Passionfruit Production Technology (Adhoc)

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Introduction

Passion fruit is known in Hawaii as lilikoi, golden passion fruit in Australia, maracuja peroba in Brazil, and yellow granadilla in South Africa. It is also known as parcha, granadilla, maracuya, ceibey and linmangkon. It is a vigorous, shallow rooted, perennial vine that climbs by means of tendrils. Passion flowers are a large genus of 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 is always a species that will be suited for any garden. Some species produce edible fruits and will offer an added value. The flowers bear 5 vividly-colored tepals and a very large corona consisting of radial filaments which often curl. The plants produce tendril 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.

There are mainly three types of passionfruit under cultivation. They are the yellow passionfruit (*Passiflora edulis forma flavicarpa*) which is suited to tropical conditions or the plains, the purple passionfruit (*Passiflora edulis forma edulis*) which grows best under sub-tropical conditions or high altitudes and the giant granadilla (*Passiflora quadrangularis*). The yellow passionfruit is tolerant to many of the soil borne pests and diseases that affect the purple type, and is more prolific, bearing larger, heavier fruit with more juice, which has a higher acid content than the purple type. The flavour of the purple type is preferred over that of the yellow type. The purple and yellow passion fruit have trilobed leaves 10-18 cm long with finely-toothed margins. The giant granadilla has rounded-oblong leaves 10-20 cm long and its stem is characteristically square in cross section. Flowers of the purple passion fruit are normally smaller, approximately 4.5 cm in diameter, than those of the yellow form, about 6 cm in diameter. Both are dull white with very deep blue centers. Flowers of the giant granadilla are quite different; they droop like old-fashioned lampshades and their petals are deep maroon on the inner surface. The purple passion fruit bears dark-purple or nearly black, rounded or egg-shaped fruit about 5 cm long, weighing 30-45 g. Fruit of the yellow passion fruit is deep yellow and similar in shape but slightly longer (6 cm) than the purple passion fruit. It weighs 60-90 g. 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. The giant granadilla bears irregularly rounded or oblong-shaped fruit 10-20 cm long and has a thick, edible rind in addition to black seeds surrounded by juice sacs. It may weigh 225-450 g or more. Its fruits are rich in mineral salts and vitamins, especially A and C, and its juice has a wonderful aroma and flavor. It is widely accepted in different markets and there is a large potential for exports, not to mention its pharmacological properties.

Passionfruit is grown in most tropical and subtropical parts of the world, and it is particularly important commercially in Australia, Hawaii, South Africa and Brazil. Brazil is the world's foremost producer of passion-fruit, with about 90% of the production, followed by Peru, Venezuela, South Africa, Sri Lanka and Australia. Brazilian production is around 478,000 t with a yield of about 13.8 t/ha. The northern and north-eastern regions of the country are responsible for more than 80% of the national production. The passionfruit is used primarily for fresh consumption and the production of

juice, which is also exported. The principal market is Europe, which imports more than 90% of the juice. However, there are very good prospects in the American, Canadian and Japanese markets. 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 Sri Lanka and proved well adapted to low elevations around Chennai 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 passionfruit vine is cultivated predominantly in small orchards, on average 1.0 to 4.0 ha, and is an important source of income for small to medium producers.

Climate

Passionfruit grows well in tropical and subtropical regions, where the climate is hot and humid. Temperature, relative humidity, light intensity and precipitation have an important influence on the longevity and the yield of the plants, but also favor the incidence of pests and diseases.

Biological processes, such as flowering, fertilization, fruit formation, maturation and fruit quality depend on temperatures. The temperature range between 21 and 25°C is considered as the most favorable for the growth of the plant, being best between 23 and 25°C, but passionfruit is being successfully cultivated in temperatures between 18°C and 35°C. Lower temperatures slow the growth of the plant and reduce the uptake of nutrients and fruit production, while very high or very low temperatures affect fruit bearing. At intermediate temperatures of 23°C to 28°C, the fruit growth period is 60 days, when the temperatures were lower (23°C) and higher (33°C) the period was 75 days. The germination period of the seeds is shorter in summer time than in the coldest months, when the period is longer.

Growing passionfruit at altitudes between 100 m and 1,000 m is recommended. Plantations at lower altitudes last for a shorter period of time than those with higher altitudes. In South Africa, at altitudes between 1,200 and 1,400 m, plantations may be productive for eight years, owing to the longer cycles, implicating a greater longevity.

Relative humidity has a great influence on vegetative development and the phytosanitary state of the passionfruit. Air relative humidity of around 60% is the most favorable for the passionfruit. Elevated temperature, associated with constant wind and low relative humidity, causes a drying out of the tissues by excessive transpiration and impedes the development of the passionfruit. Relative humidity of greater than 60%, when associated with rains, favors the incidence of disease, like citrus scab and anthracnose (black spot) in the aboveground parts of the vine.

The susceptibility of passionfruit to strong winds is also an important factor for this crop. Besides direct damage to the plant, it has to adapt its conduction systems. Strong winds cause plants to fall and cold winds cause flowers and new fruits to fall, as well as delay plant growth. In regions prone to high winds the use of windbreaks, like bamboo, grevillea, pine, hibiscus, eucalyptus and grass species is indispensable.

Light is an important factor affecting growth due to its effects on photosynthesis. An increase in the hours of daylight results in greater photosynthetic activity, with an increase in the plants vigour and the size and quality of the fruit. Inadequate light affects the formation of the flowers and fruit. Regions in which the day length is greater than 11 hours have the best conditions for flowering. In the winter months, the plants do not flower because the days are shorter. In the semi-arid regions of Brazil, with more than 11 hours of day light associated with high temperatures throughout the year, the passion flowers continuously producing fruits throughout the year, as long as there is an adequate supply of water. Light intensity greatly influences the phenological phenomenon of flower opening in the yellow passionfruit. The flowers normally open at 12.00 hrs, immediately following the maximum incidence of photosynthetically active radiation (PAR), and close at 15.00 hrs; however when light intensity is lower, they close at 14.30 hrs.

Passionfruit develops continuously and so needs a constant supply of water. The demand for water varies from 800 to 1750 mm and must be well distributed throughout the year, preferably with 60 to 120 mm of water each month, by rain complemented when necessary with irrigation. Generally, annual rainfall should be at least 900 mm. It is reported that annual rainfall in passionfruit growing areas of India ranges between 1000-2500 mm. Although the plant withstands droughts relatively well, prolonged drought damages its vegetative development, causing, in severe cases, leaf fall and the formation of smaller and lighter fruits. On the other hand, intense rains in the flowering period also damage production, because they inhibit pollination by diminishing the activity of pollinating insects and causing pollen grains to burst. In regions where the rains occur in specific periods, resulting in shortage for a few months, irrigation is indispensable to guarantee good production and fruit quality.

Soil

Passion fruit vines grow on many soil types but light to heavy sandy loams with a pH of 6.5 to 7.5 are the most suitable. Also, the soil should be rich in organic matter and low in salts. If the soil is too acidic, lime must be applied. Because the vines are shallow rooted, they will benefit from a thick layer of organic mulch. Well-drained soil is essential. Otherwise, root problems develop that soon destroy these plants.

Passion fruit has a superficial root system (60% of the roots located within 30 cm of the surface). So it is important that there is no impedance to root growth in the top 60 cm. Passionfruit can be grown on a range of soils, sandy to clay loams. In general, it is recommended that the soil should be deep, relatively fertile and well drained. Poorly permeable soils with high clay content, subject to flooding, are not recommended. The best soils are sandy clay. For good growth, it is recommended that the soils have neither impermeable, rocky or hardened layers, nor a water table at less than 2 m to avoid the appearance of dry rot.

The availability of an adequate supply of oxygen is of fundamental importance for good root development of the plant. Oxygen deficiency results in roots losing their structure, and they may quickly rot. Poor soil aeration may be induced by soil compaction or flooding. Soils subject to flooding favor the occurrence of root diseases. Flat and smoothly undulated lands (gradients less than 8%) are most suitable because crop management, mechanization, harvest and soil cultivation and conservation are facilitated. On steeper slopes (in the range of 8 to 30%), besides erosion control measures (including levelling to create terraces, etc.), irrigation and/or fertigation are more difficult. In very steep areas, passionfruit should be grown individually and the soil constantly replenished to maintain a natural soil covering.

Variety

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*, *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 fragnance and flavour, cryout for a little touch of sugar. Another type, the giant granadilla (*Passiflora quadrangularis*) is also cultivated rarely. The characteristics of the three types under cultivation are given in Tables 1 and 2.

Table 1. Fruit characteristics of the three *Passiflora* types under cultivation

Sl. No.	Species	Common name	Characteristics
1	*Passiflora edulis* Sims f. *edulis* Degener	Purple Passion Fruit / Mountain Sweet Cup	Round to ovoid fruit (5-8 cm long and 4-8 cm diameter), purple in color with tough, waxy smooth rind and orange yellow colored pulpy juice with pleasant and sub-acidic flavored arils.
2	*Passiflora edulis* Sims f. *flavicarpa* Degener	Yellow Passion Fruit / Golden passion fruit	Round to ovoid fruit, larger in size (8-10 cm long and 4-10cm diameter) with smooth, glossy, light and airy thick (3-4mm) rind of yellow to light orange pulp having highly aromatic and acidic juice.
3	*Passiflora quadrangularis* Medic	Giant Granadilla	Oblong-ovoid fruit of very large size (20-30 cm long and 12-15 cm diameter) thick skin, greenish-white to pale yellow color, whitish to yellowish sweet acid arils having mild flavor.

Source: Sema and Maiti, 2006

Table 2. Physico-chemical composition of various species of ripe passion fruits

Characteristics	*P. edulis*	*P. edulis f. flavicarpa*	*P. quadrangularis*
Fruit weight(g)	45-60	80-115	120-480
Fruit length(cm)	3.5-6	8-10	20-30
Fruit diameter(cm)	3.5-7	5-7.5	10-12
Pulp weight(g/100g)	32-44	26-31	22-48
Rind weight(g/100g)	51-65	57-68	42-65
Juice recovery(%)	30-34	24-26	22-26
TSS(oBrix)	14-18.4	12.4-16.4	16-18
Titrable acidity(%)	2.4-3.o	3.4-3.8	2.4-3.2
TSS/Acid ratio	5.8-6.1	3.64-4.31	5.6-6.6
Total sugar(%)	5.8-8.0	5.4-6.8	4-4.8
Reducing sugar(%)	3.5-4.2	4-5.2	3-3.8
Non reducing sugar(%)	1.8-2.5	1.2-2.o	2.2-2.8
Ascorbic acid(mg/100g juice)	22-32	16-20.4	14-18
Weight of residues(g/100g)	3-5	6-12	10-15

Source: Sema and Maiti, 2006

No well-established cultivars are regularly available, so plants are customarily grown from seed or cuttings of vines selected for desirable characteristics. A form of yellow passion fruit that sets fruit abundantly from self-pollination is often grown from cuttings or seeds. Its fruit is usually smaller than that of other cross-pollinated yellow passion fruits. Seeds of large fruited selections of yellow passion fruit were brought from Hawaii and plants from this source are grown. Locally selected purple passion fruit is vegetatively propagated for commercial production.

Propagation

Seeds, cuttings, grafts or layering can be used to propagate Passionfruit. The first three methods are most commonly used. The seeds are planted 1.5 cm deep on a sterile seed bed and are transplanted into individual bags containing enriched potting mixture at the three leaf stage.

All 3 passion fruits can be propagated from seed, which should be fresh (less than 1 year old) because seeds lose viability rapidly. Seeds may be sown in flats or pots of sterile soil and kept in a moist place shaded from direct sunlight. Seeds ordinarily germinate in 10-20 days and young plants grow rapidly. Seedlings should be potted individually in small containers as soon as practical after germination. They can be transferred to a permanent location when they are 25-40 cm tall.

Dehydrated seeds of many *Passiflora* species may require from many months up to two years to germinate. Passiflora seed coats are very tough, in nature they are 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 mm 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. Plantlets are grown under shaded conditions and hardened before being transplanted into the field. It takes 6 to 8 weeks from the time of sowing to transplanting in the field.

Cuttings from young, newly mature wood with 2-3 internodes, may be rooted in about one month and ready for setting out in 90 days. The most desirable cutting material is that portion of the stem from the first fully expanded mature leaf, back to the area of the fully extended branch. The best period to obtain cutting material is when the vines are actively growing, after the summer and winter crops. Cuttings are taken from vigorous, actively growing vines. 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 (eg. IBA). Tap of 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 about 4 weeks to appear, don't interfere with them. Water the pot from a tray - watering from the top will collapse the airy soil. Then it should be treated similar to seedlings. Plants from rooted cuttings are less vigorous than seedlings and could be planted at a closer spacing than seedlings.

Purple passion fruit is sometimes grafted onto a yellow passion fruit rootstock to alleviate nematode and disease problems affecting the root system of purple passion fruit. Seedlings of both stock and scion should be about 45 cm tall and have a stem diameter about that of a pencil when grafted. Scions should be about 8-10 cm long and contain at least 2 nodes. The stock should be cut off 25-30 cm above the soil line. For grafting, a long, slanting cut is made from one side to the other through the base of the scion for about half its length, and a similar cut is made through the stem of the stock. The two cut surfaces are then placed together with cambia aligned and the graft is tied firmly with budding tape. The graft is enclosed in a small plastic bag tied shut below the graft, and placed in a warm, shady location for 10-14 days or until the union takes. Then the bag is loosened to admit air and is removed when scion buds begin to grow. The budding tape is removed before it thickens the growing stem.

Plant growth and development

The passionfruit plant is a woody vine (climber) with very fast, vigorous, continuous and exuberant growth. The growth rate is reduced at fruiting and at low temperatures. In areas where flowering is continuous due to very little variation in the photoperiod and high temperatures; in such way, the

absorption of nutrients should be constant. In other regions development and nutrient absorption are reduced in the winter because of a shorter photoperiod and/or lower temperatures.

In the south-east region of Brazil, stem and leaf growth increases at around 250 days (8th month), and decreases after about 340 days (11th month). Branch growth is linear from 160 days (5th month), reaching more than 8 m at 370 days (12th month). Fruit formation starts at 280 days (9th month), starting from the axillary flowers developed on new branches, with a fast accumulation of dry material within the first 60 days and then establishing itself during maturation (370 days, 12th month). With the root system, there are three phases of growth: up to 220 days (7th month) the growth is slow, with reduced production of dry matter; from 220 (7th month) up to 310 days (10th month) there is expansion; later growth stabilizes.

There is little absorption of nutrients until 220 to 250 days (7th to 8th months), because of the small production of dry matter. After the appearance of the fruits (8th and 9th months), growth becomes exponential, increasing the uptake of N, K and Ca and also that of the micro-nutrients, especially Mn and Fe.

Site Selection

Passionfruit vines require full sunlight for proper growth. It is best grown in areas with annual rainfall of at least 900 mm. Passionfruit may be grown on a wide range of soil types, but the best suited soils are light to heavy sandy loams of medium texture having a pH range of 6.5 to 7.5. The plant needs good drainage. Vines will not tolerate waterlogged conditions for long periods. The passionfruit vine grows better in areas that are protected from the wind. Flat and smoothly undulated lands (gradients less than 8%) are most suitable, on steeper slopes (in the range of 8 to 30%) irrigation and/or fertigation are more difficult while in very steep areas, passionfruit should be grown individually with good natural soil covering.

Land Preparation

Land preparation may be conducted one to two months before planting the vines. The land must first be cleared. This produces green mulch that can be incorporated back into the soil when ploughing and rotovating. This ensures a quick and even establishment of vines. Soil analysis should be conducted and all necessary adjustments made before planting. Ploughing in organic matter to soil is beneficial. Organic mulch can be added around these vines because they are shallow rooted.

Land preparation aims to improve the soil conditions for root development, by way of increasing aeration and water infiltration and reducing soil resistance to root growth. Manual soil preparation starts with clearing existing vegetation and using it as mulch or burning it. Soil preparation is limited to the manual opening of the pits for planting the vines. Mechanical preparation is done by machine, taking care to not remove the superficial layer of soil, which is rich in organic material. This is followed by ploughing and then pit digging or creating of furrows for planting. Surface scarifying may substitute for ploughing for minimum soil preparation.

Trellis Construction

Horizontal trellises have cross-pieces at the top of each post with 2-4 wires strung horizontally 60 cm (2 ft.) apart along the top of each cross-piece. Vertical trellises consist of heavy posts without cross-pieces, with 2 or 3 wires strung along the row like barbed wire fencing, attached to the posts from the top down at intervals about 30-40 cm (12-16 in.) apart.

Trellis wires should be No. 9 or 10 galvanized steel. The posts need to be stout enough to withstand the weight of the vines throughout a season that normally includes the buffeting of strong winds. Ideally they should be long enough to provide a trellis height of 1.5 m (5 ft.), with 45-75 cm (18-30 in.) in the ground. Trellis rows should be oriented north-south for maximum exposure to sunlight, and the vines should be allowed to grow together along the trellises to promote cross-pollination.

Trellises are required for the commercial production of passionfruit. Trellises contribute most to the cost of production of the crop and should be constructed properly. Trellises should be constructed in the same direction with the wind wherever possible. On sloping terrain, trellises should be constructed across the slope. Although the passionfruit has been shown to be more productive if allowed to climb a tall tree, trellising is recommended for many reasons.

Large crops are obtained on trellises 7'—8' tall or taller. Such a tall trellis with a wire attached near the top of the posts and two other wires each attached near the ends of cross-bars a foot or more below the top of the posts tends to give the best spread of vines and the greatest convenience of working in the planting but is expensive especially for a short-lived planting.

In rocky or gulch areas it is often possible to use standing trees to guy the trellis wires. In some circumstances heavy cables are stretched between trees to support lighter wires at right angles to the cable. In other locations, rather tall trees have been used and the wires guyed to shorter trees or posts, giving a tent-like appearance. However, a standard trellis has the advantage of giving early returns, greater yield, accessibility for fertilization and harvesting; also more leaf surface can be exposed to the light.

In constructing the standard trellis, it is desirable to use at least eight or nine gauge heavy wire. To withstand the weight of the vine and tension on the wire, the wire should be placed on top of the cross-arm or post and stapled securely or holes drilled through the cross-arm and post and the wire strung through the holes. It is then possible to adjust the tension of the wires which is not possible when wires are stapled.

If a wide spacing of 20' or more is used between posts, the cross-arms must be mortised into and securely nailed or bolted to the post. Greatest strength and stability, with very little loss of surface, are attained when the wires are tied directly to the end post, rather than securing the wires to a cross-arm on the end or strainer post.

With the yoke trellis, the cross-member at the end of the trellis should be sufficiently sturdy to support the strain that will be placed on it. A 20' length of trellis 3' wide is required to support a minimum weight of 150kg of vine and fruit.

The posts should be about 10' long, the end posts at least 3' in the ground and firmly braced to support wire tension and vine weight. Inside posts need not be planted so deeply.

A vine offers considerable wind resistance after having become established on a trellis so this must be securely constructed to prevent both vine and trellis from being blown over by a strong wind.

Posts may be almost any material adequate for supplying strength for five or more years and may be 10" butts for anchor posts, 6" butts for internal posts and 2" x 4" or more for cross-arms.

All wooden posts must be treated to prevent decay, especially the portions in contact with soil. Creosote, which is toxic to plants, should not be used. Copper naphthenate may be brushed onto the wood in two applications about 30-40 minutes apart, then the wood permitted to dry completely.

Transplanting and Training

Root-pruning should precede transplanting of seedlings by 2 weeks. Transplanting is best done on a cool, overcast day. Plants are transplanted during the cooler part of the day (early morning or late evening).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. One or two vigorous leaders are selected and trained to the top wire. 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.

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 4.5-6 m apart and spaced 3-4.5 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. The roots normally form mycorrhizal associations and benefit from inoculation with superior strains of fungi.

Some kind of temporary support at each plant is necessary to train it to get a good hold on the wires of the trellis, after which it takes care of itself and needs no other support. The principal objective is to get the vine to the trellis wires in the simplest, quickest and least expensive manner.

If the young vine is supported in an upright position, with a strong wire or light pole to grasp, it usually will grow quickly to the trellis wire with a minimum of lateral branching. A terminal branched portion of bamboo, inverted and hung over the trellis wire, provides an excellent support for the vine and eliminates the necessity for frequent tying.

Four to six laterals may be trained in both directions onto the overhead wire, and the sooner they come to a horizontal position on the trellis the more quickly they will flower and fruit.

Passion vines in their native state clamber up available trees or rocks and spread out to catch the available sunlight. The yellow passion fruit has naturalized in this manner. In cultivation, vines should be trained to cover the wires of the trellis or fence on which they are grown.

Young vines are trained by aiming a growing up toward the top of the trellis and once there, allowing a shoot to grow along each wire in each direction. A 2-wire trellis provides 4 sprouts growing along the trellis away from the vine's trunk. Once started, the vine should be allowed to grow without pruning throughout the season, since the more vine there is, the more bearing surface there will be. With self-incompatible forms of yellow passion fruit it is particularly desirable to allow 2 different, cross-fertile vines to grow through each other and intertwine so as to promote heavy fruit production.

Weed control

Weed control can be done manually in the rows and mechanically between the rows. During harvest weed control needs to be especially well done in the rows parallel to the planting lines because the fruits are usually collected from the ground. Mechanical weeding (close to the plant less than one meter) is not recommended in order to prevent damages to the roots, which are largely concentrated within 15 to 45 cm from the stem. Chemical weeding, using selective herbicides eliminates not only the weeds, but reduces operational costs and simplifies the work.

The best pre-emergence herbicides are "diuron" and "bromacil". Paraquat or glyphosate have been used in some plantations at 1.5 to 2.0 l/ha, and applied between the rows, leaving the dead weeds as a form of mulch covering the soil surface. While studying the selectivity of pre-emergence herbicides "diuron" (1.2, 2.4 and 4.8 kg/ha), "oxyfluorfen" (0.48, 0.96 and 1.92 kg/ha), "alachlor" (2.8, 5.6 and 11.2 kg/ha) and "atrazine" + "metolachlof (3.0, 6.0 and 12.0 kg/ha), in yellow passionfruit seedlings, observed that only "atrazine" + "metolachlor", in doses of 6.0 and 12.0 kg/ha, caused serious injury to the seedlings, while the others proved promisingly useful. Due to the fact that herbicide activity, in general, is limited to a specific plant or group of plants, it is recommended to use mixtures and planned combinations of herbicides pre-emergence and post-emergence, aiming to increase the period and active spectrum of the chemical control.

Mineral nutrition

Uptake and export of nutrients

For growth and production, passionfruit requires an adequate nutritional state at all stages of growth and this requires a fertilization plan to permit the maintenance of an adequate nutritional state of the crop. From the start of fruit formation there is a great demand for energy by the plant and a strong translocation of nutrients from the leaves to the developing fruits and this reduces the vegetative growth of the plant.

The total quantities of nutrients taken up and exported by the entire plant, including the fruits, at 370 days, with 1,500 plants/ha, are shown in Table 3. The macro-nutrients N, K and Ca are taken up in the greatest quantities, followed by S, P and Mg. Of the micro-nutrients, Mn and Fe are absorbed in the greatest quantities, followed by Zn, B and Cu. Of the nutrients removed in the harvested fruits by far the largest quantity is K followed by N. Although only small quantities of Mg, S, Ca and P are removed, the amounts of P and Mg represent 40% and 29% of the total taken up, respectively. Of the micro-nutrients, Mn is taken up most, but by percent Zn, followed by Cu, are the most exported. In spite of the large amount of Mn found in the fruits, it represents only 6.4% of the total taken up; however 34% of Zn, 32% of Cu, 13% of B and 11% of Fe are accumulated in the fruit and, thereby, removed at harvest. In this way for a crop yielding about 25 t/ha, the export of macro-nutrients in the fresh fruits, in kg/t, is 1.82 of N, 0.28 of P, 3.01 of K, 0.28 of Ca, 0.17 of Mg and 0.17 of S; while that for micro-nutrients, in g/t, is 1.54 of B, 2.61 of Cu, 3.59 of Fe, 7.35 of Mn and 4.41 of Zn.

Table 3. Quantities of nutrients absorbed by the whole plant and exported in the fruits of the yellow passion-fruit, at 370 days of age, at the yield level of 13 t/ha.

Nutrient	Quantity	
	Absorbed	Exported
Macro-nutrient (kg/ha)		
N	205	44.6
P	17	6.9
K	184	73.8
Ca	152	6.8
Mg	14	4.0
S	25	4.0
Micro-nutrient (g/ha)		
B	296	37.8
Fe	779	88.0
Mn	2,810	180.2
Zn	317	108.2
Cu	199	64.0

Source: Haag *et al.,* 1973.

Functions and importance of nutrients

Nitrogen (N): It is fundamental for the growth of all plant parts. It stimulates the development of floral and fruit buds, as well as increasing the amount of protein. In its absence, growth is slow and the plant's size is reduced, with thinner and fewer branches. There is a greater quantity of total soluble solids and lower acidity in yellow passionfruit juice, as well as higher productivity, with the application of larger amounts of N to the soil.

Phosphorus (P): In its absence passionfruit growth is reduced, affecting the quantity of dry matter, root growth and fruit production.

Potassium (K): Its deficiency reduces the weight of the plant and the production of fruits, which fall prematurely or shrivel. Increases in length and diameter of the fruit were observed with the application of larger amounts of K.

Calcium (Ca): Its deficiency results in deformed leaves due to the breakdown of leaf tissue structure, because Ca affects cell elongation and the process of cell division.

Magnesium (Mg): In nutrient culture experiments, the absence of Mg affected the nutrient state of the plant, resulting in a greater absorption of P, K and Ca, relative to plants grown using a complete solution.

Boron (B): Boron deficiency results in an increase in N, P and S in the tendrils and Mn in the stem and leaves of passion-fruit.

Visual diagnosis

Based on the fact that each nutrient has a specific role in the physiological functions of plants, then excesses or deficiencies, i.e. imbalances, often result in characteristic symptoms, which permit the identification of the cause of the disorder. To establish the cause of visual symptoms requires knowledge of the symptom and its cause determined in both controlled experiments, which simulate the nutritional disorders systematically, and from soil and plant analysis. In Table 4 symptoms of nutritional deficiencies are described.

Table 4. Visual symptoms of nutrient deficiency in passionfruit leaves

Nutrient	Leaf age	Leaf symptoms and causes
N	Oldest	Light green and smaller area. Yellowing and premature falling. *Cause:* low composition of organic matter, acidity (lower mineralization), leaching, prolonged drought.
P	Old	Dark green, later yellowing from the edges to the centre. *Cause:* low composition of P in the soil, low pH (lower availability).
K	Old	Progressive chlorosis from the edges to the centre, necrosis and tissue "burn". *Cause:* low composition of K in the soil, leaching and excessive liming.
Mg	Old	Yellowish spots between the veins, wizened lamina curling down. *Cause:* soils low in Mg, acidity and excessive potassium in fertilization.
Ca	Young	Death of apical sprout, interveinal chlorosis and necrosis. *Cause:* low Ca composition in the soil, excessive potassium in fertilization.
S	Young	Chlorotic, yellowish veins on the bottom side of the leaves. *Cause:* low soil S composition, low organic matter content.
Cu	Old	Large and wide leaves, dark green in color and partially shrivelled, thickening of the veins on the upper side, curved downwards. *Cause:* low soil Cu composition, excessive liming and high levels of organic matter.
Mo	Old	Interveinal chlorosis. *Cause:* acidity, excessive sulphate.
B	Young	Plants atrophied, necrosis of the terminal sprout. Smaller and shrivelled leaves with waves along the edges. *Cause:* low soil B composition, low organic matter content, excessive acidity, leaching.
Fe	Young	Interveinal chlorosis. *Cause:* Excessive liming, elevated organic matter content, low soil Fe composition and elevated moisture.

Mn	Young	Chlorotic spots between the veins. *Cause:* excessive liming, elevated organic matter content, low soil Mn composition.
Zn	Young	Small leaves, gaunt and pointed lobes, milky white spots with yellow edges *Cause:* low soil Zn composition, excessive liming and phosphatized fertilization.

Source: Borges and Lima, 2003

However, it is not sufficient to just rely on visual symptoms, to confirm that an anomaly is due to a disorder provoked by a specific nutrient. Because many factors may act simultaneously, to rely on one diagnostic based only on visual symptoms is not prudent. Visual symptoms should be confirmed by leaf and soil analysis of samples taken from crops grown in the field. Once it has been confirmed that deficiency or excess of a specific nutrient is the cause of the problem appropriate corrections can be made.

Leaf diagnosis

This consists of the determination, via chemical analysis, of the nutrient composition of the leaf which is the organ that best reflects the nutritional state of the plant. To be successful appropriate leaves in relation to stage of growth and position on the plant must be taken for analysis. For passionfruit it is recommended to sample the 4th leaf from non-shaded and non-pruned branch apices, taking four leaves per plant, from both sides, including the leaf stem. In the first year, samples should be taken between the 8th and 9th months and, in the following years, during the flowering period. Adequate ranges of macro- and micro-nutrient compositions are given in Table 5.

Table 5. Adequate ranges of macro- and micro-nutrients in passionfruit leaves.

Nutrient Concentration	
Macro-nutrient (g/kg)	Micro-nutrient (mg/kg)
N 47.5-52.5	B 2.0-4.0
P 2.5-3.5	Cu 5.20
K 20.0-25.0	Fe 100-200
Ca 5.0-15.0	Mn 50-200
Mg 2.5-3.5	Zn 45-80
S 2.0-4.0	

Source: Borges and Lima, 2003

Manuring/Fertilization

A balanced fertilizer that supplies nitrogen, phosphorus and potassium in approximately equal proportions, as well as essential micronutrients (magnesium, manganese, copper, zinc and iron), is adequate for passion vines on the slightly acid, sandy soils. On the alkaline, rocky soils, phosphorus is needed less than nitrogen and potash, but micronutrients must be applied for normal growth and production. These can be applied 4 times a year in foliar sprays. In addition, iron chelates can be applied directly in solution to the soil near the roots.

Fertilizer should be applied in early spring before growth begins. Light applications should be given at 4-6 week intervals during active growth and production phases from July to October. Passion vines are heavy feeders, but over-fertilization will damage the roots, and possibly destroy the plant. The amount to apply depends on the size of the plant, and can be determined by experience. No more than 10 g each of NPK/plant should be applied at one time until it has been determined that more can be applied safely. It should be evenly spread in a circle of about 45 cm radius about the stem, and then irrigated.

Organic manures

Using organic manures helps to maintain soil productivity, because it has beneficial effects on the physical, chemical and biological properties of the soil. The materials to be applied in the planting holes, especially in sandy soils and those of low fertility, depend on their availability. The quantities vary according to the nutrient composition of the materials available and may be, FYM/compost (10 to 20 kg), poultry manure (5 to 10 kg) and neem cake (2 to 4 kg) amongst others.

Inorganic fertilizer

Fertilization consists of supplying nutrients in quantities sufficient for the plant to be able to reach its production potential. Fertilization aims to increase both productivity and quality, without compromising the fertility of the soil, especially in irrigated areas, keeping in mind that fertilization can degrade soil. Any fertilization programme should take into account the fertilizer to be used, the quantity, the time of year and the location of application relative to the plant. Thus, there is no single formula that would be the best for all conditions. It is important that, for each plant, one takes into account soil fertility, evaluated by soil analysis, and the expected productivity (Table 6). Amounts of fertilizer used during early growth of the plant are, to a certain extent, comparable amongst the different regions. Fertilizer recommendations are related to soil analytical data and the potential productivity of the site and the phenological phase of the plant.

Table 6. Fertilization recommendation at planting, growth and production phases of irrigated yellow passion-fruit.

	N (kg/ha)	P_2O_5 (kg/ha): P-resin (mg/dm^3)			K_2O (kg/ha):K-soil (cmol/dm^3)				
		0-15	16-40	>40	0-0.07	0.08-0.15	0.16-0.30	0.31-0.50	>0.50
At planting	150[(1)]	120	80	0	0	0	0	0	0
During growth									
Days after planting									
30	10	0	0	0	20	10	0	0	0
60	20	0	0	0	30	20	10	0	0
90	30	0	0	0	40	30	20	10	0
120-180	40	0	0	0	60	40	30	20	0
During fruit production									
Expected yield (t/ha)									
<15	50	50	30	20	100	90	70	50	0
15-25	70	90	60	40	160	120	90	70	0
25-35	90	120	80	50	200	160	120	80	0
>35	120	150	100	60	250	200	150	100	0

[(1)] In the form of bovine manure. *Source:* Borges and Lima, 2003

Taking into account all the factors the schedule of manures and fertilizers for passionfruit grown in the two premier belts of India is given in Table 7.

Table 7. Schedule of manures and fertilizers for passionfruit grown in two premier belts of India

	Manures and Fertilizers	South India			Northeast India		
		Planting	2-4 years	>4years	Planting	2-4 years	>4 years
i.	FYM (kg/vine)	5	10	15	2	4	6
ii.	Nitrogen (g/vine)	25	80	150	20	60	80
iii.	Phosphorus (g/vine)	10	30	50	10	40	40
iv.	Potassium (g/vine)	25	60	100	10	50	50

Source: Sema and Maiti, 2006

Fertilization with micro-nutrients

In the absence of soil analytical data apply 50 g of micro-nutrients mixture in the planting hole. Zinc and B are the micro-nutrients taken up in largest amounts by the plant, followed by Mn and Fe. With Zn deficiency, apply 20 g of zinc sulphate ($ZnSO_4.H_2O$) per plant, and of B, apply 6.5 g of boric acid (H_3BO_3) per plant. Boron and zinc recommendations for the yellow passionfruit are given in Table 8.

Table 8. Boron (B) and zinc (Zn) recommendation for the irrigated yellow passion-fruit.

Nutrient	Soil composition (mg/dm^3)	Classes of fertility	Nutrient dose (kg/ha)
	Hot water		
B	<0.2	Low	2
	0.21-0.6	Medium	1.0
	>0.6	High	0
	DTPA		
Zn	<0.5	Low	6
	0.6-1.2	Medium	3
	>1.2	High	0

Source: Borges and Lima, 2003

Splitting fertilization applications

Deciding whether to split fertilizer application depends on the texture and the CEC of the soil, as well as the pattern of rainfall. In sandy soils and those with a low CEC, fertilizers should be applied weekly or biweekly. In more clayey soils, fertilizers can be applied monthly or bimonthly, especially when applied to the soil. With fertigation nutrients can be applied weekly or biweekly, depending on soil texture.

Fertilization position

Passionfruit has a shallow superficial root system, i.e. about 60% of the roots are found in the upper 30 cm of soil, and 87% between 0 and 45 cm from the base of the stem. In young orchards, fertilizers should be distributed in a 20 cm wide area around and 10 cm from the trunk, gradually increasing this distance with the age of the plants (Fig. 1). In mature vines it is recommended to apply fertilizer in a band 2 m long and 1 m wide, on both sides of the plants and 20 to 30 cm from the trunk.

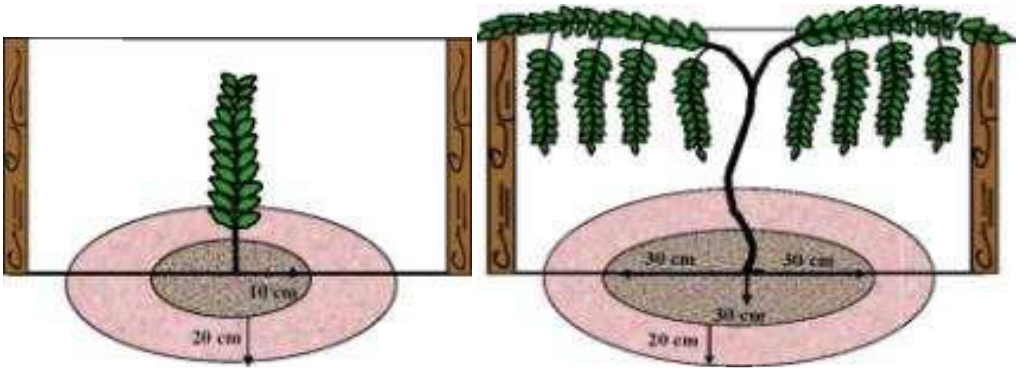

Fig. 1. Localization of fertilizers in young (left) and adult (right) passionfruit plants.

Source: Borges and Lima, 2003

Irrigation

Rainfall in the range of 800 to 1,750 mm, regularly distributed throughout the year, is ideal for passion-fruit. Productivity of around 40 t/ha, has been obtained with a total water supply (rain + irrigation) of 1,300 to 1,470 mm, where 826 mm came from rain. In areas where the rains are insufficient or poorly distributed, irrigation is essential, not only to increase productivity, but also to improve the quality of the fruit, via continuous and uniform production.

Irrigation is needed in areas where the annual rainfall is below 1200 mm per year. 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 soil water level influences passionfruit flowering. A lack of moisture results in loss of leaves and fruits, especially at the start of their development, and this affects the production and quality of the fruits.

The method most frequently used is localized irrigation, using drip and spray systems. Spraying promotes a greater wetted area of soil compared to dripping, thus permitting greater volume of root system expansion. The drip irrigation system has been more widely adopted by farmers because it provides moisture and aeration conditions that favor the development and productivity of the plants. Drip irrigation has the advantage of not contributing to the formation of a humid transitory microclimate within the culture orchard, thus helps to decrease the risk of diseases.

Fertigation

The application of fertilizers via irrigation water results in more rational use of fertilizers in irrigated agriculture, because there is an increase in efficiency, and a reduction in labour and energy costs. In addition, it allows flexibility in the time of nutrient application, which may be divided according to the needs of the crop in various stages of development. Drip irrigation is the most appropriate for fertigation, because nutrients are applied directly to the zone of greatest concentration of active roots.

Nitrogen is the nutrient usually applied via irrigation, because it has high mobility in the soil, especially in the form of nitrate (NO_3^-), but care must be taken not to favor loss by leaching. In fertigation, N is applied accordingly to the demand of the plant to reduce losses, especially in sandy soils. Because it is so mobile in soil, N should be applied frequently at three to seven day intervals, except in sandy soils when the interval should be around three days. The recommended quantity should be distributed throughout the period between the first four months of growths, corresponding to the formation phase of the plant and the beginning of the production phase (first year). Solid N fertilizers are available in four forms: ammoniacal (ammonium sulphate), nitric (calcium nitrate), ammoniacal-nitric (ammonium nitrate) and amide (urea), all being soluble in water and adequate for fertigation, including drip irrigation. In general, these N sources behave similarly and can be applied with other nutrients. Their different effect on the soil pH has to be considered.

In general, P is not often applied with irrigation due to the low solubility of most P fertilizers and their tendency to precipitate, causing blockage of the lines and emitters. Phosphoric acid, apart from a risk of corrosion in metallic lines and connections, does not cause problems of emitter blockage, and is applied via irrigation water to promote cleaning of the lines and emitters in fertigation systems. Apart from this, diammonium phosphate (DAP) and monoammonium phosphate (MAP) can be used in fertigation.

Like N, the application of K via irrigation water is viable, because K fertilizers are soluble. When using split applications, it is important to consider its potential loss by leaching in very sandy soils and its adsorption by clay minerals in heavy soils. Potassium fertilizers normally used in fertigation are potassium chloride, potassium sulphate, potassium nitrate and potassium and magnesium sulphate. The application of K with irrigation may be done every six or seven days and it is recommended to continue the distribution throughout the growth of the plant. Starting from the second year, the

recommended quantity of K_2O for the production period may be divided between the 5th and the 12th month after the seedlings have been transplanted.

Drip irrigation emitters are usually placed at two emitters per plant at a distance of 60 cm between them and each one placed 30 cm from the stem.

Pruning

Vines should be pruned in late winter when they are not actively growing. All dead and weak wood should be cut out and the vine pruned back to vigorous, well-budded stems so that it can resume healthy, active growth in early spring. Disinfect pruning shears between each pruning to avoid spreading disease from vine to vine. A good time to make the first fertilizer application is after pruning.

The pruning of passionfruit vines is conducted in order to reduce the level of pests and diseases and to encourage new vine growth. Heavy pruning should only be performed once per year, after the July to September crop. Since pruning tools are means by which diseases are spread they should therefore be kept clean.

Generally, pruning is done while the vine is dormant and consists of removing any growth that is weak or trailing on the ground, and shortening strong canes by about one-third. Regular pruning is necessary because the fruit is borne on new shoots arising from old canes. This pruning encourages new growth and removes unproductive wood.

A spur should be left at the base of each cane to replace the old cane after it has borne fruit for a year or two. This pruning is done when the vine begins active spring growth. Vigorous vines branch freely and branches that trail on the ground should be removed.

Severed stems and pruned branches should be allowed to become dry and brittle so that they can be disentangled easily from the vine.

In Australia and New Zealand, purple passionfruit vines in commercial plantings usually are pruned to facilitate spraying or to force new growth.

In South Africa, they are pruned to maintain an environment which discourages infestation and encourages healthy growth, and to facilitate cultural practices. However, unpruned vines of purple and yellow passionfruit have been shown to consistently out-yield those which have been pruned.

The evidence on pruning is conflicting. Although in the literature there are frequent admonitions against severe pruning, some growers do practice severe pruning of established vines in spring, cutting each shoot of the preceding year back to a stub with 2-4 or 5 buds to start all new shoots close to the wires. Others merely cut out the shoots that trail to the ground and thin out shoots where they become thick enough to lodge abscissed mature fruit. This method is better suited to plantings where the fruit is permitted to fall for harvest.

In Sri Lanka, pruning all shoots to stubs with two or three nodes in the fall months of January or February, soon after the crop was off, was reported to cause heavier yield than any less severe pruning or no pruning at all.

On the other hand, in some experiments in South Africa, certain types of pruning seemed to reduce yield. Possibly in Sri Lanka, where fruit-setting tends not to be very good, the severe pruning caused some of the shoot growth and flowering to be in seasons more favorable for setting.

In Hawaii, it has not been determined whether or not the commercial yellow passionfruit requires periodic pruning. For short-lived plants trellising and pruning are expensive, as is the rather long harvesting period with rather frequent gathering of fallen fruit.

Pollination

Most cultivars of yellow passionfruit are self-incompatible therefore cross-pollination is necessary. Some natural pollinators of passionfruit are the Carpenter Bee (*Xylocopa sonorina*) and the honeybee (*Apis millifera*). It has been proven that hand pollination increases fruit yield in passionfruit.

Pollination is essential for fruit production on passion vines. Flowers of the purple passion vine normally set fruit when self-pollinated, but many yellow passion vines will not set fruit unless their flowers are dusted with pollen from a different vine that is genetically compatible. Thus, 2 plants grown from cuttings taken from the same vine cannot pollinate each other. Moreover, some vines from a group of seedlings can cross-pollinate and others cannot. This must be learned by trial and error as the plants develop. Ordinarily, many opportunities for cross-pollination exist in a large seedling population.

The most effective insect for pollinating passion fruit is the carpenter bee (Apidae, subfamily Anthophoridae), a large, solitary bee similar to the bumble bee in appearance. The native bee population may ensure adequate pollination in areas where wild maypops fruit naturally. Elsewhere, other means must be supplied. Carpenter bees can be encouraged by placing hollow logs in the field near the vines. Honeybees are less effective because of their small size and because they prefer to work other flowers at the time Passiflora is in bloom. They may be successful with the relatively small-flowered (and self-compatible) purple passion fruit under some conditions, however.

The giant granadilla also needs pollination to ensure fruit set. It requires mild temperatures for normal fruiting and may bloom but set no fruit (or misshapen fruit) during the hottest part of the summer. Hand pollination may be the easiest way to ensure fruit production on a few passion vines growing in the home garden.

Crop protection

Pests and diseases may attack plants as early as the nursery stage. Caterpillars and slugs may attack the plants, while fungi may cause damping-off and loss of plants. Both insect and fungal problems in passionfruit could be controlled through proper cultural practices and chemical sprays. Nematodes also attack Passiflora species. The purple passion fruit, in fact, is impossible to grow in many situations unless grafted on the root of the yellow passion fruit or another resistant species. Nematodes and 2 fungi, species of *Phytophthora* and *Fusarium*, have been found on the roots of declining or drying vines. The yellow passion vine is more resistant to harmful soil organisms than the purple, but it is not immune. Vines may show cankers or stem lesions near the soil line, and slowly decline after growing for as long as 5-7 years. When this happens, it is advisable to start new vines, preferably in a new site, for replacements.

Insect Pests

Beneficial insects as pollinators have already been discussed. There are also harmful insects associated with passion-fruit. This entails solving the problem of eliminating the injurious insects without destroying the beneficial insects.

One approach to this problem is through the proper timing of spray applications. The flower of the commercially grown yellow passionfruit opens during the afternoon hours and closes at night. Observations have shown that insect pollinators are most active during the period when the flowers are in bloom. Therefore, less damage to the pollinating insects might result if spray applications were confined to the early morning hours when pollinators are inactive.

Also, since exposed pollen grains burst upon contact with water, becoming non-functional, it is imperative that any spraying for insect or disease control be done only when the flowers are closed but preferably when the plants are not flowering at all.

Fruit Flies

The most troublesome pests are fruit flies.

Oriental fruit fly (*Dacus dorsalis*)

Melon fly (*Dacus cucurbitae*)

Mediterranean fruit fly (*Ceratitis capitata*)

Generally, the Mediterranean fruit fly is found at high elevations. The Oriental and the melon flies seem to prefer lowlands.

Fruit flies usually puncture the immature passionfruit while the rind is still tender. A woody area develops around the puncture as the fruit enlarges. If the fruit is undeveloped at the time of puncture, damage may be sufficient to cause it to shrivel and drop off. If the fruit is well-developed, it may grow to maturity.

At the time of ripening, the area around the puncture has the appearance of a small woody crater which, while it does not impair juice quality, does disfigure the fruit. The oviposition scars on ripening fruits generally do not contain living larvae, which seem to develop better in immature than in mature fruit.

The main objective in fruit fly control is to destroy the gravid females which usually breed elsewhere but lay eggs in the orchard. An important step, then, is to eliminate nearby overripe fruits on which the adults feed and breed.

Fruit fly adults may be destroyed with various insecticides. One is Malathion 25% wettable powder, which is sprayed at 1.5 kg/ha in 500 l of water. Absolute caution should be exercised in making applications and every precaution taken to do so as safely as possible.

Fruit fly adults may be destroyed also by use of bait sprays made with 1.5 kg of Malathion and 0.5 kg of yeast hydrolysate in 500 l of water per hectare.

Because the adult fruit flies roost on plants that are not necessarily host or crop plants, applications should be made not only on the passionfruit vines but on all nearby vegetation which might harbor the flies.

Frequency of application depends on the population. When adults are numerous, applications twice weekly may be necessary when young fruit is present.

Mites

Several mites are also serious pests.

Spider mites (*Brevipalpus phoenicis*); *Tetranychus telarius*; the broad mite (*Hemitarsonemus latus*).

Mites are generally most damaging in areas of low rainfall and during prolonged dry seasons.

Presence of the spider mite is indicated by scattered reddish patches on the lower surface of the leaf, along the midrib and veins, as well as on the surface of the fruit.

Spider mites cause shriveling, yellowing, premature leaf fall and sometimes complete defoliation. A heavy infestation might also cause vine dieback and shriveling and dropping of immature fruit.

Indications of the presence of the broad mite requires a lens for detection. The very minute female white mites can be seen often carrying the smaller males on their posterior ends. Under the lens, eggs with white markings may also be seen sticking to the leaf surface.

An attack by the broad mite can most readily be detected by the symptoms of injury during the period of vine growth since this mite attacks the young terminal leaves, causing them to be stunted, deformed, slender and rugose.

Mites can be normally controlled by hosing them with a soap solution for at least three days in succession - make sure you spray every part of the plant, especially the underside of the leaves.

Severe infestations of mites on passionfruit can be effectively controlled by spraying wettable sulfur at 2.5 kg/ha in 500 l of water. Monthly applications serve as a precautionary measure.

Aphids

Severe damage by aphids usually results from their attacks on young plants. Two aphids, *Myzus persicae* and *Macrosiphum solanifolii* are efficient vectors of the passionfruit woodiness virus. These aphids are present in Hawaii but the virus is not.

Woodiness disease has been identified in Australia as cucumber mosaic virus 1. It is thought to be transmitted by aphids and is the most serious threat to the purple passionfruit in Australia and Kenya. Much research has been devoted to combating it.

In this disease, the leaves become leathery and malformed; the fruits gradually decrease in size and the rind becomes thick and hard and little pulp is produced.

Scale insects and mealy bugs

They are often raised and protected by ant colonies. Note that ants by themselves do not pose a danger, they can often be found feeding on the nectar in the flower. The barnacle scale (*Ceroplastes cistudiformis*) has been found in large numbers attacking the passionfruit vine. Heavy infestation results in severe defoliation.

Greenfly and blackfly

They attack the young developing parts of the plant, leading to deformities as they grow. The damage can be recognized by isolated brown patches on the leaves, and parts of the leaves (mostly the edges) constricting. These insects are also one of the main causes of viral infections - by sucking the juice out of your plants they can inject viruses.

Snails

Some species of Passiflora attract snails. These have to be dealt with by making the plants unaccessible: create a bed of sharp sand around the base or curl copper around the foot of the plant (snails hate copper). Slug bait should be spread around seedling or a liquid slug control could be incorporated into the fungicide drenches (benomyl) for the control of damping-off.

Caterpillars

Caterpillars have been destructive of the passionfruit plants, especially attacking new leaf growth. *Heliconius* caterpillars have an appetite for Passiflora and most cause allergic reactions or skin-irritation when picked off by hand. Avoid using chemical weapons but put on pair of gloves and pick them off - some of these insects are more beautiful than your plants and play an important role in the ecosystem. Hairy caterpillars can cause respiratory problems or irritation to exposed skin - wear protective glasses and mask and keep your body covered when removing them. Tortrix moths have caterpillars which are known as leaf-rollers, they fold the leaf to create a protective cocoon whilst munching away at your plant. An insecticide is sprayed at the recommended rate every two to four weeks for caterpillar control.

stinkbug (*Chondrocera laticornis*) punctures the yellow passionfruit but only the appearance of the fruit seems to be affected.

Although severe attacks appear to be exceedingly rare, the thrip, *Selenothrip rubrocinctus*, has been observed to attack passionfruit leaves.

The passion vine leaf hopper (*Scolypopa australis*) requires protective measures in Queensland, Australia.

Biological Controls

Ladybird beetles or Ladybugs (*Rodolia cardinalis* and *Hiippodamia convergens*) and Praying Mantes (*Mantis religiosa* and *Paratenodera sinensis*) are among the most beneficial insects known to man. They devour many times their own weight in destructive pests.

Ladybugs consume aphids, fruit scales, tree lice, mealy bugs, leaf hoppers, thrips, fleas and the eggs and larvae of many plant-destructive insects.

Young Praying Mantes devour aphids, flies and other small insects; Older ones consume enormous quantities of beetles, caterpillars, grasshoppers and other damaging insects.

The most startling breakthrough in biological controls is evidence found by a team of Penn State chemical ecologists that plants control mating in insects. This contradicts the current theory that female insects manufacture their own sex lures and that each male will respond to a single attractant unique to its species.

Dr. Laurence B. Hendry and his coworkers at Penn State University discovered that the attractants originate in the plants on which the insects feed. He believes the female simply stores the attractants, called pheromones, not changing them in any way. He has found the attractants in plants in concentrations corresponding to the amounts found in females. He also has evidence that males of a single species can be sensitive to as many as 20 different chemicals, depending on their diet.

Dr. Hendry theorizes that the insect is imprinted or programmed, while still in the larval stage, to respond to whatever pheromone is present in its earliest food. Therefore the male and female insects which feed on the same plants as larvae will be imprinted with the same attractant and mate as adults.

Thus, pest-control programs based on sex lures may be the most effective; a field may be sprayed with an inexpensive compound which insect larvae would eat and imprint. Later the same chemical could be used as a sex lure to confuse the males and prevent mating.

Integrated Control

Integrated control is being studied under which all of these - natural enemies, cultural practices, resistant-crop varieties, microbial agents, genetic manipulation, messenger chemicals, selective chemical controls such as green soap and water, and even pesticides - become mutually augmentative, rather than individually exclusive.

Diseases

The most serious diseases of the passionfruit are brown spot, root rot and nematodes. Brown spot, caused by the fungus *Alternaria passiflorae* in warm weather, is easily recognized. On the leaf, the first symptoms are minute reddish-brown spots about 0.3-0.6 cm in diameter which, under the humid conditions required for its development, have a water-soaked margin.

Spores or conidia produced by the fungi are readily spread by the wind and germinate on leaf and fruit surfaces, causing the telltale brown spots.

As infection progresses, the spots enlarge, forming a series of concentric rings with premature leaf drop. Symptoms on the fruit are characterized by circular, sunken necrotic areas, about 2-5 cm diameter, which, as on the leaves, are reddish-brown. Infection occurs on half-grown to nearly mature fruit but apparently does not impair juice quality. However, it is objectionable from the processing standpoint because the brittle, necrotic rind tissues drop into the juice during extraction.

Brown spot can be controlled by Maneb (80% WP) at the rate of 1 kg/ha in 500 l of water applied biweekly or Captan, Zineb or copper fungicide.

Since this is a disease caused by moist conditions, growers probably can minimize fruit damage by picking up the fruit before it can be damaged by fungal spores on the damp soil.

Root rot, the second most serious disease of the passionfruit, is caused by the fungi *Pythium splendens* and *P. aphanidermatum* in Hawaii. In South Africa the fungus has been identified as being of the *Phytophthora* genus.

Symptoms are a general decline in vigor as feeder roots are destroyed by the fungus. Some California vines show these symptoms. *Passiflora edulis*, the purple passionfruit, is highly susceptible to root-knot nematode attacks. Symptoms are severe stunting of the vine which may eventually die. *P. edulis f. flavicarpa* seems not to be affected by this disease and is resistant as well to woodiness disease and *Fusarium* wilt. It is being used in many countries as rootstock for the purple passionfruit.

However, it is evident that maintenance of vigorous, healthy plants by consistently good fertilization and cultural practices will reduce or eliminate disease or minimize their effects.

Viruses

Viral infections will persist in a plant and include Chrysanthemum B carlavirus, Passiflora latent carlavirus, Passiflora ringspot potyvirus, Passionfruit woodiness potyvirus, and Purple granadilla mosaic virus. They are transferred via wounds from sucking insects (greenfly, blackfly) or from utensils that weren't cleaned. The virus and susceptibility depends on the species or hybrid and remains in the plant once it's infected there is no treatment. The damage resembles that of nutrient deficiency: yellowish spots on the leaves, deformed growth and bad flowering or low yield in fruit. A virus can kill your Passiflora, but its immune-system and some regular feeding with fertilizer will keep the plant healthy and happy. The damage is most noticeable in the beginning and end of the season. A trick to produce virus-free plants is by cutting fast growing shoots. In these shoots the virus might not have propagated yet. Any vines whose leaves show mosaic or vein-clearing symptoms should be removed and destroyed. Also, plants should be propagated from seed whenever possible. A vine used as a source of cuttings should be kept insect free in a screen house to protect it from viral infections.

Harvesting

The passion fruit vine, especially the Yellow, is fast-growing and will begin to bear in 1 to 2 years. Ripening occurs 70 to 80 days after pollination. A passionfruit orchard may have a economic life span of 3-5 years. There are two major seasons of production, June to August and November to January. The first season may extend from May to October. Fruits are harvested when they have dropped to the ground. Green or immature fruits should not be picked off the vine as they will not ripen, they will also be off flavored and have a higher concentration of cyanogenic glycosides (a toxin produced by the vine). Fruits fall after ripening on the vines and are picked up from the ground 2 to 3 times weekly. Fruit yield is 7-10 t/ha or more. Yields up to 40 t/ha have been reported.

Seedlings set in the spring will spend most of the first season in the field in vigorous vegetative growth, although a few flowers and fruit may appear in late summer on vines of the yellow passion fruit. Vines grown from cuttings flower more profusely and set more fruit the first year in the field than do seedlings, but cutting-grown vines are more expensive to produce and often less vigorous than seedlings. Furthermore, one must exercise great caution to keep the plants from which cuttings are taken free of disease, a task that is not necessary when seedlings are used.

Approximately 3.5-7 kg of fruit per plant is likely to be the best production that can be expected of the yellow passion fruit in Florida until more productive cultivars become available. With these levels of production and a spacing of 3 x 4.5m, one might optimistically expect a production of 2.5-5 t/ha of yellow passion fruit here. At best, the purple passion fruit would likely to produce yields only as great. Insufficient data are available to predict yields of the giant granadilla.

The entire crop of purple passion in fruit and the early crop of the yellow form matures in late spring and early summer. Then the vines grow vegetatively and most do not flower when days are longest, from about June 21 to July 4. Yellow passion fruit vines begin the season's second flowering in the

latter half of July, usually peaking in mid-August and continuing until October or November. Fruit set from the second flowering ripens from September through early February.

Developing passion fruit remains green until fully mature, then change colors rapidly within a few days. Both yellow and purple fruits drop to the ground when ripe. The fruit should not be harvested until it drops, because fruit picked from the vine has an unripe "woody" taste. In some regions, the soil beneath the vines is kept weed free and the newly fallen fruit is collected once or twice a week for market. Summer fruit is better collected daily because of higher temperatures and the danger of sun-scalding.

The passion vine is a short-lived perennial. Some yellow passion fruit vines have persisted in the field for 10 years, but this is exceptional. A more realistic life expectation is 3-5 years. A vine that appears to have excessive deadwood may have lost so much vigor that it should be removed and replaced with a young, healthy plant.

Fruit quality

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.

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.

Processing

Passion fruits are processed into juices, which are sold either in single strength or as frozen concentrates. The passion fruit juice is also used in the production of cordials, alcoholic beverages, ice creams, and confectionery and mixed fruit blends.

Both purple and yellow passion fruits begin to lose moisture as soon as they fall and quickly become quite wrinkled if held under hot, dry conditions. Juice in these fruits is wholesome, but they are unsightly and thus unmarketable. Clean fruit can be stored in polyethylene bags at 10°C for as long as 3 weeks without loss.

Experimentally, wire netting strung on inclined frames beneath passion vines has been used to collect ripe fruit which falls and rolls forward to be gathered easily like eggs from a battery.

Fruit of the giant granadilla turns deep golden when fully ripe and may be picked for local consumption at this stage. Giant granadilla fruit to ship may be picked just as the area immediately surrounding the fruit's stem turns yellow.

Uses

Passion fruit is proved to have analgesic, anti-anxiety, anti-inflammatory, antispasmodic, cough suppressant, aphrodisiac, cough suppressant, central nervous system depressant, diuretic, hypotensive and sedative activities. Besides, it is traditionally reported to possess anticonvulsant, antidepressant, astringent, cardiotonic (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.

The fruit can be grown to eat or for its juice, which is often added to other fruit juices to enhance aroma. The fruit is eaten alone or in fruit salads, sherbets, ice cream, jams, cool drinks and as concentrates. 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).

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. The nutritive value of passionfruit juice is given in Table 9.

Table 9. Nutritive value of passionfruit juice

	Components	Range
1.	Relative density (20°/20° C)	1.05-1.07
ii.	°Brix	12.0-18.0
iii.	Total soluble solids (g/l)	125.8-193.5
iv.	Fiber (g/100 g edible portion)	4.4-15.9
v.	Starch (g/100 g edible portion)	1.0-3.7
vi.	Protein (g/100 g edible portion)	0.6-2.8
vii.	Calories (kcal /100g edible portion)	32-92
viii.	Vitamin A (mg/100 g edible portion)	650-684
ix.	Vitamin B: (mg/100 g edible portion)	0.1-0.2
X.	Vitamin C (mg/100 g edible portion)	20-25
\i.	Titrable acids as tartaric acid (g/l)	30-55
xii.	L-Malic acid (g/l)	1.3-5.0
xiii.	Citric acid (g/l)	25-50
xiv.	Isocitric acid (mg/l)	170-380
XV.	Glucose (g/l)	20-55
xvi.	Fructose (g/l)	20-53

xvii.	Sucrose(g/l)	10-45
xv iii.	Potassium (mg/l)	2200-3500
xix.	Magnesium (mg/l)	100-200
XX.	Calcium (mg/l)	35-150
xxi.	Chloride (mg/l)	50-300
xx ii.	Phosphate (mg/l)	350-850
xx iii.	Sulfate (mg/l)	250-400
xx iv.	Iron (mg/l)	25-30
xxv.	Zinc (mg/l)	5-10
xvi.	Proline (mg/l)	150-1500
xvii.	Aspartic acid (mmol/l)	3-12
xv iii.	Alanine (mmol/l)	1.0-4.5
xix.	γ-aminobutyric acid (mmol/l)	1.5-4.0
XXX.	Histidine (mmol/l)	0.1-0.4
xxxi.	β-carotene(mg/l)	7-28

Source: Sema and Maiti, 2006

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