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PASSION FRUIT CULTURE IN HAWAII

Passion Fruit Culture in Hawaii

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FOREWORD

A growing passion fruit industry has been made possible through development of adequate processing procedures and increased passion fruit production through improved cultural methods. This industry's full development depends upon production of products of highest quality at prices comparable to other competitive products. In order to attain such a competitive position in the market, the most efficient methods of processing and production must be developed. The improved cultural practice, which led to lower production costs, and the improvement of varieties toward higher juice yields with the best juice qualities will greatly aid the growth of this new industry.

Market prospects for passion fruit juice products appear to be good. Tests on public acceptance of the flavor have shown that approximately 90 percent of the people surveyed liked the taste of passion fruit juice. The market acceptance studies indicate a good sale of the frozen juice at prices competitive to other juices. The development of a market for the frozen juice has been slow, because it is necessary to demonstrate that this is a high quality product with public acceptance, and that a continued supply of the juice can be guaranteed to support the sales promotion in the highly competitive frozen juice market.

Passion fruit juice has excellent prospects in the blended juice trade. Here, a small quantity gives either the characteristic flavor of passion fruit or enhances the other fruit flavors of the blended product. The flavoring trade is another good outlet for passion fruit juice. Passion fruit sherbet has proved to be an extremely popular product. The juice should have an equally good acceptance as a flavoring in soft drinks and bakery goods.

It is recommended that anyone who intends to grow passion fruit should first develop good relations with the processors of his area. County agents on each island have the very latest information on growing and marketing passion fruit. Keep in touch with them for developments.

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BOTANICAL RELATIONS

The passion fruit belongs to the genus *Passiflora.* This is a genus of about 400 species of plants, mostly perennial woody vines native to the tropical regions of North and South America. About 20 species have been introduced into Hawaii, where they are found as cultivated fruit or ornamental plants in home gardens, or as naturalized wild plants along roadsides, or wastelands, and in the lower forest regions.

The passion fruit which seems best suited to commercial production in Hawaii is the one known locally as yellow passion fruit or yellow lilikoi. Botanically it is known as *Passiflora edulis,* botanical form *flavicarpa.* It is considered to be a yellow-fruited form which originated from the more widely known purple passion fruit or lilikoi, *P. edulis.* The purple passion fruit is the type most extensively cultivated in other countries.

Of the species in Hawaii, only a half dozen or so bear fruit which can be considered at all palatable. They are:

P. edulis: purple passion fruit or lilikoi. Cultivated to a limited degree as a garden plant. Also found in a naturalized wild state in the lower forest regions on all the larger islands at elevations of 400 to 3,000 feet.

P. edulis f. *flavicarpa*: yellow passion fruit or yellow lilikoi. Cultivated in gardens and, presently, as a commercial crop on a small scale. Found as an escape from cultivation on the larger islands at elevations from near sea level to 1,500 feet.

P. ligularis: sweet granadilla, watermelon, lemiwai, or poka. Rarely cultivated. Found mostly in a naturalized wild state in shady, damp, lower forest regions on the larger islands at elevations from 500 to 2,500 feet.

P. quadrangularis: giant granadilla. Found occasionally in garden cultivation at elevations from sea level to 1,500 feet.

P. mollissima: tacsonia, banana passion fruit. Found as an escape from cultivation, mostly in the vicinity of Keanakolu, Hawaii, at elevations from 4,000 to 5,500 feet.

P. laurifolia: bell-apple, Jamaica honeysuckle, sweet cup. Occasionally found in gardens on lowlands up to an elevation of 1,500 feet.

HISTORY

Because the purple passion fruit *(P. edulis)* is known locally by a Hawaiian name, lilikoi, many persons believe it to be native to the Islands; actually, it is native to Brazil. The first seeds were brought to Hawaii from Aus-

tralia by Eugene Delemar about 1880. These were planted in the district of Lilikoi on East Maui. Within a few years after the plants began to fruit, new plants appeared in the wild and soon became widespread in the district, and the name of the district became attached to this particular species.

The yellow passion fruit *(P. edulis* f. *flavicarpa)* presumably originated in Australia as a sport from the purple passion fruit; however, it may have been introduced into Australia from tropical America. The first seed of the type was left with the Hawaii Agricultural Experiment Station in 1923 by Mr. E. N. Reasoner of Oneco, Florida, who was returning from a visit to Australia where he had collected it. In the years which followed, numerous plants were grown by the Station and distributed to interested growers in the Islands. Subsequently, vines have appeared in many places in the wild on all the larger islands.

Some yellow passion fruit was grown as a commercial crop in a vineyard at Pupukea, Oahu, during the middle and late 1930's. Production was discontinued soon after the outbreak of World War II in the Pacific in 1941.

COMMERCIAL TYPES

Only the purple passion fruit *(P. edulis)* and the yellow passion fruit *(P. edulis* f. *flavicarpa)* are considered of value for commercial growing.

The purple passion fruit is used almost exclusively in commercial production in Australia, New Zealand, South Africa, and other countries; in Hawaii, the yellow is preferred.

Locally, the purple passion fruit appears to grow better at the higher elevations and, therefore, has not attracted attention. The fruit tends to be smaller and the vines less productive than those of the yellow passion fruit. However, it is generally considered to have better flavor and aroma, both as fresh fruit and after canning or freezing, than the yellow passion fruit.

The yellow passion fruit in Hawaii is best adapted to the lower elevations, sea level to 2,500 feet. The fruit is generally larger and the vines are much more vigorous and productive than those of the purple. The pulp and juice are more acid, and there is a higher percentage of juice to pulp than in the purple species.

In most countries where passion fruit is grown commercially, a limited amount of variety or strain selection work has been undertaken. However, commercial plantings generally are based upon seedlings progenies of individual vine selections which apparently give satisfactory results.

In Hawaii, what appears to be a natural hybrid between the two forms has been discovered. In Queensland, Australia, the cross has been made artificially in order to combine the most desirable qualities of both parents. Seedlings of the hybrid types vary within rather wide limits; many possess the more pleasant flavor of the purple passion fruit, but none as yet has attained the fruit size and vine productivity of the usual yellow passion fruit.

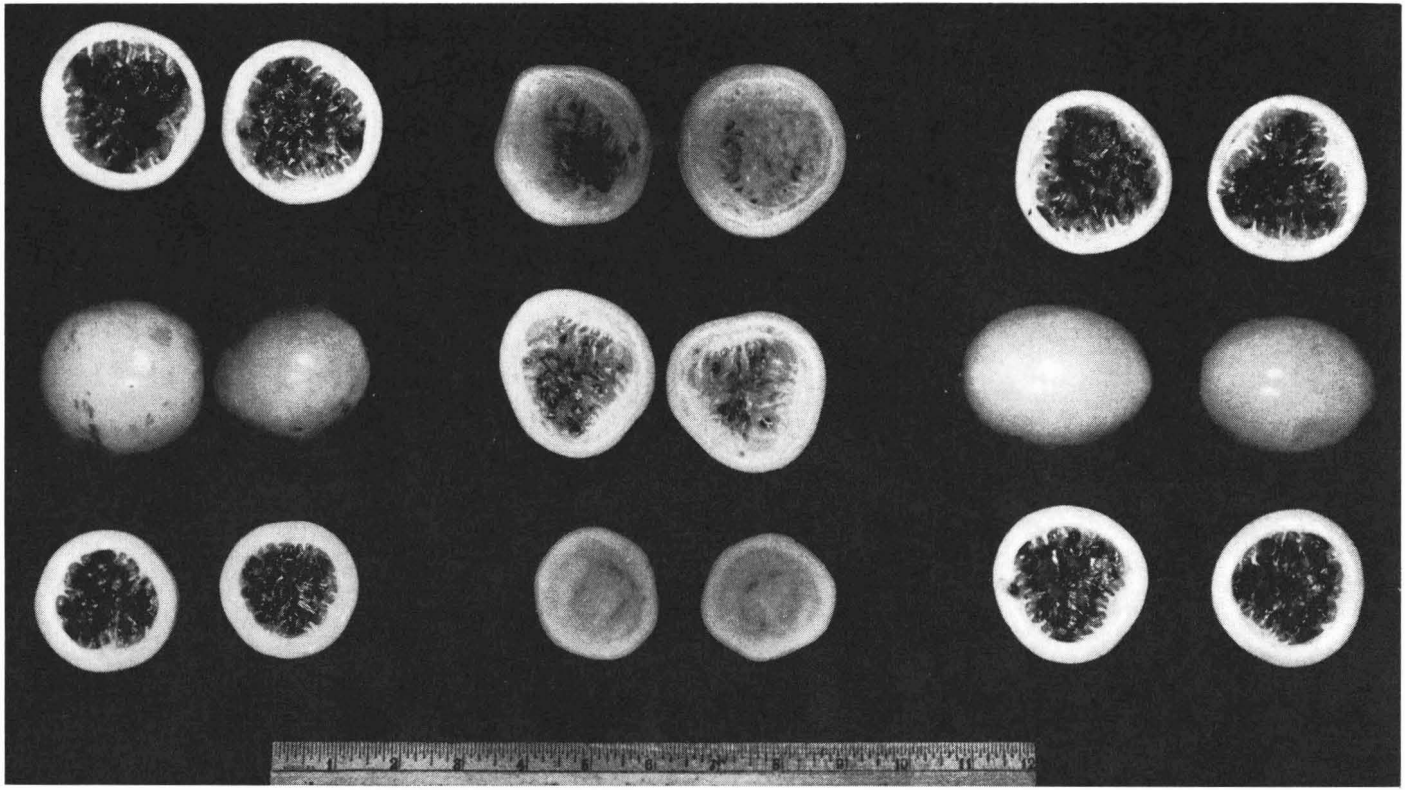

Figure 1. *Left group,* round fruit. *Center group,* partly and wholly undeveloped fruit useless for juice production. *Right group,* oval fruit. Either round or oval fruit may have thin skins, as in the top row, or thick skins as in the bottom row. Thin-skinned oval fruit are recommended for they usually produce about one-third more juice than round fruit.

Description

P. edulis. A woody, perennial vine which is a robust climber under favorable conditions. The stems, tendrils, and leaves are clear green without traces of reddish or pinkish color. The leaves are three-lobed with finely toothed edges and a cordate or heart-shaped base. The flowers, which open at dawn and close before noon, occur one at each node on new growth, have five whitish sepals, five whitish petals, and two rows of thread-like rays (the corona) which are faintly purple near the base and white toward the end. There are five stamens, each terminating in a heavy, pollen-bearing anther. The ovary, which ultimately develops into the fruit, is in the center of the flower at the top of a long slender stalk. At the top of the ovary is a tripartite style, each branch of which terminates in the sticky, pollen-receiving stigmatic surface. The fruit is round or oval, 1½ to 2 inches in diameter, and deep purple when ripe. Within the hard, leathery rind are numerous small, blackish seeds, each enclosed in yellowish, aromatic, juicy pulp which has a tart but pleasing flavor. On maturing, the fruit falls from the vine.

P. edulis f. *flavicarpa.* The vine is much like that of the purple variety, although a more vigorous grower under most conditions. It is distinguished by the suffusion of reddish, pinkish, or purplish color in stems, leaves, and tendrils. The leaves resemble those of the purple species but usually are somewhat larger, and the bases of the corona filaments are a much deeper, brighter purple. The average fruit is slightly larger than the purple type and has a bright canary-yellow rind. The pulp is somewhat more acid, and the seeds are dark brown rather than black. The flowers open about noon and close about 9 or 10 P.M. The mature fruit falls from the vine. Probably because there is little or no overlapping of the functional period of the flowers, not much crossing takes place between the two species.

Horticultural Varieties

Seed of outstanding passion fruit plants selected by the University has been distributed and is being grown in various locations. With this open pollinated seed there is variation between plants, although the plants generally produce fruit of a type and quality characteristic of the known parent. From these seedling progenies, the best of the vines should again be selected and propagated by seed or perhaps even by cuttings.

No horticultural or clonal varieties of either the yellow or purple passion fruit have been selected either here or in other countries where the fruits are grown commercially. In order to develop a superior horticultural variety it is essential to have a very large number of plants from which to select the highest quality and most fruitful types. If, as now seems apparent, most individual plants are self-sterile and cross pollination is required for heavy fruit setting and good filling of fruit, it will be necessary to select and plant two or more varieties that are known to be cross compatible.

Growers of passion fruit will do well to select and propagate from the highest quality and most productive vines. Detailed selection work requires considerable time and effort, but, when well done, insures a profitable crop and an improved juice product. The following are some suggestions which will help in selecting parent vines:

1. Disregard all vines bearing round fruit. Recovery of juice from these fruits has been found to be about 10 percent less than from oval fruits.

2. Disregard all fruits having orange-colored rinds. These tend to yield off-flavor fruits with a woody taste not commercially acceptable.

3. Select for flavor, together with other desirable characteristics, such as prolific set, size, thinness of rind, well-filled cavity, and yield of juice per vine. Become accustomed to the high acidity or "strong" flavor of the fruit. All other things being equal, a relatively high-acid fruit is more desirable for processing than one lower in acidity. In the field, the farmer can learn to discriminate between off-flavored fruit and the normal-flavored fruit. In a very good fruit the aroma is usually strong and pleasant. Even in good vineyards, grown from seed of selected plants, there will be a small percentage of plants which have unusually desirable characteristics. These should be selected, marked, and used for propagation stock.

4. Of those few vines selected according to the above suggestions, choose those which show the best yield and growth characteristics. Observe a vine for several seasons. Remember that pounds of high-quality juice per acre is the objective of selection work. A vine which sets heavily but produces little or poor-quality juice should not be selected.

5. Finally, having made selections of the best parent vines, make future plantings from cuttings and seeds. Cuttings may be best after they have been thoroughly tested for superiority in yield and quality over selected seedlings sufficient to justify the higher cost of planting material. Seedlings are preferred at this time. If cuttings are used, propagate several strains, not just one selection.

The work of selecting desirable strains never ends. The farmer, ever mindful of processors' requirements, should continually improve his stock with new, tested selections. Then the processor, ever mindful of the consumers' good will, can then continue to improve his product by purchasing fruit from the best growers.

FLOWERING, FRUIT SETTING, AND POLLINATION

Flowering and Fruit Setting

When grown under favorable conditions, passion fruit vines grow rapidly and will flower and produce fruit within a year after they have

been started from seed. Flowering occurs in two distinct periods, the first during early spring and the other during early fall. Because of this flowering behavior, there is a period of fruit maturity in midsummer and in midwinter.

Passion fruit flowers open and close at definite times of day. Those of the purple variety open early in the morning, usually around dawn, and close before noon. Flowers of the yellow variety, however, open about 1 P.M. and close at night. Natural hybridization between the two varieties is thus not likely to occur.

Passion fruit flowers are borne singly in the axils of the leaves in the terminal regions of new growth. Several flowers may be produced along a vine, but the last produced may not set fruit, even when pollination has been done by hand. After a certain number of fruits have set along the branch, there is a temporary cessation of further fruit setting. Later, when the first-set fruits have begun to mature, flower setting may resume again for the remainder of the flowering period. This alternation of setting and cessation of fruit setting results in two or three sections of a vine bearing fruits, with fruitless spaces in between. The reason for this fruiting behavior is not known, but it is obviously related to the physiology of the plant.

Pollination

Studies on the pollination and fruiting behavior of the yellow variety indicate that cross pollination between flowers of different vines is necessary for fruit setting. Seedlings vary somewhat in their degree of self-fertility, but it is generally of very low order. Most of them are completely self-sterile. Twenty fruits developed from 1,816 artificially self-pollinated flowers in 110 different vines. This represents a fruit set of only about 1 percent, whereas a fruit set of about 53 percent was obtained in cross-pollinated flowers. That some vines are even cross non-compatible is reflected in the relatively low average number of fruit set in cross-pollinated flowers. A similar self-sterility has been reported for the purple variety from elsewhere. If selected strains are to be planted in a vineyard, several strains which are known to be cross compatible to each other must be selected. However, if seedlings are used, the problem of poor fruit set is minimized.

Field observations indicate that certain insects are important pollinators of this plant. These insects are of considerable importance because the commercially desirable strains of passion fruit are self-sterile and wind pollination appears to be of little importance. In Hawaii, the insects which visit the passion fruit flower include the nectar and pollen feeders. Among the nectar feeders are the carpenter bee (*Xylocopa sonorina*, fig. 2a), and the honey bee (*Apis mellifera*, fig. 2b) which gathers nectar. Pollen feeders include the honey bee which gathers pollen and the hover fly (*Eristolis arvorum*, fig. 2c). The carpenter bee is a more efficient pollinator than the honey bee or hover fly, because in its

quest for nectar in the nectary, this larger insect invariably brushes the anthers and stigmas more readily than the smaller insects.

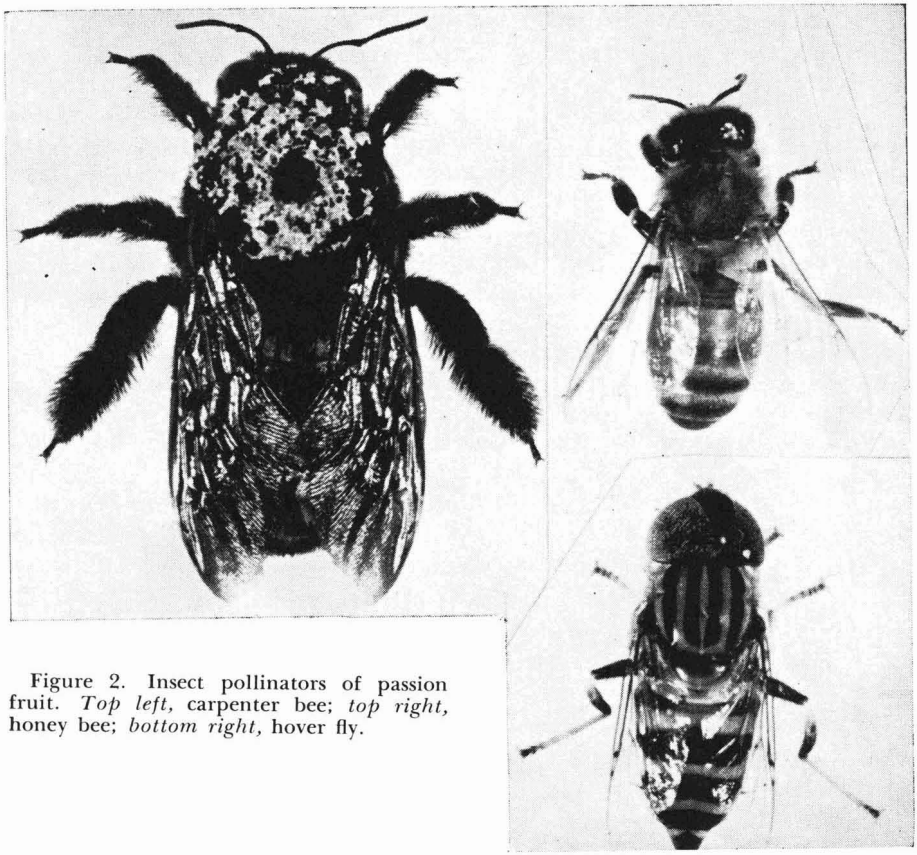

Figure 2. Insect pollinators of passion fruit. *Top left,* carpenter bee; *top right,* honey bee; *bottom right,* hover fly.

PROPAGATION

Passion fruit is propagated by seeds, cuttings, or air layers. In countries

where this fruit is grown commercially, the usual method of propagation is by seed. Whenever propagation of a particular strain or horticultural variety is desired, cuttings or air layers must be employed.

Propagation by Seed

Passion fruit seeds should be planted in ordinary soil flats containing fertile soil with good drainage. Unlike many other seeds, these do not require cleaning, drying, and storage before planting. The seeds may be planted immediately after removal from the ripe fruit, without separating them from the pulp. Sprouting begins in approximately 2 weeks, and maximum germination occurs in 1 to 3 months. Removing the pulp and washing the seeds may slightly hasten the sprouting. There are some varietal differences in germination behavior, but with the commercial yellow and purple types the behavior is similar.

If it is necessary to delay planting, the ripe fruit may be kept under room-temperature conditions for approximately a month. Seeds from such fruit germinate satisfactorily when planted.

If a greater delay in planting is necessary, the fruit may be held at about 55°F. In an experiment it was demonstrated that fruits may be held at this temperature for at least 2 months without detrimental effect on the germination of the seeds. It may be possible to hold the fruits for longer periods, provided they do not decay, but temperatures below 55°F. tend to delay the sprouting of the seeds. Freezing the fruit kills the seeds.

If it is necessary to have dry seeds, they should be separated from the pulp, washed, and then dried at room temperature. Such seeds produced a germination of better than 85 percent after a storage period of 3 months at room temperature. Seeds dried at room temperature and then stored at 35°–55° F. for 2 weeks produced twice as many sprouts as those stored at room temperature. After 10 weeks of storage, however, there was no difference between germination percentages of seeds stored at the low temperature and others stored at room temperature.

Artificial rapid drying (½ to 2 hours) at high temperatures (108°–140°F.) with forced draft was found to be harmless to germination, provided the seeds were planted within a few days after drying. Seeds artificially dried and then stored at room temperature for 2 days produced high germination, but 5 weeks later the germination was considerably lower than that of the seeds dried at room temperature. A drying temperature of 158°F. was found to be definitely detrimental to germination.

Drying the seeds by direct exposure to the sun is also harmless, provided the seeds are planted within a few days after drying; but sun drying cannot be recommended if the seeds are to be stored for an extended period subsequent to drying.

Propagation by Cuttings and Air Layers

Passion fruit cuttings, like those of most other plants, require warmth, moisture, high humidity, and a porous medium for rooting. Porous soil, beach sand, black sand, vermiculite, wood shavings, or sawdust, in a propagation box with glass cover to maintain high humidity and warmth, makes a good propagation medium for cuttings.

It has been observed in tests that, although cuttings root fairly well, shoots very frequently do not develop on the rooted cuttings. Morphological examination of the vine seems to indicate that once the bud that develops into the vegetative shoot is injured, destroyed, or already extended into a branch, no other shoot will develop from the same leaf axil. For this reason, the older part of the vine makes inferior cutting material.

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. It is advisable not to take stem material that is immature or material that is too old.

The best period to obtain cutting material is when the vines are actively growing. In Hawaii this seems to be between the summer and winter crops, and also after the winter crop.

Because of the length of the internodes, cuttings should not have more than three nodes each. Three-node cuttings are the most desirable. The basal part of the cutting should be cut right at the node, and the terminal part should be cut slightly above the node. The branch should be cut slightly above the first bud. A leaf or portion of a leaf left intact on the terminal may help rooting. The lower two thirds of the cutting should be buried in the rooting medium. Cuttings begin to root in about a month.

Passion fruit vines are readily air-layered by the usual horticultural practice. In the process, care must be exercised not to break the brittle stem. Very young stems should not be used, and the completed layer should be supported somehow in order to prevent the vine from breaking at the layered zone. Layers root in 4 to 8 weeks.

Handling Seedlings, Rooted Cuttings, and Air Layers

When seedlings are approximately 2 inches tall, they should be transplanted into small individual cans or other containers. When about 6 inches tall, they are ready for field planting. Rooted cuttings and air layers should be transferred from the propagation bench to individual containers. In transplanting, care should be exercised not to injure the delicate roots. When the young plants are well established, they should be set out in the field.

PLANTING SITES

The yellow passion fruit is hardy and grows well from sea level to 2,500 feet in a wide variety of soils, when they are reasonably deep and fertile. Good vineyards have been observed on the rocky soils of Kona and Puna,

the heavy black soils of Maunawili and Punaluu, and the red soils of Wahiawa. The vines will not stand water logging or flooding for any considerable period. Most of the losses observed in plantings to date may be attributed directly or indirectly to this factor.

Except for a relatively short period following the winter crop, the vine grows throughout the year. A uniform and reasonably abundant rainfall seems to be needed. If grown at Waimanalo and other dry areas where summer rainfall is extremely limited, irrigation water should be provided. Heavy soils and areas of rainfall in excess of 85 inches per year would normally be expected to be more susceptible to root and fruit diseases. Drainage must be provided so as to eliminate puddling.

Sites buffeted by high winds should be avoided unless adequate windbreaks are planted and developed well before the vineyard is planted. Winds not only damage the vines but make it more difficult to train the vines to the trellis. After having become established on the trellis, the vines offer considerable wind resistance and the trellis may blow over unless securely constructed.

Planting Distances

The topography or slope and contour of the field may be an important factor in determining the field layout and planting plans. On reasonably level lands, straight rows and tight wire trellises may be used, while on uneven, sloping land other planting schemes may be required. The width of rows is of course determined by the type of trellis used.

Assuming that the land is reasonably level and straight rows will be used, the distance between rows or trellises is the most important decision to be made in planting the new vineyard. This space will be used for all the mechanical operations such as cultivation, spraying for disease and insect control, fertilization, and especially harvesting. If the rows are short, such that the harvested fruit may be carried easily to the ends of the rows or the spraying is done from the end of the row, they perhaps may be spaced rather close together; but if the rows are long and the fruit is to be carried out in a trailer, and if mechanical cultivation and power spraying are used, the rows must be wide enough to permit efficient use of such equipment. In no event should the trellises be so close together that the tractor or sprayer cannot be driven between the rows or such that the vines would spread from one trellis to the next.

When a crossbar or T-type trellis is used, the distance between the ends of the crossbar is the important measurement. Experience indicates that 7 feet between the ends of the crossbars is the minimum, while the distance between the rows of posts should perhaps never be less than 10 feet. If crossbars longer than 3 feet are used, this width should be increased to maintain the 7-foot clearance between the ends of the bars. If a double row or yoke-type trellis is used, the operational distance across the row between the outer posts of the trellis should be at least 10 feet.

Spacing of the vines in the row may vary within wide limits, even to 10-foot intervals. Actually the more vines per acre, that is, the closer spacing in the row, the heavier will be the first-year crop. The first annual pruning after the crop is harvested might then consist merely of thinning out alternate vines and removing from the remaining vines those branches trailing on the ground. This thinning procedure will give the grower an opportunity to select the more fruitful and vigorous vines and to remove the less desirable ones. While planting and early training require considerable labor, the increased first-year yield and the better vine quality after thinning would probably justify the initial cost.

Spacing in the row, therefore, may vary from 12-15 feet to 20 feet or more. The latter is more frequently used. It is usually advisable to plant at or near a trellis post. Thus, to a certain degree, the construction of the trellis will determine the planting distance. With rows 10 feet apart, the following numbers of plants per acre will be required when the planting is:

10 feet apart in the row — 435 plants per acre
12 feet apart in the row — 363 plants per acre
15 feet apart in the row — 290 plants per acre
20 feet apart in the row — 217 plants per acre

TRELLISING

Unlike most other vine crops, passion fruit is harvested after it matures and falls from the vine; this has a direct bearing on trellis construction.

There are a number of different types of trellises, each of which may have numerous variations, such as height, distance between posts, length and method of attachment of cross-arms, bracing of end posts, weight of posts and wire, as well as many others.

Basically these types may be grouped as: "Fence" or "grape" type with one, two, or even three wires strung along upright posts; T-type with a cross-arm, normally with two wires at or near the top of each post and a third wire on the top of the post when the cross-arm is 3 feet long or more; yoke type with a crossbar 6 to 8 feet long on which four to six wires may be run and which is supported at or near the ends by upright posts.

All the above types require heavy and well-braced end posts to withstand the strain of the tight wire and the weight of the vines. Somewhat lighter posts can be used at regular intervals of 15 or 20 feet to support the weight of the vines. Some consideration and trial is being given to a wider spacing, 50 to 60 feet, of the permanent posts with lighter and cheaper supporting posts which may not need to be placed in the ground. Such construction might have merit where heavy winds are not an important factor.

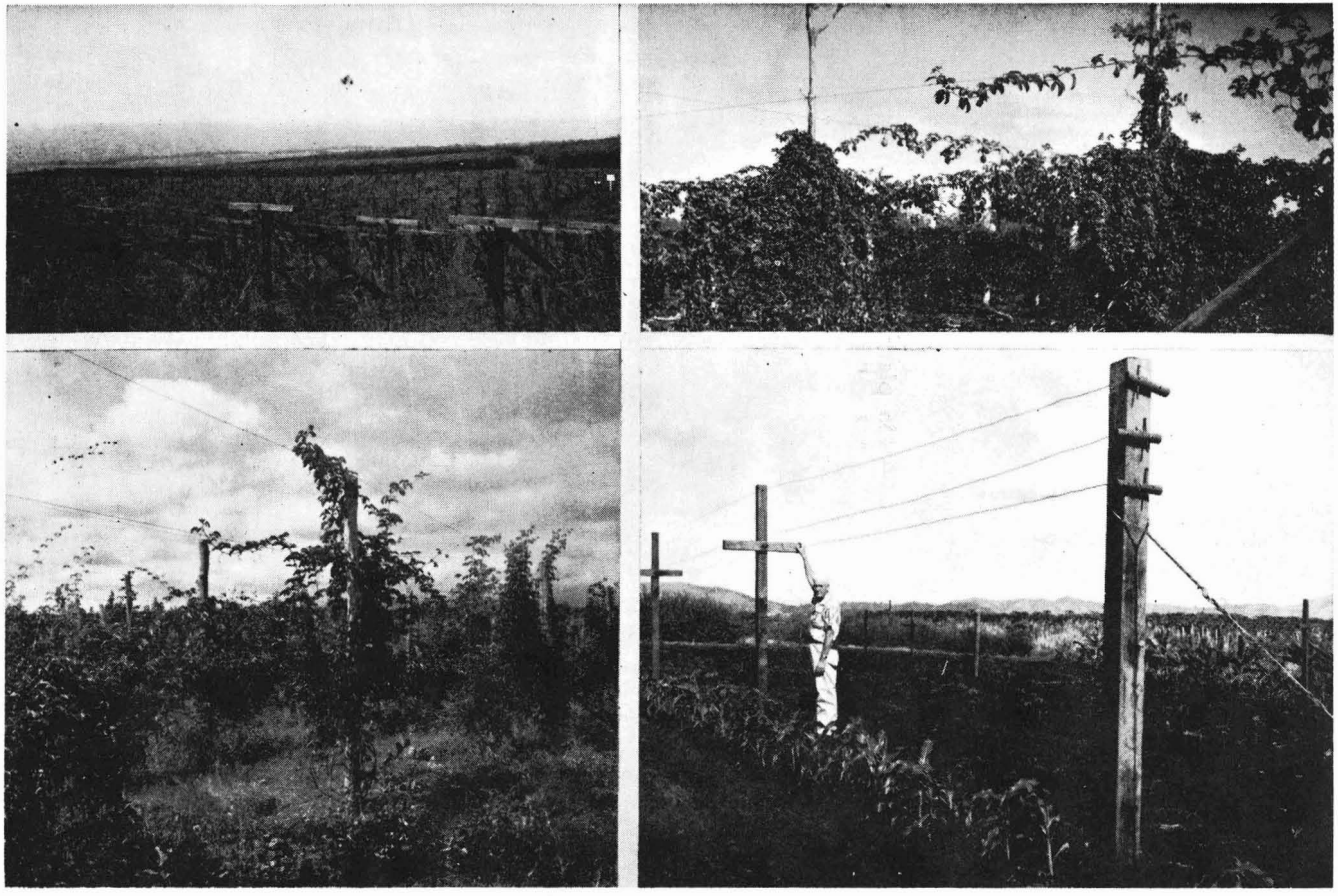

Figure 3. *Top left,* T-type trellis with internal braces at end-posts; *top right,* trellis using live trees for posts; *bottom left,* grape or fence-type trellis, matting of vine on both sides of trellis; *bottom right,* extended T-trellis using Australian winches and external dead-men to anchor end-post, a recommended type.

Experimental evidence has shown that a low trellis (4-5 feet) of any type results in a vine that trails on the ground at an early date. Lifting the vine to the top of the trellis merely aggravates the piling effect of the foliage and results in depressed yields; 8 to 10-foot trellises overcome this condition in part, and yields of fruit are significantly higher. The height is dictated by a number of factors:

1. Except under quite adverse conditions, the yellow passion fruit is an extremely vigorous and aggressive plant. In its second year of growth and fruiting this is particularly noticeable. Even with a trellis 8 feet high, the vines will trail from the top of the trellis to the ground, hiding the fruit and complicating the harvesting, spraying, and other operations.
2. A high trellis holding the vines well above the ground makes it much easier to reach under the vine to apply fertilizer, to spray weeds, and especially to harvest the fruit from the ground.
3. The high trellis presents a greater surface of vine to the sun and, in consequence, might be expected to yield more. For the same reason, the yoke trellis might yield somewhat less than two T-type trellises containing an equal length and weight of timbers.
4. A trellis higher than 8 feet requires proportionately heavier construction than lower trellises; also, the cost of training the vine to the trellis, as well as the cost of pruning, may be greater if a ladder is required.

Minimum width of row for the grape trellis is considered to be 10 feet, in order to permit use of mechanical equipment. If the T-type trellis with a 3-foot crossbar is used, there would be a distance of 7 feet between the ends of the bars of parallel trellises. If longer crossbars, 4 feet for example, are used, then the distance of 7 feet should be maintained, and the distance between posts increased from 10 to 11 feet in order to retain adequate working space for a small tractor or spray equipment and to prevent the vines from reaching across from one trellis to the next.

In new clearings, particularly in rocky or gulch areas, it is often possible to use standing trees to guy the trellis wires. In some locations, heavy cables are stretched between trees to support lighter wires run at right angles to the cable. In other circumstances, rather tall trees or poles have been used and the wires guyed to shorter trees or posts, giving much the appearance of a tent. Several years may be required for the vines to completely cover such structures, and early returns might not be as great as with a standard trellis. Such trellises may have the advantage of economy of construction. However, in all such construction, the important factors of yield and accessibility for spraying, fertilization, and especially for harvesting must be carefully analyzed. Obviously, unless an abundance of fruit is produced and unless it can be harvested economically, even a very cheap trellis may be the most expensive in the end.

In constructing the standard trellis it is desirable to use heavy wire, at least 8 or 9 gauge, to withstand the weight of vine and tension on the wire. For the same reason, the wire should be placed on top of the cross-arm or post and stapled securely. Another good plan is to drill holes through the cross-arm and post and to string the wire through the holes; thus there will be no danger that the wires will fall or be blown off the support. Also, it is possible to tighten and adjust the wires which is not possible when they are stapled. When wide spacing of 20 or more feet between posts is used, it is essential that the cross-arms be mortised into and securely nailed or bolted to the post. In most instances, it is undesirable to secure the wires to a cross-arm on the end or strainer post. Greater strength and stability with very little loss of surface is attained when the wires are tied directly to the end 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 upon it. It has been estimated that a 20-foot length of trellis 3 feet wide may be required to support a weight of at least 300 pounds of vine and fruit.

Posts should be about 10 feet long. The end posts should be at least 3 feet in the ground and firmly braced or tied to a "dead man" to support the tension and weight on the wires. The inside posts need not be planted so deeply and greater height can be used.

Posts may be of almost any material supplying adequate strength with a life expectancy of 5 years or more. Suggested sizes for posts are: 10-inch butts for anchor posts; 6-inch butts for internal posts; and cross-arms at least 2 x 4 inches or greater.

Treatment of all wooden posts to prevent decay, particularly that portion in contact with soil, is essential if the trellis is to have a long trouble-free life.

TRAINING

Training the passion fruit vine is a very simple operation. The principal objective is to get the vine to the wires of the trellis in the simplest, quickest, and least expensive manner, after which the vine takes care of itself. Observation and experience indicate little or no merit in the detailed training procedures as practiced with grapes and sometimes recommended for passion fruit.

If the young vine is supported in an upright position and is given a string, wire, or light pole to grasp, it will usually grow quickly to the trellis wire with a minimum of lateral branching. It has been observed that the terminal branched portion of bamboo when inverted and hung over the trellis wire provides an excellent support for the vine and removes the necessity of frequent tying.

Vigorous vines will branch freely, and those branches that trail on the ground should be removed. Four to six or more of the laterals may be trained to the overhead wire and others removed in order to minimize wind resistance which often causes difficulties in establishing the vines on the

wire. After the vines reach the wire they spread laterally in both directions and soon begin to flower. Thus the quicker the vines come to a horizontal position on the trellis the more quickly they will flower and fruit. Systematic and prompt attention to training the young plant until it reaches the trellis will be time and effort well spent.

PRUNING

Whether or not commercial passion fruit plants in Hawaii will require regular periodic pruning has not been determined. In Australia and New Zealand, purple passion fruit vines in commercial plantings are usually pruned in order to facilitate spraying or to force new growth.

On the other hand, experimental evidence from South Africa, where both the purple and yellow passion fruit are grown, has shown that unpruned vines consistently outyielded those which had been pruned. Yields of unpruned vines during the third and fourth years of growth exceeded those from pruned vines by about 35 percent. Another warning against indiscriminate pruning of the yellow passion fruit is given by Parsons of the Ceylon Department of Agriculture in the following statement: "This variety [yellow fruited form of *P. edulis*] too is propagated by both seed and cuttings and its culture is similar to that of the purple variety, but it does not stand such severe pruning as the purple variety and must be allowed to roam to a certain extent."

It has been indicated in earlier paragraphs that when "filler" vines are used, the initial pruning after the first year's growth and fruiting might consist merely of removing alternate vines if the trellises are well-covered and the vines are somewhat overlapping. Other pruning would consist only of removing at or near the wire the dangling growth which if left would trail and fruit on the ground during the following season. New growths starting from the height of the wire will produce the main crop of fruit in the following harvest.

As has been stated above, pruning will reduce yield and if done improperly may seriously retard the vine. The principal reasons for pruning are largely mechanical and may be listed as follows:

1. To facilitate spraying for disease and insect control;
2. To reduce the total weight of vine on the trellis;
3. To remove those portions of the vine that by trailing on the ground interfere with harvesting;
4. To eliminate, so far as possible, the matting or piling up of vine on the trellis that causes the ripe fruit to lodge and prevents its being gathered at the normal time.

Normally, pruning would be done after the winter harvest. If pruning is limited to alternate vines and to cutting the dangling growths of the remaining vines at the height of the wire, no particular problem is presented. However, if more severe pruning, such as dehorning or cutting back to the

main stem is done, it is best to wait until the vine begins an active spring growth. Severe pruning of dormant or relatively inactive vine may result in a severe setback or even death of the vine.

The operator should not attempt to remove the severed stems and branches from the trellis for several weeks after the actual pruning or until the prunings have become dry and brittle. Generally it is much easier to break and remove the dried wood and leaves and to clean out the trellises than to attempt to disentangle the green branches from the trellis at the time of pruning.

FERTILIZING

The fertilizer recommendations given here for passion fruit will be tentative. They are based on observations of scattered fertilizer trails and our knowledge of the growth of similar crops. An application of a complete fertilizer is recommended at planting time and at the beginning of the spring growth. The recommended complete fertilizer is a 10-5-20 analysis, or fertilizers having similar ratios. In newly transplanted orchards, the application should be 2-4 ounces of fertilizer per plant. This application should be repeated 6 weeks after planting. The application of fertilizer in a matured, bearing orchard should be made at the time when the plants begin their spring and summer growth periods.

From nitrogen analyses of fruits, it is estimated that in order to produce 40,000 pounds of fruit per acre it will take 1,320 pounds of 10-5-20 fertilizer if all of the fertilizer taken up by the plant goes into the fruit. But we cannot expect that the plants will get more than about 50 percent of the nitrogen applied as fertilizer. On this basis, at least 2,640 pounds of 10-5-20 fertilizer would be necessary to produce 40,000 pounds of fruits. If there are 217 plants per acre, 12.2 pounds of 10-5-20 fertilizer per plant must be applied. The time of application must be determined by the rate of growth of vines and general appearance of plants. It may be desirable to make three applications of 3 pounds per plant before the summer crop beginning in early February, and then one application between the summer and winter crops. However, this will depend upon the environmental conditions in which the plants are growing.

Lime

Although the desired pH requirements for passion fruit have not been established, and although it is believed that the plant will grow in a fairly wide range of acidity, the application of lime is recommended for strongly acid soils. Soil samples are taken for chemical analysis from the planting site at least two months before planting. These samples are sent to the University soil testing laboratory through your local county agents. The lime requirement of the soil will be determined and recommendations will be made as to amount of lime to apply per acre and how it should be applied.

INSECT PESTS

There are a number of insects associated with the passion fruit plant; some are beneficial while others are harmful. There are also insects which appear to be neither beneficial nor harmful. The role of the beneficial insects as pollinators has been discussed under the section on flowering, fruit setting, and pollination.

The control of pests which attack the passion fruit concerns two basic problems: first, the destruction of insects which attack the plant; and second, the preservation of the insects whose function in pollination is of vital importance to fruit set. The problem is complicated because both beneficial and destructive insects are so closely associated with the plant; the injurious insects must be eliminated 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 variety opens during the noon hours and closes at night. Observations showed that insect pollinators were most active during the period when the flowers were in bloom. Hence, less damage to the pollinators might result if spray applications are made during the early morning hours when pollinators are not active. Moreover, since exposed pollen grains burst upon contact with water and thus become nonfunctional, it is imperative that any spray application for insect or disease control be done only when the flowers are closed or when the plants are not flowering.

The most troublesome pests are fruit flies: the Oriental fruit fly *(Dacus dorsalis),* the melon fly *(Dacus cucurbitae),* and possibly the Mediterranean fruit fly *(Ceratitis capitata).* Several mites are also serious pests: the spider mites *(Brevipalpus phoenicis* and *Tetranychus telarius),* and the broad mite *(Hemitarsonemus latus).** In addition, there are a few other pests of minor importance.

Fruit Flies

The Oriental, melon, and possibly the Mediterranean fruit flies are the most injurious pests of the fruit. These pests usually puncture the immature fruit while the rind is still tender. As the fruit enlarges, a woody area develops around the puncture (fig. 4). If the fruit is still quite small and undeveloped, the damage may be sufficient to cause it to shrivel and fall from the vine. If the fruit is well along in development, it may grow to maturity. At the time of ripening, the area around the puncture has the appearance of a little woody crater which disfigures the outer appearance of the fruit but apparently does not impair the quality of the juice. Although oviposition scars are present on ripening fruits, they generally do not contain living larvae. Larvae appear to be able to develop better in immature than in mature fruit.

*Information on mites supplied by Dr. I. M. Newell, Dr. W. Wayne Boyle, and Mr. Frank Haramoto is gratefully acknowledged.

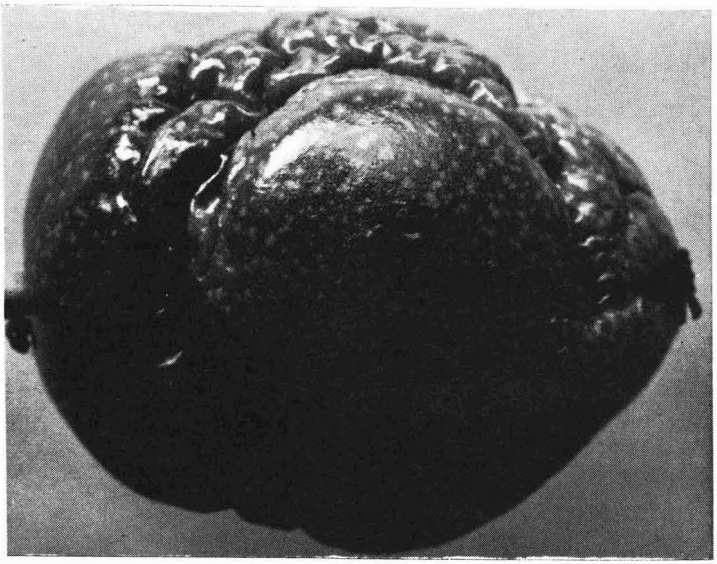

Figure 4. Young passion fruit of the yellow variety damaged by fruit fly.

The relative importance of each of the three species of fruit fly appears to vary with the location of the vineyard. Generally, the Mediterranean fruit fly is found at high elevations, while the Oriental and the melon flies seem to prefer lowlands.

In fruit fly control, the main objective is to destroy the gravid females which usually breed elsewhere but come into the orchard to lay eggs. One of the most important steps, therefore, would be the elimination of nearby overripe papaya, tomato, and other fruits in which the flies might breed and on which the adults feed. If such breeding places are not eliminated, frequent insecticide applications would be necessary, and probably less effective control would be obtained.

Fruit fly adults may be destroyed with various insecticides. However, sprays of malathion at 3 pounds of a 25 percent wettable powder per 100 gallons of water are suggested. Applications should be made with power equipment and with precaution. The adults may also be destroyed by use of bait sprays made with 3 pounds of malathion and 1 pound of yeast hydrolysate per 100 gallons of water.

Because the adult fruit flies roost on certain plants which are not necessarily host or crop plants, applications should be made on not only the passion fruit vines, but also on all nearby vegetation which might harbor the flies. Frequency of application varies with the abundance of flies. When adults are numerous, applications twice a week might be necessary during the period when young fruit is present.

Mites

The spider mites and the broad mite may cause serious damage to the vines. Unless damage from these mites is checked, the vines may die or the growth may be so adversely affected that there is a marked reduction in yield. Mites are generally most damaging in areas of low rainfall and during prolonged dry seasons.

Presence of the spider mite can be detected by close examination of the leaves and fruits. To the naked eye, this mite appears as scattered reddish patches on the lower surface of the leaf along the midrib and veins, as well as on the fruit surface. The spider mite causes shriveling, yellowing, and premature falling of the leaves. Complete defoliation has been observed on passion fruit growing on the University campus. A heavy infestation might also cause dying back of the vine, and shriveling and dropping of immature fruits.

The presence of the broad mite is difficult to detect without the aid of a lens. Under the lens, very minute white mites can be seen; the females are often seen carrying the smaller males on their posterior ends. Eggs with white markings may also be seen sticking to the leaf surface. An attack by this mite can be most readily detected by the symptoms of injury during the period of vine growth. This mite attacks the young terminal leaves, causing them to be stunted, deformed, slender, and rugose (fig. 5).

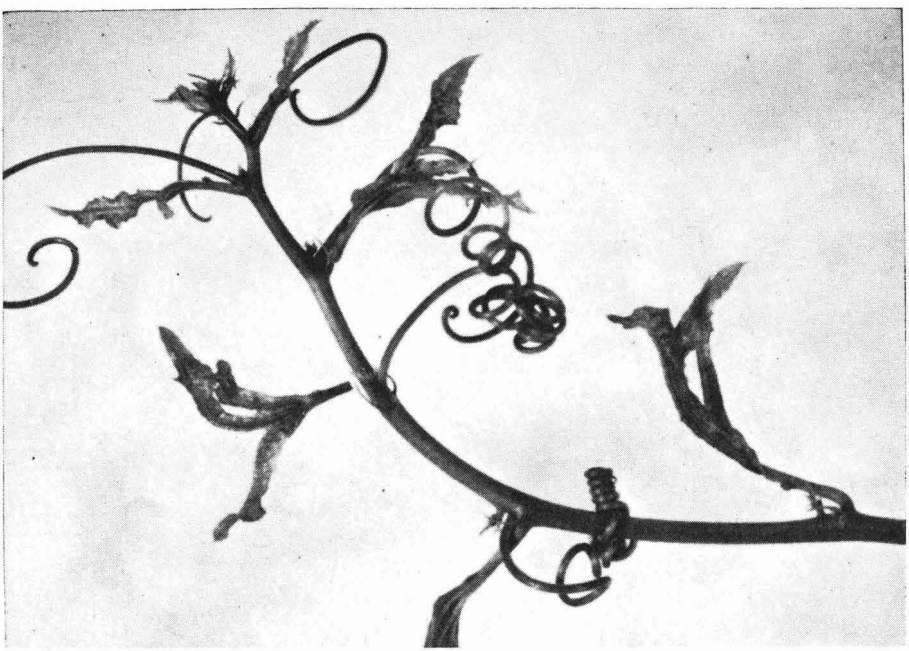

Figure 5. Terminal shoot of passion fruit vine deformed by broad mite.

Mites on passion fruit can be effectively controlled with a sulfur spray containing 5-6 pounds of wettable material per 100 gallons of water. As a precautionary measure, applications should be made at intervals of about a month, rather than waiting until the symptoms of attack have become evident. With heavy infestations, treatment at intervals of 10 days may be necessary.

Other Pests

Aphids are known to attack the passion fruit plant. On fully grown vines, severe damage seldom results from their attack; however, on seedlings, aphids may cause severe damage. Two aphids, *Myzus persicae* and *Macrosiphum solanifolii,* should be regarded as potentially important insects. These aphids, which are of common occurrence in Hawaii, are efficient vectors of the passion fruit woodiness virus, a serious disease of the passion fruit in Australia. Should the virus be introduced accidentally in Hawaii, it might be spread rapidly by these aphids.

The barnacle scale (*Ceroplastes cistudiformis*) has been found in large numbers attacking the passion fruit vine. Heavy infestation results in severe defoliation.

The thrips *(Selenothrip rubrocinctus)* has been observed to attack the leaves of the passion fruit; however, severe attacks appear to be exceedingly rare.

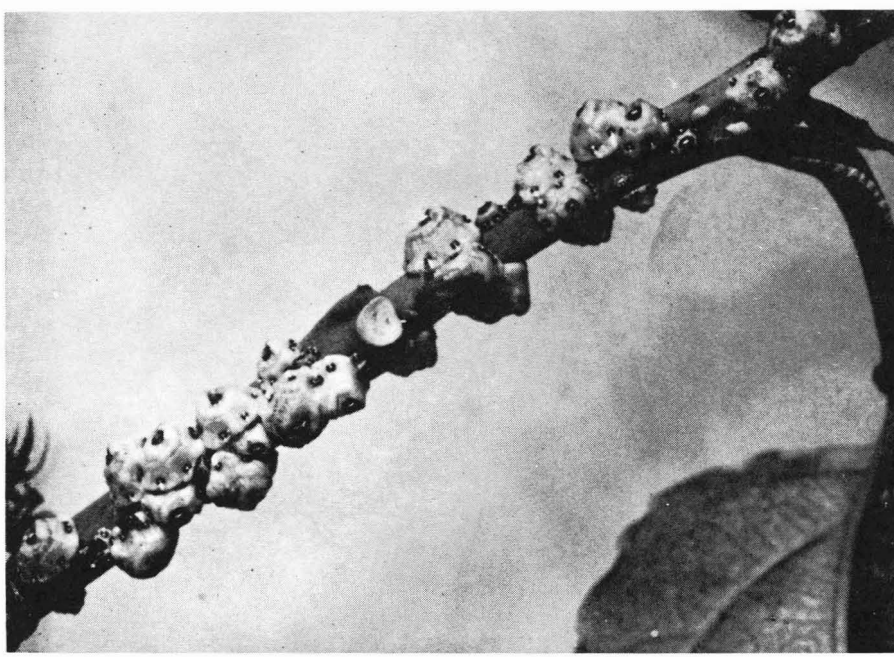

Figure 6. The barnacle scale on passion fruit vine.

PASSION FRUIT DISEASES

Passion fruit in Hawaii is relatively free of serious diseases, especially where vigorous plantings can be established in good soil. At present, brown spot is the most important local disease, followed by root rot.

Brown Spot

Symptoms of brown spot on the leaves or fruit may be easily recognized. On the leaf, the first symptom is minute reddish brown spots which range in size from 1/16- to 1/8-inch in diameter. Under humid conditions these spots have a water-soaked margin. As the infection progresses, the spots enlarge, forming a series of concentric rings (fig. 7, *left*), and the infected leaves drop prematurely. Symptoms on the fruit are characterized by circular, sunken necrotic areas which are also reddish brown (fig. 7, *right*).

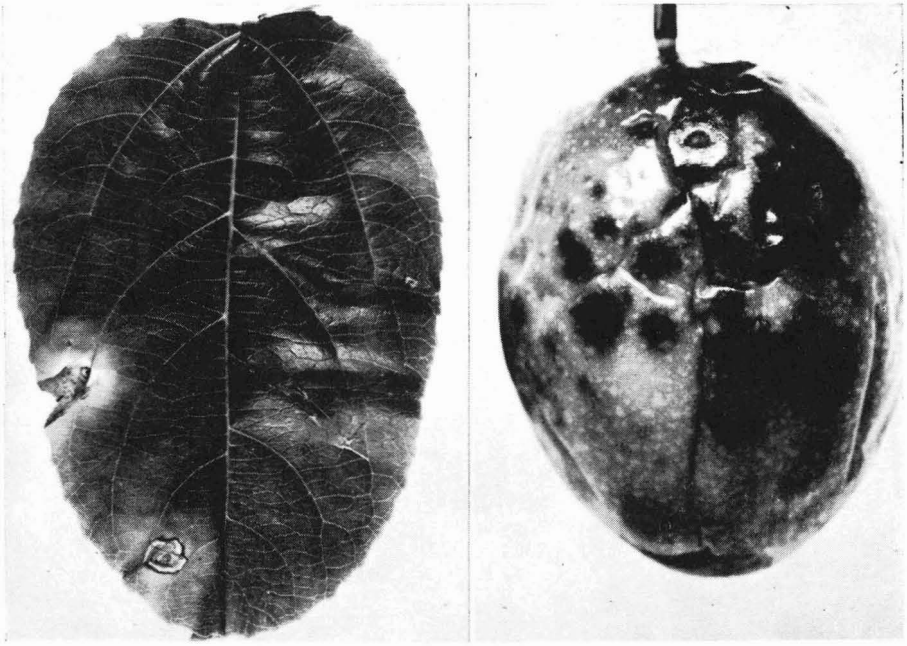

Figure 7. Symptoms of brown spot. *Left,* leaflet; *right,* fruit.

The diameter of these necrotic areas ranges from ½ to 2 inches. Infection occurs on half-grown to nearly mature fruit. This disease apparently does not impair juice quality, but from the processing standpoint it is objectionable because the brittle necrotic tissues of the rind tend to drop into the juice during extraction.

Brown spot is caused by the fungi, *Alternaria passiflorae, A. tenuis,* and *A. tomato.* At the site of infection, these fungi produce numerous spores or conidia which are readily spread by wind. On coming in contact with the fruit or leaf surface, the spores germinate and cause necrotic areas. Because the fungus requires a humid environment for development, brown spot is most prevalent in the areas of high rainfall.

Brown spot can be effectively controlled by either Daconil 2787 (75% WP) or maneb (80% WP) at the rate of 2 pounds per 100 gallons of water, applied once every 2 weeks. Although maneb and Daconil are effective, they cannot be recommended for brown spot because they do not have FDA clearance for use on passion fruit. In humid areas it is believed that many of the large lesions on fruit can be prevented by not leaving ripe fruit on the moist ground for long periods.

Root Rot

Root rot, the second most important disease of passion fruit, is caused by *Pythium splendens.* Symptoms are a general decline in vigor of the feeder roots being destroyed by the fungus. *Pythium aphanidermatum* also has been isolated from the roots but is not considered as important. *Rhizoctonia solani* is frequently isolated from diseased passion vine roots but its role in causing the death of the vine is not fully understood.

Maintenance of vigorous, healthy plants by good fertilization and cultural programs will reduce or minimize effects of root rot.

HARVESTING

Harvesting can be the most difficult and expensive operation in passion fruit culture. Normally, the grower will pass through his entire planting at least once a week, possibly twice in rainy weather, to gather the fallen fruit during the 7–8-month harvest period. Therefore, the layout of the vineyard, including access roads, length of line, width of rows, height of trellis, and all other factors having a bearing upon this operation, should be given careful consideration before planting.

The fruit as it matures must be harvested at regular intervals to avoid spoilage and other losses. Normally, the fruit is harvested from the ground. If the latter is somewhat ridged and smooth beneath the trellis, the fruits will roll to the side, thus making it easier to pick them up directly or to rake them together in piles to be picked up later with a fork or other implement. Obviously, the less area to be covered the more concentrated will be the fruit, and the faster the operation. This fact emphasizes the importance of height of trellis as well as one of the important differences between the grape and the yoke or flat-top trellis; the latter covers a greater ground area per unit of vine surface or per number of fruit.

The actual manner of handling and transporting the fruit in the vineyard will of course depend upon each operator. Basically, however, the following factors are of importance in the harvesting operation:

1. Only ripe fruit should be harvested. Green-ripe fruit, even if allowed to ripen off the vine before processing, possesses a woody off-flavor.

2. Ripe fruit loses weight rapidly after falling from the vine; and if it is sold by weight, the grower may lose as much as 10 to 20 percent by weight if it is not harvested and sold promptly.

3. In rainy weather, considerable spoilage due to disease may occur unless the fruit is harvested and placed in a dry, cool place.

4. Fruit should be placed in open crates and stored in a cool, well-ventilated area. The quality of warm, moist fruit will deteriorate rapidly from decay and overheating if stored in unventilated sacks or cartons.

5. In most cases it would seem advisable for the processor to wash and cool the fruit as quickly as possible upon receipt to avoid spoilage and loss of weight.

SELECTION AND CARE OF FRUIT FOR PROCESSING

Processors are the only practical outlet at present for Hawaii passion fruit. Growers who raise fruit which best meets the requirements or preferences of processors thus will best serve their own interests.

Now, and probably for a few more seasons, due to the shortage of passion fruit, processor will pay high prices for fruit, and they will often accept fruit of decidedly inferior quality. When supply approaches demand, processors will necessarily become more careful in their purchasing, and growers of inferior fruit may find it difficult to find outlets for their product.

To assure continued growth of the passion fruit industry, and thus assure a continuing outlet for the grower, the processor must have access to high-quality fruit, and he must maintain rigid quality standards in his manufacturing operations.

The qualities which the processor must have in the fruit he buys are those which a grower can provide only if he selects the best planting material. By good cultural practices he can maintain or even improve these desirable fruit qualities, which are:

1. First and most important, the quality of the juice. Flavor should be characteristic of the fruit and very abundant. Many passion fruit have interesting but not characteristic flavors. Unfortunately, many plants produce fruit which, regardless of maturity or handling practices, have a definite off-flavor. Such plants should be replaced; even a few such fruit may detract materially from the quality of the juice pack.

Good fruit has rich, fragrant, characteristic aroma. High acidity is preferred, for it can be balanced with sugar to make top quality juice. The best juice has a rich golden color.

2. Juice yield of the fruit is a very important consideration. Passion fruit as commonly received at processing plants usually yields about 30 to 33 percent weight of juice. Some deliveries produce even less than 25 percent, while deliveries from certain well-selected vineyards may produce 40 percent juice.

Figure 8. Current packaging of various passion fruit products.

3. Fruit which is clean and free from disease is also very important and reflects in the quality of the juice. All passion fruit is thoroughly washed in specially designed equipment as the first step in making the juice. After washing, the fruit is carefully sorted, usually on conveyor or roller belts. Even with expert help on the sorting belts, the more dirt, foreign material, and damaged fruit there is in any lot the more defects will be missed in the sorting, and they will damage the finished juice in one way or another.

Brown spot is the most common disease of the fruit. The number of fruit affected and the degrees of browning and softening are very important influences on the quality of the finished juice. Pulp from soft

brown spots becomes separated from the rind and goes into the juice, sometimes seriously affecting the flavor of the juice; and even more damaging, the mold material which caused the brown spot, can be found in the finished juice regardless of the juice-making procedure. Technical methods for detecting mold or decomposed materials in foods have been developed and are regularly used to examine other juices. Results of these examinations are routinely used to measure the soundness of the raw produce used in processed foods and also as a measure of the cleanliness of factory equipment and operations.

4. There are other desirable characteristics of passion fruit that processor may watch for because they improve fruit and juice production in general. Processors would like to see well-established vineyards of passion fruit which are uniformly of high production. This feature stabilizes the industry and improves the marketing situation. Growing characteristics of all selected plants or strains of passion fruit are of much importance to growers and processors because some of these characteristics may materially influence fruit production costs. Passion fruit selections in which the fruit are firm and have other good handling qualities are much preferred for they may be harvested, shipped, and handled with least loss or damage.

While certain strains of passion fruit make superior juice in both quality and quantity, there are other factors which must be considered. Quite consistently, the best juice has been made from fruit from a few favored areas. Growing and handling practices may greatly affect the juice-making quality of passion fruit. Some of these are not yet well known and may be subject to much change as research and experience point to better methods.

Current passion fruit purchasing and handling practices vary a great deal, and, while many of them are quite efficient, it may be expected that they will be much simplified and speeded up. Commonly, fruit is purchased on the open market or by contracts at stated prices. Fruit grade conditions have been lacking because of shortage of fruit, but everyone may expect that all grade factors such as maturity, size, cleanliness, freshness, percentage juice yield, disease, damage, and others will be carefully stated in contracts of the near future. Juice yields in terms of weight percentage will probably allow for premiums or deductions for higher or lower juice yields.

Containers are now commonly furnished by the processor, but other arrangements are common. Wooden boxes and sacks are most commonly used. Suitable boxes are quite expensive and should be charged out and accounted for through the season. Boxes protect the fruit well by avoiding bruises, and they also may allow for ventilation. Burlap sacks have been much used, but they permit excessive bruising of the fruit. This bruising reflects seriously in the keeping quality of the finished juice. Sacks often become offensively dirty, and they do not offer good ventilation, which is necessary for the best keeping of the fruit. Large crates, built on pallets

and known as tote boxes, power handled, may come into use for handling passion fruit as larger tonnages and mechanization develop.

Picking of mature, fallen fruit from the ground at periods of 2 to 7 days is now the common harvesting method. Frequency of picking is perhaps too often influenced by the amount of fruit which has fallen. Under certain weather conditions, the time between pickings should be much less to avoid damage and loss by evaporation and by rotting. Mechanical harvesters, such as those used to harvest ripe prunes and walnuts, may in the near future be used for harvesting passion fruit where planting layout and soil conditions are right.

Frequent harvests may become much more important to both grower and processor than they are now. Weight loss of passion fruit after harvest is often quite rapid. Fruit should be delivered and processed promptly after harvest, for this weight loss is sometimes considerable. Most of the loss is from the rind, but significant loss of juice weight has been found. More detailed tests are to be made.

If delivery or processing are unavoidably delayed and storage is necessary, then such storage should be well-ventilated, out of the sun, and as cool as possible. In addition to shrinkage losses, passion fruit may rot quickly and severely in storage. Any rot seriously complicates the sorting and always reflects in the quality of the juice, even though sorting may seem to have been done well.

These and all other harvesting and handling details are of mutual importance to everyone concerned. It is well that they be completely understood and then incorporated in the contracts and operations of growers and processors.

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