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Passion fruit

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Introduction

Passion Fruit *(Passiflora edulis* Sims) is a native of Brazil. It belongs to the family *Passifloraceae*. It is grown mostly in tropical and sub-tropical parts of the world from South America to Australia, Asia and Africa. Common names of passion fruit are granadilla, *parcha*, *parchita*, *parchitamaracuya*, or *ceibey* in Spanish, *maracuja peroba* in Portuguese and *grenadille*, or *couzou* in French. The purple form is called purple, red, or black granadilla, or, *lilikoi* in Hawaii, mountain sweet cup in Jamaica and *linmangkon* in Thailand. The yellow form is widely known as yellow passion fruit and is called yellow *lilikoi* in Hawaii, golden passion fruit in Australia and *parchaamarilla* in Venezuela.

In India, passion fruit was introduced in early part of twentieth century in the Nilgiris, Coorg and Malabar areas of Southern India. Passion fruit is a perennial, vigorous, climbing, woody vine that produces round or ovoid fruits. Fruits have a tough, smooth, waxy dark purple/yellow coloured rind with faint, fine white specks. Fruit contains orange colored pulpy juice with large number of small, hard, dark brown to black pitted seeds. The fruits are generally not used for table purpose. But they use in several preparations due to unique aroma , nutritional and medicinal properties. They are processed to make fruit juice , concentrate etc. The juice is delicious and has an excellent flavour. It is known for its blending quality. Fruits contain good proportion of reducing and non-reducing sugars and acids. Fruits are rich in Vitamin A (1300-2500 IU/100 g pulp), Vitamin C (30 –50 mg/100 g pulp) and minerals such as potassium, sodium, magnesium, sulphur and chlorides (Table 1). Passion fruit is used for urinary infections and as a mild diuretic, digestive stimulant and health tonic to treat asthma, whooping cough, bronchitis, coughs, gastric cancer etc. The juice of passion fruits is a digestive stimulant and beneficial for gastric cancer. There is currently a revival of interest of the pharmaceutical industry in passion fruit, especially in Europe, in the use of the glycoside, passiflorine, especially from *Passiflora. incarnata* L., as a sedative or tranquilizer. Italian chemists have extracted passiflorine from the air-dried leaves of *Passiflora. edulis.*

Table 1: Nutrient and approximate composition of passion fruit per 100 g of edible portions

Composition	Species		
	P. edulis	*P. edulis var. flavicarpa*	*P. quadrangularis*
Moisture (%)	85.6	84.9	88.0
Protein (g)	0.9	0.7	0.9
Fat (g)	0.1	0.2	0.2
Carbohydrate (g)	13.6	13.1	10.1
Ash (g)	0.3	0.5	0.9
Ca (mg)	3.6	3.8	10.0
P (mg)	12.5	24.56	22.0
Fe (mg)	0.2	0.4	0.6
Vitamin A (IU)	717	2410	70
Thiamine (mg)	Trace	Trace	-
Riboflavin (mg)	0.1	0.1	-
Niacin (mg)	1.5	2.2	2.7
Ascorbic acid (mg)	30	20	20

Origin and distribution

The edible commercial species of passion fruit originated on the edges of South American rain forests in the Amazon region of Brazil and possibly in Paraguary and Northern Argentina (Knight *et al*., 1962). The purple passion fruit (*Passiflora edulis)* is adapted to the cooler subtropics or at high altitudes in the tropics, while the golden passion fruit (*Passiflora edulis var. flavicarpa*) is more suited to tropical lowland conditions. The two forms of passion fruit hybridize readily and produce fertile seedlings intermediate in appearance between the parents. Passion fruit 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. Brazil, Ecuador Venezuela, South Africa, Sri Lanka, Australia, Papua New Guinea, Fiji, Hawaii, Taiwan and Kenya account for more than 90% of the world's passion fruit production. Brazilian production is around 478,000 t with a yield of about 13.8 t/ha. The total global supply of passion fruit is estimated at 8.52 lakh tons. Brazil and Ecuador have dominant share in the world export market. It is followed by Australia and New Zealand in export of the fruit to other countries. Kenya and South Africa also have a decent production of passion fruit and its area under cultivation is growing rapidly.

In India, though passion fruit was introduced in early part of twentieth century but its cultivation was limited to few districts of Karnataka, Kerala and Tamil Nadu. Since last one decade passion fruit cultivation started in some parts of northern India, especially North - Eastern states. The area under this crop is rapidly increasing in Mizoram, Nagaland, Manipur and Sikkim. There is a great potential for passion fruit cultivation in these states. Presently passion fruit is cultivated in Munnar and Waynad of Kerala, Nilgiri hills and KodaiKanal of Tamil Nadu , Kodagu (Coorg) region of Karnataka and parts of Mizoram, Nagaland, Manipur and Sikkim. The estimated area and production of passion fruit is 9.11 thousand ha and 45.82 thousand tones, respectively. Manipur and Nagaland are the leading states in passion fruit production contributing 70 percent area and production of the country(Table 2). In Nagaland Kohima, Mokokchung, Wokha, Phek are main passion fruit producing districts. The average productivity of passion fruit in India is around 5.02 tons/ha which much lower than countries like Brazil, Australia, Colombia etc where productivity is 30-35 tons/ha. There is immense potential passion fruit cultivation in North Eastern states , humid tropical areas parts of Karnataka , Kerala and Tamil nadu. These areas have all sets of climate and sufficient rainfall for growing passion fruit successfully.

Table 2 : Area and production of Passion fruit in India

State	**Area (ha.)**	**Production (T)**	**Productivity(t/ha)**
Nagaland	7540	13741	1.98
Manipur	3,952	44,850	11.34
Meghalaya	943	-	-
Mizoram	820	7850	9.57
Sikkim	500	-	-
Karnataka	500	-	-
Kerala	300	-	-
Tamil Nadu	100	-	-

Taxonomical classification of *Passiflora*

Passion fruit (*Passiflora edulis* Sims.) belongs to family *Passifloraceae* which includes 12 genera with more than 500 species. *Genus Passiflora* has about 400 species out of which few are economic importance. Within these species there are two district forms i.e., the standard purple (*P. edulis*) and the yellow (P. edulis f. flavicarpa Deg.). The chromosome number ranging from 2n=18 to 2n=22. Zeven and Zhukosky (1975) mentioned is detailed about12 species of Genus *Passiflora* which are being enumerated.

a. *Passiflora alta* Dryland: It is native of Peru and Brazil. It is a woody vine cultivated in Brazil for its fruits.

b. *Passiflora antiquiensis* Karst. (Syn. *P. valxsemii* (Len.) Traina& Planch.):It is native of Colombia and known as banana passion fruit. This species is also a woody vine cultivated for its fruit.
c. *Passiflora cearensis* Barb : It is native of Brazil and cultivated for its fruits.
d. *Passiflora edulis* Sims. : It is real passion fruit which is native of South Brazil. This species is widely distributed throughout the tropics and subropics. The fruits are especially used for juice preparation.
e. *Passiflora foetida* L . : It is woody species native of West Indies and South America. It is distributed to many tropical countries in Africa and Asia where it has naturalized. The fruits are hardly edible however, in Malaysia and East Africa it is used as cover crop.
f. *Passiflora laurifolia* L. : It is native of thickets and forest fringes of West Indies and North-East South America. Cultivated for fruits and spread throughout the tropics (Parseglove, 1968).
g. *Passiflora ligularis* Juss*:* It is native of Tropical America and commonly known as Sweet granadilla. Its sweet fruits are much used in mountainous region of Mexico and central America).
h. *Passiflora maliformis* L.: A vine native to Tropical America and cultivated for fruits.
i. *Passiflora mallissima* (H.B.K.) Bailey. It is native of Andes and commonly known as Banana Passion fruit. It is especially cultivated in Equador and Bolivia.
j. *Passiflora psilantha* (Sodiro) Killip: It is native of Ecuador and known as Gullan. It is a vine grown for fruits.
k. Passiflora quadrangularis L. *:* It is commonly known as Giant granadilla and Barbadine and native of tropical South America. Widely distributed in tropics where it is grown for fruits.
l. *Passiflora tripartite (Juss.) Poir:* It is native of Ecuador and cultivated for fruits. It is commonly known as Tasco.

Morphology

The passion fruit vine is a shallow-rooted, woody, perennial, climber. The leaves are alternate, evergreen leaves, deeply 3-lobed when mature, finely toothed, measuring 7.5-20 cm long, deep-green and glossy above, pale and dull beneath. The young stems and tendrils tinged with red or purple, especially in the yellow form. A single fragrant flower, 5-7.5 cm wide is borne at each node on the new growth. The flowers have 3 large, green, leaf like bracts, 5 greenish-white sepals, 5 white petals, a fringe like corona of straight, white-tipped rays, rich purple at the base, also 5 stamens with large anthers. The ovary has triple-branched style forming a prominent central structure. The flowers of the yellow passion fruit are showier, with more intense color. The fruits are round or ovoid , 4-7.5 cm diameter, with tough, smooth, waxy rind. The colour of fruits range from dark-purple with faint, fine white specks, to light-yellow or pumpkin-color. The rind is 3 mm thick, adhering to a 6 mm layer of white mesocarp. The fruit cavity is more or less filled with an aromatic mass of double-walled, membranous sacs filled with orange-colored, pulpy juice with 200- 250 small, hard, dark-brown or black, pitted seeds. The flavour is appealing, musky, guava-like and sub acid to acid.

Anatomy

Passion fruit has hermaphrodite, solitary flowers, located in the leaf axils. There are usually five stamens. The ovary is borne over the androgynophore. There are three styles united at their base, and at the top of style there are three bifurcated stigmas (Vanderplank, 1996). Passion fruits are protandrous as anther dehisces before stigma becomes receptive and stigma remains receptive from the time of flower opening to closing (Cox, 1957). Purple, giant and *Passiflora foetida* are self-fruitful, so they bear more fruits per vine. The flowers of the yellow are perfect but self-sterile and self-incompatible which lead to poor fruit set (Bruckner *et al*., 1995).The style of passion flower shows rhythmic movement, at anthesis, its style is in upright position and it starts curving in due course of time. According to the style curvature, there are three kinds of flowers in passion fruit: a) completely curved (CC) style, where style is curved in such a way as to bring stigmas close to the anthers; b) partially curved (PC) style, where the style curves partially, but stigmas remain above the anthers, forming a 45° angle with them; and c) style without curvature (WC), where the style does not curve, and the stigmas for an angle of approximately 90° with the anthers. The three flower types can be found on a single plant; however, CC flower are the most common, and WC flowers are relatively less common (Knight & Sauls, 1994).Flowers are large, attractive, colourful and fragrant and produce plentiful nectar and pollen that facilitates insects for cross-pollination.

Cytology and Embryology

Passion fruit is a diploid . *Passifora edulis* has 2n=18. Most of the species of *Passiflora* genus have similar number s of chromosomes but some species have higher number of chromosomes ie. *Pasiflora foetida* has 2n= 18,b20 and 22.

The integration of cellular and molecular data is essential for understanding the mechanisms involved in the acquisition of competence by plant somatic cells and the cytological changes. Arbosa *et al* (2007) examined and ccompared meiosis and pollen viability of interspecific somatic hybrids of yellow passion Fruit and *P. incinnata*, a wild species. The mmeiotic behaviour revealed relatively high stability, with most of the hybrid cells showing 18 Bivalents. High values of pollen viability (>70%) were found in the diploid parents as well as in the hybrid plants. Haploid induction in passion fruit via gynogenesis provides inbred lines that can be used in production of hybrid cultivars was studied by Rego *et al* . (2011). They found that some accession were highly responsive, showing a mean yield of haploid embryos per cultured ovules (7.67%). The haploidy of gynogenic plants was confirmed by cytological analysis. Diego Ismael Rocha *et al*. (2016) investigated the dynamics of passion fruit cotyledon explants .They found that somatic embryogenesis by characterizing the associated ultrastructural events and analysing the expression

of a putative P. edulis ortholog of the Somatic Embryogenesis Receptor-like Kinase (SERK) gene. Embryogenic calli were obtained from zygotic embryo explants cultured on Murashige and Skoog medium supplemented with 2,4-dichlorophenoxyacetic acid and 6-benzyladenine. Callus formation was initiated by the division of cells derived from the protodermal and subprotodermal cells on the abaxial side of the cotyledons. The data also demonstrated that the dynamics of the mobilization of reserve compounds correlated with the differentiation of the embryogenic callus.

Agronomy

Climate and Soil requirement

Passion fruit prefers a tropical and sub-tropical climate with moderate rainfall ranging between 100 and 250 cm. It is found growing at an altitude of 800-1500 m above sea level. In purple passion fruit, cool temperatures are favourable for flower initiation and fruit set (18-23^{O} C), while relatively high temperatures is necessary for promoting juice production (18-23^{O} C) and improvement in quality. Yellow passion fruit grows under low land tropical conditions, whilst, the purple type tends more to be cultivated in subtropical areas or at higher altitudes in the tropics. The low temperature effects fruiting of the vines and upper parts suffered cold injury. It generally requires an average annual rainfall of 100 cm. In India, it is found to be grown in areas of receiving rain from between 100 cm and 250 cm.

Passion fruit is grown on many soil types but light to heavy sandy loams, of medium texture are most suitable. Soil with a pH of 6.5 to 7.5 is the most suitable. If the soil is too acid, lime must be applied. The soil should be rich in organic matter and low in salts because the vines are shallow rooted. Good drainage is essential to minimize the incidence of collar rot. Water logging and soil without drainage should be avoided.

Varieties

Passion fruit has two distinct forms , the standard yellow (*Passiflora edulis* f. *flavicarpa* Deg.) and the purple (*Passiflora edulis f. edulis*). The yellow are more acidic and less starchy while the purple are less acidic and more starchy. Both two form *viz.,* purple passion fruit *(P. edulis)* and yellow passion fruit *(P. edulis* var. *flavicarpa)* are of commercial importance. The hybrids of these two have also been developed for cultivation.

Purple Passion Fruit

The vines of purple passion fruit are moderately vigorous and more productive at higher elevation. Generally fruits are smaller than yellow passion fruit. Fruit are 4 to 5 cm in diameter and deep purple colour when ripe. The average fruit weight ranges between 37-50 g. The juice content of the fruit varies from 35-38% and has a better flavour and aroma as fresh, canned and frozen juice or pulp than the yellow one. The seeds are black in colour. The commercial cultivars of the purple form are Ouropretano, Muico, Peroba, Pintado etc. in South America. In India, there is no standard cultivar. The local lines such as Ooty Purple, Coorg Purple, Moodabidri Purple, Thrissur Purple, Cherapunji Purple, Thaliparamba Purple, Ambalavayal Purple etc. are cultivated by the growers.

Yellow Passion Fruit

The yellow passion fruit has a more vigorous vine. This type is suitable for lower elevation and is less productive at higher elevation due to its sensitivity to low temperature. The fruit is generally larger , weighing about 60 g , than the purple one. The fruits are round in shape with yellow mottled spots and turns to golden yellow when ripe. Juice is more acidic and its recovery is comparatively less than the purple one . Seeds are brown. This form is inferior to the purple one with regard to juice content (25-30%) and flavour. The commercial cultivars of the yellow are Mirim or Redondo and Guassu or Grande in South America and Golden Star in USA. There is no standard cultivar In India. The local lines such as Ooty Yellow, Coorg Yellow, Munnar Yellow etc. are cultivated by the growers.

Hybrid Varieties

The hybrids of yellow and purple form have been developed for combining the desirable characteristics of both the forms of passion fruits. Several hybrid varieties have been developed in Brazil, Australia ,south Africa, etc. In India, a hybrid ‘Kaveri’ of purple and yellow form was developed at Central horticultural Experimental Station, Chettalli, Coorg, Karnataka.

Kaveri Hybrid Passion fruit

This variety is a high yielding hybrid developed from Central Horticultural Experiment Station, Chettalli in 1986. This is a cross between purple and yellow varieties. The fruits are ovoid to round and purple dotted in colour. The average fruit weight ranges between 90-100 g. Each plant bears 40-60 fruits per annum .The average yield of an grown up orchard is around 60-70 tonnes per year. Its fruit yield is around 200

tonnes per ha over a three-year cropping period. Fruits contain 25-30 per cent juice, 11.5-12.0 percent sugars and 3.0-3.5 mg citric acid/100ml of Juice. This is tolerant to *Alternaria* leaf spot, *Fusarium* collar rot and nematodes. This variety is popular in Karnataka, Kerala, Tamilnadu and North Eastern States.

Propagation

Passion fruit is propagated through seed, stem cutting, grafting and serpentine-layering technique. Seedlings and grafted plants are more vigorous than the plants raised by cuttings. Passion fruit vines originating from cutting or grafting starts fruiting at 7-6 months while plants raised from from seeds come in fruiting at 10-12 months. Vegetatively propagated plants are true to type while seeding plants are not genetically uniform due to cross pollination.

Seed propagation

Passion fruit vines are usually grown from seeds but seed propagation is not preferred for commercial multiplication as lot of variable is found in seed propagated plants. For seed propagation, fruits are collected from vines known for their performance in term of yield and quality. The seeds are extracted by fermentation method by heaping up the pulp for 72 hours and extracting the seeds and drying in shade. Sowing is done preferably during the month of March-April in a well-prepared seedbed. The seeds start sprouting in about 12-15 days after sowing and germination is completed in about a month. Pre-sowing seed treatments with different chemicals (50%HCl. 5%H_2SO_4, 1% thiourea, 1% KNO_3, 2% sucrose, 2% urea, 2% bleaching powder) and growth regulator (100 ppm GA3)was found increasing on seed germination of passion fruit. Seeds treated with 2 per cent bleaching powder in 24 hrs treatment emerged was found best for germination and seedlings growth . Seed treatment with 100 ppm GA3 for 30 min was also found effective (Mehta *et al*, 2016). In some cases germination extends even up to 50-60 days. When the seedlings attain four to six leaves, they are transplanted in 10 x 22 cm. polythene bags filled with a mixture of soil, compost and sand in 2: 1 : 1 proportion. The seedlings are ready for transplanting in the field in about three months.

Vegetative Propagation

Stem cuttings

This is the most popular method of multiplication of passion fruit. Passion fruit is not an easy to root plant but rooting is satisfactorily under favourable conditions. The 30-35 cm long mature portion of the vines

having 3 to 4 nodes is selected for the cutting. It should be raised in a suitable media preferable equal mixture of sand soil and farmyard manure. Rooting may be hastened by hormone treatment. It has been found that treatment cutting with 200 ppm NAA for very short period(3-5 second) or 80 ppm NNA for 12 hour increased the rooting in cutting. Rooting takes place within a month and can be transplanted to the field in about three months (Kumar *et al*.2008).

Grafting

Grafting is used to multiply high yielding varieties and hybrid varieties. Generally vigourous and resistance lines or species are used as rootstocks. Cleft graft, whip graft or side wedge graft methods are be used for multiplication. The some lines of yellow passion fruit which are resistance to nematode infestation and diseases have been found to be a good rootstock for hybrid varieties. The seeds of yellow passion or other rootstocks are sown either in March or in October for raising the seedling depending upon the availability of the seeds. Seedlings can be raised in seedbed or in pots. The plants became ready for grafting in 3 months. Scions from healthy young vines are preferred to those from mature plants. Generally both stock and scion should be of pencil thickness for grafting. The diameter of the selected scion should match that of the rootstock. Several methods of grafting are used in passion fruit .The experiment was conducted at CHES, Chettalli to find out suitable time and method for grafting of passion fruit . It was observed that cleft grafting of passion fruit variety Kaveri (Scion) on yellow passion fruit root stock gave higher success in rainy season with highest success (75%) in the month of September. Lower success (30 %) was reported in March month. It was concluded that cleft grafting in the month of September is suitable for multiplication of grafting of Passion fruit under Coorg conditions (Anonymous, 2013). In case of grafting on resistant rootstocks (yellow Passion Fruit) can be used to avoid damage due to wilt or root rot. Grafting Plants grafted on wild species produced more elongated fruit plants originated from seeds, but within the commercialization standards (Hurtado-Salazar *et al*., 2015)

Serpentine Layering

In this method, the lateral shoots emerging from the main branches are given partial slanted cut below the nodes and shoots are allowed to root in rooting medium consisting of soil, sand and compost (1:2:1) with regular irrigation. This should be done in the month of February. The roots emerge profusely with in 45 days. These plants should be separated during April _May. The method has been found highly successful

with 90-95 percent success with 75 days of layering. The field survival of the plants propagated by this method is higher(Anonymous ,2012).

Spacing and planting

Proper spacing should be provided as this greatly influences the growth of the vine and production. A spacing of three metre from row to row and two metre plant to plant from is suitable. Pits of 45 x 45 x 45 cm size are dug and filled with a mixture containing three parts of top soil and one part of compost. Planting is done preferably on cloudy days during June-July after the onset of monsoon so that the plants are well established by the end of the monsoon. Planting is done and 3x2 m or 3 x 3 m distance. In Brazil, Australia, Colombia and other countries high planting density (2.0 x 1.25 m) within the row and between the rows with a plating density of up to 4000 plants/ha is practiced. This results in higher productivity than normal density planting. However evaluating the effects of different planting densities of passion fruit on fruit yield and quality in Brazil, Weber *et al (*2016) found that there was two years old plants showed no difference in yield as well as in the number of fruits ha-1 between the planting densities i.e. 1600 plants ha^{-1}, 2666 plants ha^{-1} and 3200 plants/ ha^{-1}.

Training and pruning

Passion fruit is a woody vine and it needs support for good growth and fruiting. The vines are trained on a frame of wires and poles 1.5 to 2 meter above the soil surface for commercial cultivation. Among the different types of trellising methods, Kniffin system is the most economical. In which, 2½ metre long poles are erected six metres apart and a wire is fixed on the top. Trellis should always run across the slope or in the direction of North-South for maximum and even exposure of vines to sunlight. In order to withstand the weight of the vines it is necessary to use eight or ten gauge wire, turning buckles and also strong stone pillars or cement or wooden poles (Fig.1 &Anonymous, 2009). This is required for regulating yield of Passion fruit as the to support a heavy weight of vines and fruits under all conditions of weather at least for five years. Weak and faulty construction of trellis may result in sagging and loss of vines. If wooden pole is used it has to be treated with tar up to the portion that is buried in the soil to prevent deterioration and white ant attack.

The young vines are supported with hardwood stake or gunny twine, which may be stretched vertically from the bottom of the plant to the top of the wire. Plants start growing very fast just after establishment and several branches arise from the base of the plants. All the shoots leaving only two vigorous shoots are

removed as and when they appear. The main shoots are bound on stake or twine and all the lateral growth in these shoots are removed till they reach the wire. Once the main vines reach the wire, the tips are pinched to encourage leader formation. Two leaders are directed on either side of the wire, and are tied with loops around the wire until the leader of the adjoining plants meet, when the tips of the leaders are cut. This forces the leaders with laterals which are trained downwards hanging from the wire (Fig 2a b &C). All the tendrils obstructing downward growth of the laterals are to be removed as and when they come.

Passion fruit vines bear fruits only on current season's growth. Systematic pruning of vine encourages new growth resulting in regular and higher yield of fruits. The lateral branches coming from leader branches are allowed to grow and fruit. Once the laterals have produced the fruits, they are cut back to four to six buds so as to induce regular bearing. Pruning is generally done twice in a year, first in March and April and another in October-November depending upon the harvest of the crop. Pruning is confined only to the cutting back of the laterals or buds of those laterals that have fruited. In the case of old laterals, cutting back is limited to the nearest active bud as otherwise with increasing age of the lateral, the basal buds become dormant or sterile. Indiscriminate and drastic pruning of inactive or dormant vine may lead to a setback in growth and reduction in yield.

Pollination

Passion fruit bear flowers around the year under tropical humid conditions .but there are two main flowering period March-April and August -September. The flowering time varies as per the climatic conditions. Pollination is not problems in purple and hybrid varieties of passion fruit but it is major concern in most the yellow passion fruit varieties. Self-incompatibility and cross-incompatibility in certain clones of yellow passion are the inherent basic characteristics attributing to lack of fruit set. Lack of or poor fruit set in mutually compatible crosses may be caused by in sufficient pollination, wetting of pollen, presence of a large percentage of upright-styled flowers, fruit fly damage, varying flower production and blossom opening time, and combinations of these. The passion fruit is in insect-pollinated. Wind pollination is practically nil and results in no fruit set. The principal insects visiting passion fruit include *Apis mallifera* (honey bee) and *Xylocopa vanpuncta* (carpenter bees). Carpenter bee is the most effective pollinator as it has large body and its body brushes along the anther and stigma while obtaining nectar. On the other hand honey bees are not effective pollinator because of their foraging habit (Hammer, 1987).

Carpenter bees may be used for effective pollination . However fruits from hand-pollinated flowers are larger and yield more juice than those from naturally-pollinated flowers. The number of pollen grains placed on the stigma influences the fruit set percentage, size of the fruit, number of matured seeds, and juice yield (Akamine and Giralami, 1959). The flowering duration in passion fruit is 15-22 days depending on the season and varieties. Generally 3-4 days are required for anthesis and fruit set. The purple passion fruit flower open in the morning while yellow passion fruit flower open in the noon and afternoon. The pollen viability in both the types ranges between 88-90 per cent.

Nutrition

The Nutrient removal pattern on whole plant including fruits analysis revealed that an hectare area accommodating 1500 plants and producing average 37 tons fruit yield remove: 202.5 kg N ,17.4 kg P, 184.2 kg K , 151.6kg Ca , 14.4 kg Mg ,25.0 kg S , 770. 4 g Fe, 2810.2 g Mn, 198.7 g Cu , 316.9 g Zn and 295.8 g B. This suggests the nutritional requirements of passion fruit in order to determine the optimum fruit yield and to improve the longevity of passion fruit vine and to recommend an optimum dose of fertilizer for the crops. However, this may vary according to the fertility status of the soil. The fertilizer recommended for South Indian states is more than the recommended fertilizer schedule for North Eastern states. A fertilizer dose of 110g N, 60g P_2O_5 and 110g K_2O per vine per year is recommended for the 4 year old orchards in South India while 80g N, 40g P_2O_5 and 50g K_2O per vine per year is recommended for the 4 year old orchards for North Eastern States. For Kaveri hybrid, 100g N, 50g P_2O_5 and 100g K_2O per vine per year is recommended. Nitrogen should be applied in 3 split dozes in the months of February-March, July-August and October -November along with farmyard manure evenly spread in a circle of 50-45 cm radius around the stem. Phosphorus and potassium should be given in the two split doses. Sufficient moisture in soil at the time of fertilizer application ensures better use efficiency. In addition to this, 2-3 sprays of 0.5% Urea can be given during summer months. The foliar application of micronutrients is recommended for deficient areas. Surveys have been made to identify the nutrition disorders in passion fruit. In leaf nutrient concentration of passion fruit grown in Nagaland, Mizoram and Manipur in relation to fruit yield/vine showed that vines are severely underfertilized due to sub-optimum concentration of most of the nutrients (Table 3). In experiment on effect of irrigation and nitrogen on passion fruit var. Purple, Rao *et al* . (2014) found that 150 kg N/ha was most suitable helpful for improving the growth, yield and quality of passion fruit under foothill condition of Manipur.

Table 3. Leaf nutrient composition of passion fruit vine in relation to fruit yield in northeast and south India

Location	Leaf nutrient concentration						Yield (kg/vine)
	N(%)	P(%)	K(%)	Ca(%)	Mg(%)	Zn(ppm)	
Wokha, Nagaland	2.4-2.8	0.12-0.14	1.2-1.6	1.1-1.6	0.12-0.14	14-16	2-3
Mokokchung, Nagaland	2.6-3.0	0.11-0.12	1.4-1.6	1.2-1.8	0.10-0.12	13-18	4-5
Kolasib, Mizoram	1.8-2.1	0.10-0.14	1.3-1.8	1.2-1.4	0.10-0.14	12-14	5-6
Aizawal Mizoram	1.9-2.6	0.11-0.12	1.8-2.0	1.4-1.6	1.3-1.5	12-15	4-6
Mamit Mizoram	2.0-2.4	0.10-0.12	0.98-1.1	1.3-1.8	0.11-0.13	15-16	2-3
Tamenglong, Manipur	2.6-3.1	0.14-0.16	0.92-1.2	1.3-1.5	0.13-0.15	13-15	3-4
Ukhrul, Manipur	2.5-3.4	0.12-0.14	1.1-1.3	1.2-1.4	0.12-0.14	15-18	4-5
Coorg , Karnataka	2.1-2.7	0.06-0.17	2.3-2.9	1.4-1.6	0.18-0.24	-	6-8

The comparison of nutrient status reveals that higher fruit yield in Coorg is due to more favourable soil pH (5.8-6.2), allowing easy supply of nutrients. These observations suggest that passion fruit is nutritionally neglected in North East and needs proper fertilization to be exploited the potential of this crop to transform passion fruit industry.

Irrigation

A limited research has been published on the irrigation and water requirement of passion fruit. Leaf production and expansion are both sensitive to water deficits, while water stress reduces leaf and floral bud initiation. A single axillary flower bud forms at each leaf node of new growth along with a tendril. Flower bud development and fruit set are less sensitive to water stress than leaf initiation. Heavy rain during pollination prevents fertilization. Unevenness in crop distribution during the year is possibly linked to water stress and temperature variation. Prolonged dry spell during reduce crop yield and may also affect adversely the development of flowering laterals. The value for the crop coefficient increases from about 0.6 during apical vegetative growth up to about 1.25 during flowering and fruiting. On an average, passion fruit requires irrigation of 12-15 litre /vine/day in summer and 6-8 litre /vine/day) in winter. If there is no rainfall during the dry months, supplementary irrigation is essential. Rao *et al* (2014) found that irrigation at 12 days interval recorded higher growth and fruit yield which was at par with plants irrigated at 18 days interval. Micro-sprinklers and drip are the most effective ways of applying irrigation water with precision

to passion fruit. Passion fruit vine responds significantly to fertigation. In a study on response of passion fruit to potassium fertigation showed highest commercial production.

Interculture

Passion fruit being shallow rooted having most of the feeder roots within 15 cm. of the soil surface require light digging. Deep digging is avoided and weed growth is checked by surface weeding or by scraping and scuffling. Mulching with dried leaves or grass is done to conserve moisture during summer months. Weed management is one of the important operations for better plant growth of passion fruit. Except for a space of about 60-90cm radius around the base of each vine which has to be kept clean at all times, the rest of the plantation may be allowed to have an undergrowth of grass. Most of the passion fruit can infect legume crops and therefore it is not advisable to have cover crops of legumes. Furthermore, some weeds are hosts of aphid vectors which are responsible for passion fruit mottle and ring spot virus transmission. Therefore, these weeds should be eliminated. Use of weedicides is not recommended as passion fruit vines are extremely susceptible to them, therefore the mechanical weed control measures should only be attempted.

Disease Management

There are number of diseases which affect the production potential of passion fruit in the world. The major diseases are *Septoria* spot, brown spot, *Phytophthora* blight, *Alternaria* spot, woodiness virus and base rot.

Root rot: This disease caused by *Phytophthora nicotiana* var. *parasitica* has been found causing considerable damage. Rotting of the root starts and ultimately the plant dies. To control the disease, water logging should be avoided by providing proper drainage. Drenching with Bordeaux mixture (1 %) may be done and affected plants should be mounded with soil to encourage new root formation.

Brown spot: Brown spot is a serious disease followed by Root rot. The disease is caused by *Alternaria macrospora* Sims. and is recognized by the presence of concentric brown spots with greenish margin. It infect leaves, stems and fruit of passion fruit. Excessive leaf fall occurs due to infection of septoria spot while serious infections of brown spot causes wilting and death of long section of vines. Leaf lesion of Alternaria spot are often inconspicuous and the vine itself may appear healthy. The main economic loss associated with these diseases is the down grading of fruit. Infected fruit are acceptable only for processing purpose. The fruit infected with septoria sot, brown spot and Alternaria spot occurs at any stage of growth and is characterized by light brown blotches on the skin. In septoria spot, these blotches may collapse to cover much of the fruit. In brown spot, the blotches become sunken and wrinkled as they enlarge covering

up to half of the fruit. In contrast, young fruit infected with Alternaria spot have lesion characterized by a brown centre and greasy water soaked margins. The spots are superficial and confined to the skin and are rarely more than 7mm wide. If the disease is not checked in time, the decline of the orchard results. The affected branches should be pruned and burnt and spraying with mancozeb or diathene Z- 78 (0.2%) should be done for the control of the disease after every three to four weeks during May to September and at every 10-15 days during October to April.

Phytophthora blight: This disease causes blackening and death of new growth, defoliation, wilting and collapse of the vine. Large grey green water soaked areas appear on the fruits causing them to drop rapidly. Fruits become unmarketable.

Woodiness virus: The affected vines have mottled green yellow puckered leaves, retarded growth and bear small abnormal fruit having thick rind and small pulp cavity. Affected fruits are unmarketable from most of the vine disease affected vines. The virus is transmitted from diseased to healthy vines by migrating aphids and on pruning implements. Vines show the greatest symptoms of PMV-N during cool winter and may out grow the virus in the warmer months. Careful selection of grafting tips (scion) in winter from vines not showing virus symptoms can often reduce the incidence of PWV-N. Once vines are established in the field, it is essential to maintain plant vigour because regular sprays of insecticides to control the virus vectors is not completely effective ed. The long term solution to woodiness is through breeding a resistant variety.

Pest Management

Number of pest attack on passion fruit vines and fruits causing economic losses. The major pests are fruit fly, citrus mealy bug, California red scale and passion vine mite.

Fruit fly (*Dacus sp*.) : It is a most serious pest of passion fruit which causes heavy loss. The insect punctures the immature fruit while the fruit is developing and rind is still tender. Fruits become woody around the punctured area and in several cases, they are deformed and the pulp content is reduced. This can be controlled by a spray of malathion (0.05%). Spraying may be done only in the afternoon to minimize the destruction of insects pollinating the flowers.

Thrips (*Selenothrips sp*.) : This feeds on bud and developing fruits. Affected fruits are deformed and fruit weight and juice content are reduced. This is only observed to cause damage to the main summer crop. This can be effectively controlled by spraying with malathion (0.05%).

Mealy bug: Mealy bug attacks on leaf nodes, flowers and fruit bracts and dead leaves. It is also encrust in developing fruiting. Out break of mealy bug is more common in late summer and autumn when the growth cycle from egg to adult is shortest (four week). Unchecked infestation may cause loss of vigour, leaf drop, fruit malformation and eventgually vine death. Honey dew excreted by the mealybug promotes the growth of sooty mould on the leaves and fruits. It can be naturally controlled by ladybirds, wasp parasites and lacewing larvae and therefore it is important to maintain these practices to keep the mealy bug population below threshold levels. Spraying of any insecticide to control the mealybug population has not been much effective.

Mite (*Tetranychus sp*.): It is a common pest of passion fruit affecting both young and old vines during summer and autumn. Mites feed on leaf and tender fruits. Severe infestation cause leaf drop and stunted growth. It can be controlled by spray of Kelthane (0.05%) or wettable sulpur (2g/litre).

California red scale: It is the common pest of old vine during dry weather in December and January. Older vines are first infested and as the population increases the scale spreads to young section of vine as well as fruit. Some times due to severe infestations, reduction of the plant vigour and death of the vine has also been observed. It can b control by the use of parasites. Parasitic wasps are the important one to control the red scale.

Harvesting and Yield

The flowers are borne singly in the axils of the leaves in the terminal region of the new growth. Passion fruit flowers and fruits throughout the year under favourable conditions, yet there are two main periods of fruiting: the first harvest extends from August to December and the second one from March to May. The first fruits are obtained from the ninth month and full bearing is reached in 16-18 months. About 60-70 days are required from fruit set to the harvest of fruit. The fruit when ripe falls down from the vine. Harvesting is done when fruit turned slightly coloured. Fruit should be harvested along with the stalk. On an average, yield of 10-12 tonnes per hectare per year can be obtained. The vines are perennial and can produces yield for 10 to 15 years but maximum production can be obtained up to six years after that yield declines. Fruits harvested should be harvested in morning hours to keep them fresh for longer period. The harvesting may be done depending on the distance of market.

Post harvest Handling and Marketing

Fruits harvested should be disposed off quickly to prevent the loss in weight and appearance. About 10-20% loss in weight results from storage, and fruits wrinkle and give a bad appearance. To avoid this they can be stored in polythene bags and for transport to distant markets polythene-lined crates may be used. Fruits are packed in 0.03 mm perforated polyethylene bags can be stored for 28 days at $5^{O}C$ temperature.

Processing

Passion fruit juice is sold to juice manufacturers and other processors as a single strength aseptic juice (14-16 ^{o} brix) or frozen concentrate (50 ^{o} Brix). Many buyers prefer to source concentrate over single strength form. The juice is used in ice cream, syrup, cocktails, and juice blends. It is rich in carotene, vitamin C , vitamin A and potassium. The demand for passion fruit concentrate is estimated by industry sources have grown to 16,000 MTs. The growth in the European and US markets is estimated at around 6-8 percent annually. However, production frequently exceeds or falls short of demand as a result of erratic weather patterns and price reactions in major passion fruit growing countries such as Brazil, Ecuador etc. The market is therefore subject to "boom and bust" production cycles: as shortages lead to higher market prices and , surplus leads to lower prices.

Phytochemistry

Several alkaloids, phenols, glycosyl flavonoids and cynogenic compounds have been found in genus *Passiflora.* Phytochemical analysis of *Passiflora edulis* revealed the presence of carbohydrates, glycosides, flavonoids, resins, alkaloids and phenolic compounds. Tannins were present in the leaf and fruit, saponins were present in the leaf and stem (Akanbi *et al* 2011). Organic extract (methanol, ethanol) of passion fruit leaves were reported to possess tannins, flavonoids, terpenoids, steroids and saponins (Nayak and Panda, 2012) .Leaf and stem of passion fruit contains new cyanogenic (2R)–â-Dallopyranosyloxy-2-phenylacetonitrile and (2S)–â-Dallopyranosyloxy-2-phenylacetonitrile along with smaller amounts of (2R)–(2S)-sambunigrin) (Seigler *et al.* 2002). Passion fruit has been reported to be rich in glycosides Which include flavonoid glycosides, viz., luteolin-6-C-chinovoside, luteolin-6-C-fucoside (Mareck *et al* 1991). Sixteen apigenin or luteolin derivatives were characterized, which included four mono-C-glycosyl, eight-O-glycosyl and four-O-glycosyl derivatives indentifies by HPLC-DAD-MS/MS method (Ferreres *et al* ,2007). The alkaloids present are harman, harmine, harmalol, harmol and harmaline of which the highest concentration of harman alkaloids were found in leaves. Edulans I and Edulans II pectins were also reported to be present in passion fruit (Dhawan *et al* .2004). The pigments present in the purple fruit juice

are mostly carotenoids, among which β-carotene predominates . The free amino acids reported in the purple fruit juice are leucines, valine, tyrosine, proline, threonin, glycine, aspartic acid, arginine, and lysine (Anonymous, 2001). The oil seed extraction of passion fruit seed showed high levels of unsaturated fatty acids (87.59%) including mainly linoleic (73.14%) and oleic (13.83%), tocopherol (499.30mg/kg) with high percentage of carbohydrates and fiber (48.73%) (De-Pari et al .2002).

Pharmacognostic activity and medicinal properties

The health benefits of *Passiflora edulis* are attributes to the presence of phytoconstituents like Alkaloids, phenols, glycosyl flavonoids and cynogenic compounds .These are beneficial for the treatment and prevention of of diseases such as anxiety, diabetic, cardiovascular diseases, sedative, convulsive, asthma, osteoarthritis, cancer, etc.

Diabetes

Passion fruit is reported to lower the blood sugar levels. Albino rats were administrative with passion fruit peel 100, 200, 300,400 mg/kg body weight. The study indicated reduction of blood glucose by 6.31, 7.14, 6.73 and 6.00 percent, respectively. It was also found that 200 mg/kg body weight was the most effective in reducing blood glucose levels with a maximum fall rate of 47.25% after 3 hours of glucose administration (Devaki *et al* .2011). The presence of phenols and flavonoids may be responsible for the observed hypoglycemic activity of P*assiflora edulis* . On supplementation of 30g/day of *passiflora edulis flavicarpa* fruit peel flour for 60 days among type II diabetic patient, blood was significantly reduced.The presence of fibers, pectin which forms viscous mixture can change the gastric emptying time, increases satiety and delay the absorption of simple carbohydrates, also ability to form complexes with bile salts increases the cholesterol excretion (de Queiroz et al. 2012). Passion fruit has a significant content of iron, potassium, zinc and manganese. The diet contain 5% flour of passion fruit peel reduces blood glucose by 59% in diabetic rats reaching the normal glycemic amount (112.6mg/dl). The mechanism is due to the presence of fiber, tannins and phenolic compounds which reduces the digestion and absorption of carbohydrates, increased the sensitivity of muscle and adipose tissue to insulin . The effect of dietary fiber on insulin sensitivity is the attenuation of the glycemic response to carbohydrate through their mechanical action in the intestine where they tend to slow the absorption of nutrient. Passion fruit juice also helps in reduction of total cholesterol, triglyceride, LDL-C and increased HDL-C which may have beneficial effect in prevention and treatment of dyslipidemias and hyperglycemias (Barbalho *et al*. 2011)

Sedative and anticonvulsant

Passion fruit and its flower contain medicinal alkaloids, its phytonutrients are known to have mild sedative properties. It was found that eating passion fruit relaxes the nervous system and induces sleep (Devaki *et al*. 2011). The decoction of *Passiflora edulis* dried leaves given to mice was found to possess sedative

activity, increasing total sleep induced by diazepam. The total sleep time increased from 31 ± 11 min in the control group to 77.6 ± 15 min and 78.3 ± 16 min in treatment group with extracts at the dose of 132.3 mg and 1325 mg/kg. CNS effect of the decoction in sedation could be interacting with benzodiazepine receptor. Inhibitory effect on STR-induced seizure is probably on glycine and not GABA, while NMDA induced turning effect was reduced in dose dependent manner and was mediated through NMDA receptor and blocked by D-AP7. The decoction of *Passiflora edulis* brought about these central actions by interacting with either inhibitory glycine or NMDA amino acid neurotransmitters. It also showed anti-convulsant activity protecting against seizure (Elisabeth *et al*. 2011)

Anti-microbial activity

The crude extract petroleum ether of passion fruit leaf at (500µg/disc) showed anti-bacterial activity for *Bacillus megaterium* and *Pseudomonas aeruginosa*. The chloroform crude leaf extracts (500µg/disc) showed moderate antibacterial activity (gram positive bacteria like *B. megaterium, B. Subtilis, S. Aureus* and *Sarcina lutea*, gram negative bacteria like *E. Coli, P. aeruginosa, S. Paratyphi, S.Typhi, Shigella Boydii, Vibrio Mimicus* with the average zone of inhibition of 7-10 mm by disc diffusion method (Devaki *et al* .2011). The hexane extract of passion fruit leaves at 20mg/mm showed a mean diameter of inhibition zone of 16mm for *S. paratyphi*,15mm for *S. aureus*, 14mm for *P. aeruginosa* and 13mm for *K. pneumoniae*. The flavone extract of passion fruit fruits and stem show inhibition *of S. Aureus, P. aeruginosa* and *K.pneumoniae* (Akanbieta 2011). The aqueous extract showed zone of inhibition at a maximum concentration (200µg/disc) against *E. coli* (9.5mm),*K. pneumoniae* (7.2mm), *P. mirablis* (4.7mm), P. *aeruginosa*(6mm), *S. flexineri* (8.1mm), *S. typhi* (7.3mm) respectively (Razia and Sivaramakrishnan, 2014).

Anti-oxidant activity

The petroleum ether and chloroform extracts of *Passiflora edulis* leaf on DPPH free radical scavenging assay showed antioxidant activity with IC50 of 58.88µg/ml and 56.85µg/ml respectively (Ripa *et al*.2009). A concentration of 1100 µg ml^{-1} of passion fruit leaf aqueous extract was able to scavenge 50% of DPPH radical (Da Silva *et al*. 2013)**.** A study reported a reduction in plasma lipid peroxidation in Wistar rats that received passion fruit juice twice a day for 28 days (De Souza Mda *et al*. 2012).The leaf extract of *P. edulis* exhibited potential antioxidant activity exhibiting an IC50 value of 875 ± 87.83 µg/ml studied by 1,1-diphenyl-2-picryl hydrazyl radical (DPPH) quenching assay at the concentration on 1000 (µg/ml) (Sunitha

and Devaki, 2009). There was a significant antioxidant capacity in *in vitro* at concentrations of 1 and 10μg/ml. The phenolic compounds present in the extract passion fruit might be the major contributors to the antioxidant activities (Rudnicki *et al*, 2007).

Anti-cancer activity

Passion fruit contains high amount of vitamin A and vitamin C both of which are strong anti-oxidants. They neutralize free radicals and protects from cancer. The flavonoids further enhance the potency of passion fruit in providing antioxidant to body and protecting from cancer. The studies have also shown that in cancer patients, passion fruit can kill the cancerous cells *in vitro*. Antioxidants in passion fruit primarily eliminate free radicals, which are known for mutating the DNA of healthy cells into cancerous ones. Passion fruit juice showed anticancer activity on cell cycle, apoptosis and cell viability of the MOLT4 lymphoma cell line. The effect on the cell cycle was due to the presence of organic acids, amino acids and proteins in passion fruit juice (Cindy Marie De Neira, 2003).

Passion fruit is found beneficial in high blood pressure and diabetic . High potassium content makes passion fruit highly effective in protecting from blood pressure. Potassium regulates electrolyte balance and controls the muscle function of our entire body including heart muscles that create heartbeat. Passion fruit contain high amount of fibre which reduces cholesterol levels in blood. It increases HDL-C and reduces LDL-C. The anti-oxidant activity of passion fruit clears the plaque formation along the inner lining of arteries. A daily dose of 220 mg passion fruit peel was administered to 41 type II diabetic patient to reducing cardiovascular risk and found that there was a significant reduction in blood pressure (Raju *et al*., 2013). Passion fruit is a rich source of dietary fibre, both soluble as well as insoluble fibre. Insoluble fibre helps in bowel movement and cleaning the digestive system . Passion fruit is among those healthy food which is beneficial for eye, containing high amount of antioxidants like vitamin A, Vitamin C and flavonoids.

Osteoarthritis

Thirty-three osteoarthritis patients were supplemented 150mg/ day of passion fruit *peel* extract for 2 months using WOMAC Osteoarthritis Index. At 60 days, reductions of 18.6%, 18%, 19.6%, and 19.2% in pain, stiffness, physical function, and composite WOMAC score, respectively due to the presence of antioxidant and anti-inflammatory properties present in passion fruit peel (Farrid *et al*. 2010).

Traditional uses

In Nagaland fresh leaves of *Passiflora edulis* is boiled in little amount of water and extract is drunk for the treatment of dysentery and hypertension (Jamir *et al*., 1999). The flowering and fruiting portion are dried and preserved and used as a drug in preparation of certain proprietary products. The root extracts are also used in the treatment of ulcers and haemorrhoids (Anonymous , 2001). The root has been used as a sedative and vermifuge in West Indies, Mexico and Netherlands. In Italy the plant has been used as anti-spasmodic and sedative. In Mauritius the tincture and extract of plant has been used as a remedy for insomnia due to various nervous conditions. The root has been used as a diuretic and a decoction of leaves as an emetic. Passion fruit *has* been used as a sedative, diuretic, anthelmintic, anti-diarrheal, stimulant and also treatment for hypertension, menopausal symptoms and colic of infants in South America. The fruit of *Passiflora edulis* is regarded as a digestive stimulant and used a remedy for gastric carcinoma. Fruits are eaten to get relief from constipation (Patel *et al.*, 2011).

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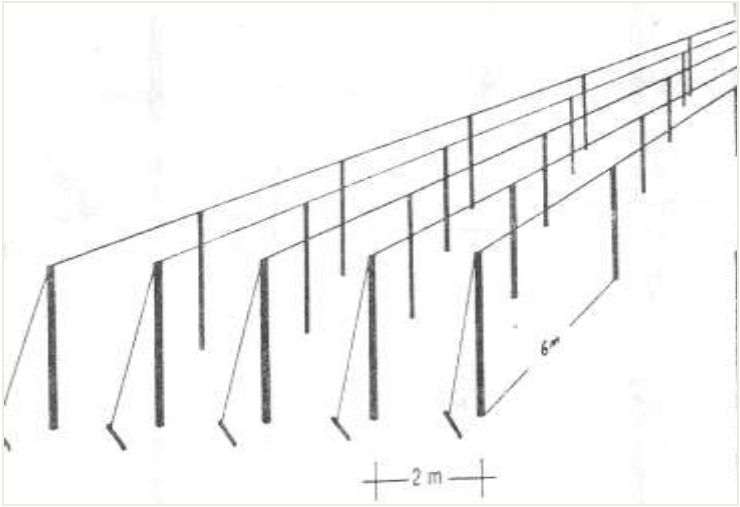

Fig 1: Trellis for passion fruit

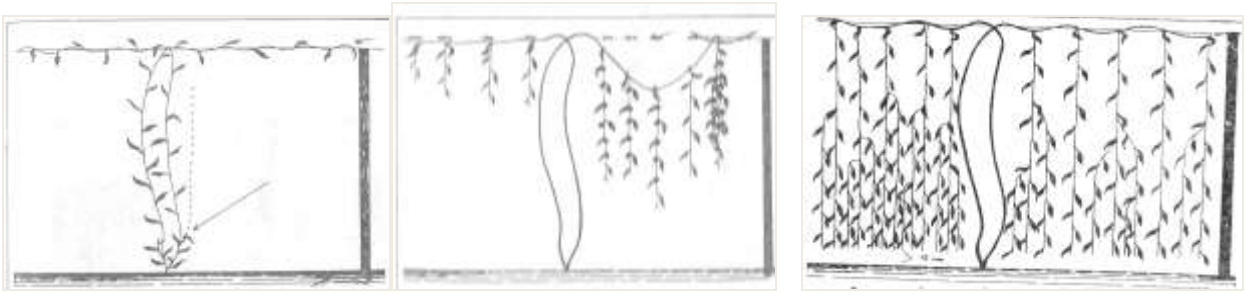

Fig 2. Training in Passion fruit