* f. *flavicarpa* Deg., and differing not only in color but in certain other features as will be noted further on.

General names for both in Spanish are *granadilla*, *parcha*, *parchita*, *parchita maracuyá*, 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, *linmangkon*. The yellow form is widely known as yellow passionfruit; is called yellow *lilikoi* in Hawaii; golden passionfruit in Australia; *parcha amarilla* in Venezuela.

Description

The passionfruit vine is a shallow-rooted, woody, perennial, climbing by means of tendrils. The alternate, evergreen leaves, deeply 3-lobed when mature, are finely toothed, 3 to 8 in (7.5-20 cm) long, deep-green and glossy above, paler and dull beneath, and, like the young stems and tendrils, tinged with red or purple, especially in the yellow form. A single, fragrant flower, 2 to 3 in (5-7.5 cm) wide, is borne at each node on the new growth. The bloom, clasped by 3 large, green, leaflike bracts, consists of 5 greenish-white sepals, 5 white petals, a fringelike corona of straight, white-tipped rays, rich purple at the base, also 5 stamens with large anthers, the ovary, and triple-branched style forming a prominent central structure. The flower of the yellow is the more showy, with more intense color. The nearly round or ovoid fruit, 1½ to 3 in (4-7.5 cm) wide, has a tough rind, smooth, waxy, ranging in hue from dark-purple with faint, fine white specks, to light-yellow or pumpkin-color. It is ⅛ in (3 mm) thick, adhering to a ¼ in (6 mm) layer of white pith. Within is a cavity more or less filled with an aromatic mass of double-walled, membranous sacs filled with orange-colored, pulpy juice and as many as 250 small, hard, dark-brown or black, pitted seeds. The flavor is appealing, musky, guava-like, subacid to acid.

Origin and Distribution

The purple passionfruit 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 Covent Garden, London. Some now think the yellow is a chance mutant that occurred in Australia. However, E.P. Killip, in 1938, described *P. edulis* in its natural range as having purple or yellow fruits.

Brazil has long had a well-established passionfruit industry with large-scale juice extraction plants. The purple passionfruit is there preferred for consuming fresh; the yellow for juice processing and the making of preserves.

In Australia, the purple passionfruit was flourishing and partially naturalized in coastal areas of Queensland before 1900. Its cultivation, especially on abandoned banana plantations, attained great importance and the crop was considered relatively disease-free and easily managed. Then, about 1943, a widespread invasion of *Fusarium* wilt killed the vines and forced the undertaking of research to find fungus-resistant substitutes. It was discovered that the neglected yellow passionfruit is both wilt- and nematode-resistant and does not sucker from the roots. It was adopted as a rootstock and plants propagated by grafting were soon made available to planters in Queensland and northern New South Wales.

The Australian taste is strongly prejudiced in favor of the purple passionfruit 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".

New Zealand, in the early 1930's, had a small but thriving purple passionfruit industry in Auckland Province but in a few years the disease-susceptibility of this type brought about its decline. Good local marketing and export prospects have brought about a revival of efforts to control infestations and increase acreage, mostly in the Bay of Plenty region. Today, fruits and juice are ex-



Fig. 91: Purple passionfruit (*Passiflora edulis*) is subtropical, important in some countries, while the more tropical yellow passionfruit excels in others. Both yield delicious juice.

ported. A profitable purple passionfruit industry has developed also in New Guinea.

In Hawaii, seeds of the purple passionfruit, brought from Australia, were first planted in 1880 and the vine came to be popular in home gardens. It quickly became naturalized in the lower forests and, by 1930, could be found wild on all the islands of the Hawaiian chain. In the 1940's, a Mr. Haley attempted to market canned passionfruit juice in a small way but the product was unsatisfactory and his effort was terminated by World War II. A processor on Kauai produced a concentrate in glass jars and this project, though small, proved successful. In 1951, when Hawaiian passionfruit plantings totalled less than 5 acres (2 ha), the University of Hawaii chose this fruit as the most promising crop for development and undertook to create an industry based on quick-frozen passionfruit juice concentrate. From among Mr. Haley's vines, choice strains of yellow passionfruit were selected. These gave four times the yield of the purple passionfruit and had a higher juice content. By 1958, 1,200 acres (486 ha) were devoted to yellow passionfruit production and the industry was firmly established on a satisfactory economic level.

Commercial culture of purple passionfruit was begun in Kenya in 1933 and was expanded in 1960, when the crop was also introduced into Uganda for commercial production. In both countries, the large plantations were devastated several times by easily-spread diseases and pests. It became necessary to abandon them in favor of small and isolated plantings which could be better protected.

South Africa in 1947 produced 2,000 tons of purple passionfruit for domestic consumption. Production was doubled by 1950. In 1965, passionfruit plantations were initiated over large areas of the Transvaal to meet the market demand and apparently there have been no serious setbacks as yet, from disease or other causes.

India, for many years, has enjoyed a moderate harvest of purple passionfruit 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.

The purple passionfruit was introduced into Israel from Australia early in the 20th Century and is commonly grown in home gardens all around the coastal plain, with small quantities being supplied to processing factories.

Passionfruit 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 passionfruit juice and pulp are exported to Australia, causing some protests from Queensland growers. The yellow passionfruit was introduced into Fiji from Hawaii in 1950, was distributed to farmers in 1960 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.

In South America, interest in yellow passionfruit culture intensified in Colombia and Venezuela in the mid-1950's and in Surinam in 1975. In Colombia, there are commercial plantations mainly in the Cauca Valley.

Since the introduction of the yellow passionfruit from Brazil into Venezuela in 1954, 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, passionfruit ice cream, and other appealing products such as bottled passionfruit-and-rum cocktail.

The purple passionfruit was naturalized in the Blue Mountains of Jamaica by 1913, and both the purple and the yellow are planted to some extent in Puerto Rico.

Various species of *Passiflora* have reached the United States Plant Introduction Station (now the Subtropical Horticulture Research Unit) in Miami, Florida, in the routine course of plant accession. Some vines were known to exist and bear fruit year after year here and there in the southern and central areas of the state since 1887 or earlier. In 1953, I requested seeds of good strains of the purple and yellow forms from the Queensland Department of Agriculture and Stock and gave seeds to experimenters. In 1955, one yellow-fruited vine from these seeds was flourishing at Pinecrest and, from the reports of hunters camping beyond that locality, it appears that bird-transported seeds have produced fruiting vines in outlying Everglades hammocks. In 1957, a very fruitful specimen was thriving at the home of Benjamin Blumberg in Coconut Grove, and an escape was bearing unusually large fruits in the treetops of a natural hammock a few miles away. At this time, the purple passionfruit was being grown successfully by a homeowner further north, at Land

Fig. 92: Flowers of the purple passionfruit are fragrant and lovely, though those of the yellow are richer in color.



O'Lakes, Pasco County, and the seeds were advertised for sale. There were small plantations of purple passionfruit in San Diego County, California, the fruits being sold on the fresh fruit market and also processed for juice. However, there was little interest in developing either form as a crop in the United States. At the University of Florida's Subtropical Experiment Station in Homestead, Florida, limited trials with the purple and yellow forms resulted in words of discouragement, the purple vine in particular having proved so susceptible to disease. Certain vines at the Plant Introduction Station had died from *Fusarium* attack and the survivors showed poor fruiting performance.

Dr. Robert Knight and Harold F. Winters of the United States Department of Agriculture prepared two reports on the pollination of the yellow passionfruit and the problems affecting yield. They expressed a dim view of economical juice production and the need for extensive field studies. They offered plant material to anyone qualified to undertake such work. The Minute Maid Company established a test plot of the yellow form at Indiantown in 1965. They found the fruit entirely satisfactory for processing but abandoned the project 2 years later, stating: "The yields are not as large as in more tropical areas where the plant remains productive all year round. Our plants went out of production during the winter season. During the windy spring months of March and April, the vines are badly damaged and no flowers are set until sometime in May. We also found that the passionfruit were expensive to harvest. The fruit has to fall on the ground and sometimes it gets hung up in the vines. There is a continual collection of small quantities of fruit throughout the [bearing] year. Special equipment is needed to obtain the juice from the fruit without bits of the calyx showing up as objectionable black specks. This equipment is costly and can only be justified when a large volume of fruit is being processed."

In 1965, the Laboratoire de Recherche des Produits Nestlé, Vevey, Switzerland, placed the passionfruit among the three insufficiently-known tropical fruits having the greatest potential for nectar processing for the European market. It is obvious, then, that in spite of the handicaps of passionfruit culture, the crop offers revenue-earning opportunities for developing countries with low labor costs.

Varieties

The yellow form has a more vigorous vine and generally larger fruit than the purple, but the pulp of the purple is less acid, richer in aroma and flavor, and has a higher proportion of juice—35–38%. The purple form has black seeds, the yellow, brown seeds.

The following are some of the older cultivars as well as some of the more recent:

'Australian Purple', or 'Nelly Kelly'—a purple selection of mild, sweet flavor, grown in Australia and Hawaii.

'Common Purple'—the form growing naturalized in Hawaii; thick-skinned, with small seed cavity, but of fine flavor and low acidity.

'Kapoho Selection'—a cross of 'Sevcik' and other yellow strains in Hawaii. A heavy bearer of large fruits but subject to brown rot; many fruits contain little or no pulp and the juice has the off-flavor of 'Sevcik' though not as pronounced.

'Pratt Hybrid'—apparently a natural cross between the 'Common Purple' and a yellow strain; subject to rot, but juice is of fine color and flavor, low in acid.

'Sevcik Selection'—a golden form of the yellow selected in Hawaii; a heavy bearer, but subject to brown rot and the juice has a peculiar woody flavor.

'University Round Selection'—Hawaiian crosses of 'Waimanalo' and 'Yee'—fruit smaller than 'Yee'; not as attractive but yields 10% more juice of very good flavor.

'University Selection No. B-74'—a Hawaiian hybrid between 'Pratt' and 'C-77', usually yellow, occasionally with red tinges; resembles 'Waimanalo'; has good juice yield and very good flavor.

'Waimanalo Selection'—consists of 4 strains: 'C-54', 'C-77', 'C-80', of similar size, shape, color and very good flavor, and 'C-39' as pollinator.

'Yee Selection'—yellow, round, very attractive, highly disease-resistant, but fruit has thick rind and low yield of juice which is of very good flavor.

What may be a great improvement over any of the above is the cultivar known as 'Noel's Special'. It is a yellow passionfruit selected in 1968 from open-pollinated seedlings of a vine discovered at an abandoned farm on Hilo, Hawaii, by Noel Fujimoto in the early 1950's. The fruit is round, averages 3.17 oz (90 g); the cavity is filled with dark-orange pulp yielding 43 to 56% bright-orange, richly flavored juice. The vine is vigorous, begins to bear in one year, and is tolerant to brown spot. It produces 88% marketable fruit in a season—a higher proportion than any other cultivar.

In 1967, two purple X yellow hybrids—'3-1' and '3-26', developed at the Redlands Horticulture Research Station, Queensland, had nearly replaced the purple passionfruit in commercial plantations on the coast of southern Queensland and New South Wales. They have a longer fruiting season than the purple, are high-yielding, with high pulp content, keep very well, and meet with little market resistance. Australian breeders continued to strive for a type that would have the needed characteristics and reproduce true from seed. Hybrid '23-E' followed. By 1981, hybrid '3-1' had succumbed to a new, more virulent strain of "woodiness" virus and had to be abandoned. Other popular hybrids are 'Lacey' and 'Purple-gold'.

In early 1980, several purple passionfruit hybrids, all insect-pollinated, were introduced into the island of Niue, as possible substitutes for the yellow form cultivated commercially there for export since 1955, with the view of eliminating the labor of hand-pollination required by the yellow for top production. However, the hybrids are more susceptible to mealybug infestation.

One New Zealand grower has exported purple passionfruits to the United States under the trade name of 'Bali Hai'.

Commercial cultivars of the purple form in Brazil include 'Ouropretano', 'Muico', 'Peroba', and 'Pintado'; of the yellow form, 'Mirim' or 'Redondo', and 'Guassu' or 'Grande'.

In the Cauca Valley of Colombia, the best-performing yellow passionfruit is the 'Hawaiiana'. Venezuelan

growers favor the 'Hawaiiana', 'Brasilera amarilla', and the purple-fruited 'Brasilera rosada'.

A highly promising hybrid, 'M-21471A' has been developed by Dr. R.J. Knight at the United States Department of Agriculture's Subtropical Horticulture Research Station, Miami. The fruit is maroon, weighs about 3 oz (85 g); is close to the purple parent in quality; is self-compatible and resists soil-borne diseases like its yellow parent. F₁ hybrids may be reddish-purple with more conspicuous white dots than on the purple parent, and sometimes there is a tinge of yellow in the background. F₂ hybrids show three variations of purple and are difficult to distinguish from the purple parent.

Pollination

Yellow passionfruit flowers are perfect but self-sterile. In controlled pollination studies at the College of Agriculture of Jaboticabal, Sao Paulo, Brazil, it was found that the yellow passionfruit has three types of flowers according to the curvature of the style: TC (totally curved), PC (partially curved), and SC (upright-styled). TC flowers are most prevalent. Carpenter bees (*Xylocopa megaxylocopa frontalis* and *X. neoxylocopa*) efficiently pollinated TC and PC flowers. Honey bees (*Apis mellifera adansonii*) were much less efficient. Wind is ineffective because of the heaviness and stickiness of the pollen. SC flowers have fertile pollen but do not set fruit. To assure the presence of carpenter bees, it is wise to have decaying logs among the vines to provide nesting places. Carpenter bees will not work the flowers if the nectary is wet. If rain occurs in 1½ hrs after pollination, there will be no fruit set, but if 2 hrs pass before rain falls, it will have no detrimental effect. In the absence of carpenter bees in Fiji, farmers cross-pollinate by hand, treating 600 flowers an hour, with 70% fruit set and 60% of fruit reaching maturity.

The purple form blooms in spring and early summer (July–November) in Queensland and again for a shorter period in fall and early winter (February–April). In Florida, blooming occurs from mid-March through April. The flowers open early in the morning (about dawn) and close before noon, and are self-compatible. The yellow form has one flowering season in Queensland (October–June). In Florida, blooming has occurred from mid-April to mid-November. The flowers open around noon and close about 9 to 10 PM and are self-incompatible.

In crossing the yellow and purple forms, it is necessary to use the purple as the seed parent because the flowers of the yellow are not receptive to the pollen of the purple, and an early-blooming yellow must be utilized in order to have a sufficient overlapping period for pollen transfer. Dr. R.J. Knight has suggested lengthening the overlap by exposing the yellow to artificial light for 6 weeks before the normal flowering season. However, despite the seasonal and hourly differences, natural hybrids between the two forms occur in South Africa, Queensland and in Hawaii. Growers of purple passionfruit in South Africa are warned not to take seed from any vine in proximity to a planting of yellow passionfruit, otherwise the seedlings are apt to produce hybrid fruit of inferior quality.

In some areas, trellis-grown vines of the yellow passionfruit require hand-pollination to assist fruit set. In the home garden, at least two vines of different parentage should be planted and allowed to intertwine for cross-pollination.

Climate

The purple passionfruit is subtropical. It grows and produces well between altitudes of 2,000 and 4,000 ft (650–1,300 m) in India. In Java, it grows well in lowlands but will flower and fruit only above 3,200 ft (1,000 m). In west-central Florida, at 28° N latitude and slightly above sea-level, 3-year-old vines have survived freezing temperatures with the lower 3 ft (.9 m) of the stems wrapped in fiberglass 4 in (10 cm) thick. The upper parts suffered cold injury, were cut back, the vines were heavily fertilized, recovered rapidly and fruited heavily the second summer thereafter.

The yellow passionfruit is tropical or near-tropical. In Western Samoa, it is grown from near sea-level up to an elevation of 2,000 ft (600 m).

Both forms need protection from wind. Generally, annual rainfall should be at least 35 in (90 cm), but in the Northern Transvaal, in South Africa, there is reduced transpiration because of high atmospheric humidity and commercial culture is carried on with precipitation of only 24 in (60 cm). It is reported that annual rainfall in passionfruit-growing areas of India ranges between 40 and 100 in (100–250 cm).

Soil

Passionfruit vines are grown on many soil types but light to heavy sandy loams of medium texture are most suitable, and pH should be from 6.5 to 7.5. If the soil is too acid, lime must be applied. Good drainage is essential to minimize the incidence of collar rot.

Propagation

Passionfruit vines are usually grown from seeds. With the yellow form, seedling variation provides cross-pollination and helps overcome the problem of self-sterility. Some say that the fruits should be stored for a week or two to allow them to shrivel and become perfectly ripe before seeds are extracted. If planted soon after removal from the fruit, seeds will germinate in 2 to 3 weeks. Cleaned and stored seeds have a lower and slower rate of germination. Sprouting may be hastened by allowing the pulp to ferment for a few days before separating the seeds, or by chipping the seeds or rubbing them with fine sandpaper. Soaking, often recommended, has not proved helpful. Seeds are planted ½ in (1.25 cm) deep in beds, and seedlings may be transplanted when 10 in (25 cm) high. If taller—up to 3 ft (.9 m)—the tops should be cut back and the plants heavily watered.

Some growers prefer layers or cuttings of matured wood with 3 to 4 nodes. Cuttings should be well rooted and ready for setting out in 90 days. Rooting may be hastened by hormone treatment. Grafting is an important means of perpetuating hybrids and reducing nematode

damage and diseases by utilizing the resistant yellow passionfruit rootstock. If seeds are available in the early spring, seedlings for rootstocks can be raised 4 in (10 cm) apart in rows 24 in (60 cm) apart and the grafted plants will be ready to set out in late summer. If seeds cannot be obtained until late summer, the seedlings are raised and grafted in pots and set out in the spring. Scions from healthy young vines are preferred to those from mature plants. The diameter of the selected scion should match that of the rootstock. Either a cleft graft, whip graft, or side-wedge graft may be made.

If approach-grafting is to be done, a row of potted scions must be placed close alongside the row of rootstocks so that the union can be made at about $\frac{3}{4}$ of the height of the plant.

Culture

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.

In plantations, the vines are set at various distances, but studies in Venezuela indicate that highest yields in yellow passionfruit are obtained when the vines are set 10 ft (3 m) apart each way. In South Africa, purple passionfruit vines are set 8 ft (2½ m) apart in cool areas, and 12 to 15 ft (3½–4½ m) apart in warm areas. Spacing of purple passionfruit in Kenya has been 10 ft (3 m) between vines and 6 ft (1.8 m) between rows. Recent 3-year trials of 4 ft (1.2 m) between rows, with light pruning the 2nd and 3rd years, resulted in the highest yield (50% of the crop being borne the first year). But it is recognized that such close planting can lead to disease problems and replanting after the 3rd year.

Commercially, vines are trained to strongly-supported wire trellises at least 7 ft (2.13 m) high. However, for the benefit of the homeowner, it should be pointed out that the yellow passionfruit is more productive and less subject to pests and diseases if allowed to climb a tall tree.

After a vine of either the yellow or purple passionfruit attains 2 years of age, pruning once a year will stimulate new growth and consequently more flower and fruit production. The average life of a plantation in Fiji is only 3 years. Judicious pruning of lateral branches after fruiting aids in disease control and can extend plantation life to 5 or 6 years. In South Africa, at elevations between 4,000 and 4,800 ft (1,200–1,460 m), plantations are kept in full production for as long as 8 years.

Regular watering will keep a vine flowering and fruiting almost continuously. Least flowers develop during the winter season due to short day length. Water requirement is high when fruits are approaching maturity. If soil is dry, fruits may shrivel and fall prematurely. Fertilizer (10-5-20 NPK) should be applied at the rate of 3 lbs (1.36 kg) per plant 4 times a year, under normal conditions. In India, trials of purple passionfruit on red sandy

loam with a pH of 6.5 and high organic content, the optimum fertilizer treatment was found to be 290 lbs (132 kg) N and 69½ lbs (31.6 kg) P per ha per year. French horticulturists have reported that, in plantations on the Ivory Coast, annual supplements of 8 oz (220 g) urea and 7½ oz (210 g) potassium sulfate per plant per year of age will have a highly favorable effect on production. It is said that 32 to 36 oz (900–1,000 g) of nitrogen are required to produce 66 lbs (30 kg) of fruits, but excessive nitrogen will cause premature fruit drop. Passionfruit vines should always be watched for deficiencies, particularly in potassium and calcium, and of less importance, magnesium.

The passionfruit 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. Injuries to the base of the vine, which allow entrance of disease organisms, can be avoided by hand-weeding or the application of herbicides around the main stems. These practices will also protect the shallow root system. In Surinam, good weed control under trellises has been achieved by covering the soil with black plastic.

Seasons and Harvesting

The different flowering seasons of the purple and yellow passionfruits have been mentioned under "Pollination". In some areas, as in India, the vines bear throughout the year but peak periods are, first, August to December, and, second, March to May. At the latter time, the fruits are somewhat smaller, with less juice. In Hawaii, passionfruits mature from June through January, with heaviest crops in July and August and October and November. With variations according to cultivar, and with commercial cultivation both above and below the Equator, there need never be a shortage of raw material for processing.

Ripe fruits fall to the ground and will roll in between mounded rows. They do not attract flies or ants but should be collected daily to avoid spoilage from soil organisms. In South Africa, they are subject to sunburn damage on the ground and, for that reason, are picked from the vines 2 or 3 times a week in the summertime before they are fully ripe, that is, when they are light-purple. At this stage, they will reach the fresh fruit market before they wrinkle. In winter, only one picking per week is necessary. For juice processing, the fruit is allowed to attain a deep-purple color. In India and Israel the fruits are always picked from the vine rather than being allowed to fall. It has been found that fallen fruits are lower in soluble solids, sugar content, acidity and ascorbic acid content.

The fruits should be collected in lugs or boxes, not in bags which will cause "sweating". If not sent immediately to processing plants, the fruits should be spread out on wire racks where there will be good air circulation.

Yield

Many factors influence the yield of passionfruit vines. In general, yields of commercial plantations range from

20,000 to 35,000 lbs per acre (roughly the same number of kg per ha). In Fiji, with hand pollination, 173 acres (70 ha) will yield 33 tons (30 MT) of fruits. Hybrids in Australia have raised yields far beyond those obtained with the purple passionfruit.

On the average, a bushel of passionfruits in Australia weighs 36 lbs (16 kg); yields 13½ lbs (6 kg) of pulp from which is obtained 1 gal (3.785 liters)—that is 10.7 lbs (4.5 kg) of juice, and 2.6 lbs (1.18 kg) of seeds. With some strains, the juice yield is much higher.

Storage

Underripe yellow passionfruits can be ripened and stored at 68°F (20°C) with relative humidity of 85 to 90%. Ripening is too rapid at 86°F (30°C). Ripe fruits keep for one week at 36° to 45°F (2.22°–7.22°C). Fruits stored in unperforated, sealed, polyethylene bags at 74°F (23.1°C), have remained in good condition for 2 weeks. Coating with paraffin and storing at 41° to 44.6°F (5° to 7°C) and relative humidity of 85 to 90%, has prevented wrinkling and preserved quality for 30 days.

Pests and Diseases

In Hawaii and Australia, infestations of the passion vine mite (*Brevipalpus phoenicis*) occur during dry weather in the warm season, defoliate the younger portions of the vines but not the terminus, and make brown blemishes on the fruits. The passion vine bug (*Leptoglossus australis*) feeds on flowers and young, green fruits in Queensland. The green vegetable bug, or stinkbug, (*Nezara viridula*) is a similar but lesser menace to the plant and young fruits. Both the immature and the adult stages suck the sap of the growing tips, as do the brown stinkbug (*Boeris maculata*), the large black stinkbug (*Anoplocnemis* sp.) and the small black stinkbug (*Leptoglossus membranaceus*). In Florida, the yellow passionfruit is commonly found to be superficially punctured by a stinkbug (*Chrodrocera laticornis*), affecting only its appearance. Thrips (*Thysanoptera* sp.) injure and cause stunting of young seedlings in nurseries. In dry weather, they also feed on leaves and fruits, leaving them defaced and prone to shrivel and fall prematurely. In East Africa, injury from the tobacco white fly (*Bemisia tabaci*) may lead to galls on the leaves. Leaf beetles (*Haltica* sp.) and weevils (*Systates* spp.) chew the foliage, and cutworms behead seedlings in nurseries. Two lepidopterous pests, *Dione*, or *Agraulis, vanillae* and *Mechanitis variabilis* are common in Colombia.

Among scales attacking the vine and petioles, white peach scale (*Pseudaulacaspis pentagona*) is most troublesome in Queensland. Not as prevalent are round purple scale (*Chrysomphalus ficus*) and granadilla purple scale (*Parasaissetia nigra*). These pests may cause dieback of the entire plant if not controlled. Red scale (*Aonidiella aurantii*) is common on mature passion vines in Queensland. Soft brown scale (*Coccus hesperidum*) is occasionally troublesome. The passion vine leaf hopper (*Scolypopa australis*) requires protective measures. The citrus mealybug (*Planococcus citri*) is a major Queensland pest in

summer. Spraying, unfortunately, kills its chief predator, the mealybug ladybird, *Cryptolaemus montrouzieri*. The aphids, *Aphis gossypii* and *Myzus persicae*, transmit the virus which causes "woodiness" (see below).

There has been no report of attack by the Caribbean fruit fly (*Anastrepha suspensa*) in Florida, though *Anastrepha* infestation was on one occasion observed by Curtis Dowling in *Passiflora* fruits in Costa Rica. In Brazil, fruit flies of the genus *Anastrepha*, and in Hawaii the Oriental fruit fly and the melon fly, deposit eggs in the very young, tender fruits. In these, the larvae seem able to develop and cause the immature fruits to shrivel and fall. If fruits are punctured when nearly mature, the only effect is an external scar. The same is reported concerning the dominant Queensland fruit fly (*Dacus tryoni*) and the less common Mediterranean fruit fly (*Ceratitidis capitata*) in Australia.

In South Africa, purple passionfruit vines are damaged by several species of nematodes. The most important, which causes extreme thickening of the roots, is the root-knot nematode, *Meloidogyne javanica*. Others include the spiral nematode (*Scutellonema truncatum* and *Helicotylenchus* sp.), and the lesion nematode (*Pratylenchus* sp.). The yellow passionfruit is nematode-resistant.

The main diseases of purple passion fruit in Australia are brown spot, *Septoria* spot and base rot, *Phytophthora* blight, *Fusarium* wilt, woodiness, and damping-off. Brown spot, caused by *Alternaria passiflorae* in warm weather, is a major affliction of the purple passionfruit also in New Zealand and East Africa. In Hawaii, brown spot is the leading disease of the yellow passionfruit and *A. tenuis* was found to be the dominant species associated with the disease in 1969. *A. macrospora* has occasioned severe leaf spot and branch lesions in India. A similar disease causing spotting and crinkling of leaves and fruit first appeared in Ceylon in 1970. *Septoria* spot, from the fungus *Septoria passiflorae*, most common in summer and fall, is evidenced by more numerous and smaller spots than brown spot, on all parts of the vine and on the fruits, and it is spread by rain, dew and overhead irrigation. Some believe this fungus to be also the source of base rot, often induced by injury from mowers or other mechanical equipment.

Phytophthora cinnamoni, the source of collar rot in Fiji, makes it necessary to replace yellow passionfruit plantings there every 30 to 35 months. *P. nicotinae* var. *parasitica* has been linked to fatal blight, or stem rot, and fruit rot in purple passionfruit vine, but not in the yellow, in wet periods of summer and fall in Queensland and South Africa. *P. cinnamoni* and *P. nicotinae* are responsible for root rot in New Zealand and Western Australia, and the latter is identified with wilt in South Africa and Sarawak, and with damping-off and leaf blight in both the purple and the yellow passionfruits in India.

Fusarium wilt, arising from the soil-borne fungus, *Fusarium oxysporium* f. sp. *passiflorae*, can be reduced only by grafting the purple, or, better still, purple-yellow hybrids, onto the *Fusarium*-resistant yellow passionfruit rootstock. However, Bedoya *et al.* have reported that, in the zones of Palmira, Cerrito and Ginebra of the Cauca

Valley of Colombia, but not in the zone of Unión, collar rot limits the life of yellow passionfruit plantations to 3 years, and they found, in inoculation experiments, that *Fusarium solani* produced the symptoms. The first signs are chlorosis, necrosis and defoliation; next there is splitting of the trunk and separation of the bark. The root becomes progressively discolored and red rays extend to the surface of the soil.

Nectria haematococca, or *Hypomyces solani*, the ascogenous state of *Fusarium solani*, has been determined to be the organism girdling the collar zone and bringing on sudden wilt of the purple passionfruit vine in Uganda.

The virus disease, "woodiness", or "bullet", appearing as small misshapen fruits with thick rind and small pulp cavity, has been the most serious plague of the purple passionfruit in Australia and East Africa, but it has little effect on the yellow form. The "woodiness" virus (PWV) is also the source of tip blight in the coastal districts of central Queensland. This virus has a wide host range, not only in the genus *Passiflora*, but also weedy species in the families Amaranthaceae, Chenopodiaceae, Cucurbitaceae and Solanaceae.

There are a number of different strains of the "woodiness" virus. For many years, inoculation of passionfruit vines with mild strains protected them from further infection, and commercial hybrids containing small doses of mild strains were released to farmers. But, in 1978, a new, more virulent, strain of virus appeared and overcame the "mild strain protection". The New South Wales Passionfruit Growers Association, in response to this new threat, established, in 1979, a Passionfruit Scion Accreditation Scheme to "improve the quality of planting material by field selection and provide scionwood free of the severe strain of woodiness virus", for a standard fee. Generally, 100 scions can be taken from each accredited vine in a season. By 1981, 16,000 scions had been supplied to commercial growers.

In 1973, two mosaic viruses—PPMV-K and PFMV-MY—said to differ from other reported *Passiflora* viruses, were found to be prevalent in commercial plantings of the yellow passionfruit in the Bantung district of Selangor, Malaya. Damping-off is caused by *Rhizoctonia solani* and *Pythium* spp. in Queensland. Thread blight of yellow passionfruit vine in Fiji and Western Samoa, seen as patches of black, papery, shredded leaves with gray to tan layer of merged "threads" beneath, has been attributed to *Rhizoctonia solani* (also called *Thanatephorus cucumeris*). It may invade the entire vine.

Food Uses

The fruit is of easy preparation. One needs only cut it in half lengthwise and scoop out the seedy pulp with a spoon. For home use, Australians do not trouble to remove the seeds but eat the pulp with cream and sugar or use it in fruit salads or in beverages, seeds and all. Elsewhere it is usually squeezed through two thicknesses of cheesecloth or pressed through a strainer to remove the seeds. Mechanical extractors are, of course, used industrially. The resulting rich juice, which has been called a

natural concentrate, can be sweetened and diluted with water or other juices (especially orange or pineapple), to make cold drinks. In South Africa, passionfruit juice is blended with milk and an alginate; in Australia the pulp is added to yogurt. After primary juice extraction, some processors employ an enzymatic process to obtain supplementary "secondary" juice from the double juice sacs surrounding each seed. The high starch content of the juice gives it exceptional viscosity. To produce a freeflowing concentrate, it is desirable to remove the starch by centrifugal separation in the processing operation.

Passionfruit juice can be boiled down to a sirup which is used in making sauce, gelatin desserts, candy, ice cream, sherbet, cake icing, cake filling, meringue or chiffon pie, cold fruit soup, or in cocktails. The seeded pulp is made into jelly or is combined with pineapple or tomato in making jam. The flavor of passionfruit juice is impaired by heat preservation unless it is done by agitated or "spin" pasteurization in the can. The frozen juice can be kept without deterioration for 1 year at 0°F (-17.78°C) and is a very appealing product. The juice can also be "vacuum-puff" dried or freeze-dried. Swiss processors have marketed a passionfruit-based soft drink called "Passaia" for a number of years in Western Europe. Costa Rica produces a wine sold as "Parchita Seco."

Food Value Per 100 g of Edible Portion (Purple passionfruit, pulp and seeds)*

Calories	90
Moisture	75.1 g
Protein	2.2 g
Fat	0.7 g
Carbohydrates	21.2 g
Fiber	?
Ash	0.8 g
Calcium	13 mg
Phosphorus	64 mg
Iron	1.6 mg
Sodium	28 mg
Potassium	348 mg
Vitamin A	700 I.U.
Thiamine	Trace
Riboflavin	0.13 mg
Niacin	1.5 mg
Ascorbic Acid	30 mg

* According to U.S. Dept. Agr., ARS.

The yellow passionfruit has somewhat less ascorbic acid than the purple but is richer in total acid (mainly citric) and in carotene content. It is an excellent source of niacin and a good source of riboflavin. Free amino acids in purple passionfruit juice are: arginine, aspartic acid, glycine, leucine, lysine, proline, threonine, tyrosine and valine. Carotenoids in the purple form constitute 1.160%; in the yellow, 0.058%; flavonoids in the purple, 1.060%; in the yellow, 1.000%; alkaloids in the purple, 0.012%; in the yellow, 0.700% (mainly harman), and the juice is slightly sedative. Starch content of purple passionfruit juice is 0.74%; of the yellow, 0.06%.

Toxicity

A cyanogenic glycoside is found in the pulp of passionfruits at all stages of development, but is highest in very young, unripe fruits and lowest in fallen, wrinkled fruits, the level in the latter being so low that it is of no toxicological significance.

Other Uses

Commercial processing of the yellow passionfruit yields 36% juice, 51% rinds, and 11% seeds.

Rind: The rinds have a very low pectin content—only 2.4% (14% on a dry weight basis). Nevertheless, it has been determined in Fiji that extraction of pectin from the rinds—up to 5 tons (4.5 MT) annually—reduces the otherwise burdensome problem of waste disposal. The rind residue contains about 5 to 6% protein and could be used as a filler in poultry and stock feed. In Brazil, pectin is extracted from the purple form which has a better quality pectin than that in the yellow. In Hawaii, the pectin is not extracted. Instead, the rinds are chopped, dried, and combined with molasses as cattle or pig feed. They can also be converted into silage.

Seeds: The seeds yield 23% oil which is similar to sunflower and soybean oil and accordingly has edible as well as industrial uses. Up to 3,400 gallons (13,000 liters) can be obtained per year in Fiji. The seed meal contains about 12% protein and 50 to 55% fiber. It has been judged unsuitable for cattle feed.

Analyses of the fresh rind show: moisture, 78.4-85.24%; crude protein, 2.04-2.84%; fat, 0.05-0.16%; crude starch, 0.75-1.36%; sugars (sucrose, glucose, fructose), 1.64%; crude fiber, 4.57-7.13%; phosphorus, 0.03-0.06%; silica, 0.01-0.04%; potassium, 0.60-0.78%; organic acids (citric and malic), 0.15%; ascorbic acid, 78.3-166.2%. The outer skin of the purple form contains 1.4 mg per 100 g of the anthocyanin pigment pelargonidin 3-diglucoside. There is also some tannin.

The composition of the air-dried seeds is reported as: moisture, 5.4%; fat, 23.8%; crude fiber, 53.7%; protein, 11.1%; N-free extract, 5.1%; total ash, 1.84%; ash insoluble in HCl, 0.35%; calcium, 80 mg; iron, 1 mg; phosphorus, 640 mg per 100 g.

The seed oil contains 8.90% saturated fatty acid and 84.09% unsaturated fatty acids. The fatty acids consist of: palmitic, 6.78%; stearic, 1.76%; arachidic, 0.34%; oleic, 19.0%; linoleic, 59.9%; linolenic, 5.4%.

Medicinal Uses: There is currently a revival of interest in the pharmaceutical industry, especially in Europe, in the use of the glycoside, *passiflorine*, especially from *P. incarnata* L., as a sedative or tranquilizer. Italian chemists have extracted *passiflorine* from the air-dried leaves of *P. edulis*.

In Madeira, the juice of passionfruits is given as a digestive stimulant and treatment for gastric cancer.
