The material contained herein was compiled by the following members of the Committee on Passion Fruit Culture:

**Hawaii Agricultural Experiment Station**
- Ernest K. Akamine, Assistant Plant Physiologist
- Richard A. Hamilton, Assistant Horticulturnist
- Toshiyuki Nishida, Assistant Entomologist
- G. Donald Sherman, Chemist
- W. B. Storey, Horticulturist

**Agricultural Extension Service**
- Warren Y. J. Yee, Junior Specialist in Horticulture

**IRAC Project**
- Thomas N. Shaw, Junior Food Technologist

Co-operative extension work in Agriculture and Home Economics
College of Agriculture, University of Hawaii
United States Department of Agriculture co-operating
H. A. Wadsworth, Director, Hawaii Agricultural Extension Service
Distributed in furtherance of the Acts of Congress of May 8 and June 30, 1914
FOREWORD

Passion fruit is an important commercial crop in Australia, New Zealand, the Union of South Africa, and Brazil, where the juice and pulp are used extensively as ingredients of beverages, salads, fruit cocktails, and desserts. Although passion fruit has been known in Hawaii for many years and made use of by persons who have gathered the fruit either from vines growing wild or from those in the home garden, interest in it as a new commercial crop for Hawaii is a recent development.

The Food Processing Laboratory of the Hawaii Agricultural Experiment Station, with financial support from the Industrial Research Advisory Council of the Territory of Hawaii, has perfected methods for processing the fruit commercially and has developed highly palatable passion fruit products which have found ready consumer acceptance. Commercial food processors have built plants to manufacture passion fruit products to meet consumer demands. It is expected that frozen passion fruit juice and nectar base will appear on retail markets in the near future. How soon this happens will depend on the increase of passion fruit production in Hawaii.

Profitable returns to present growers have started a trend toward increased planting of passion fruit for commercial processing. The increase has been so recent and so rapid that technical research on varietal improvement and recommended cultural practices has been unable to keep pace. Many farmers and prospective growers are requesting information on what varieties to plant, how to plant, what fertilizer to use, what type of trellis is best, how to control insects and diseases, and various other problems.

The University of Hawaii Agricultural Extension Service, recognizing the need for information on passion fruit culture, has asked the horticulturist, the soil chemist, the plant pathologist, the entomologist, the plant physiologist, and the food technologist to contribute the best local knowledge possible on the subject and to supplement their knowledge, where needed, with information made available by agriculturists in other lands. This circular is the result of their efforts.

The object of this circular is to help get the growing passion fruit industry firmly on its feet by giving to the grower the best information now available on cultural procedures. Some of the information contained herein is drawn from the personal observations and experiences of the individual contributor. Some, when it has seemed adaptable to Hawaiian conditions, has been drawn from the publications of workers in other countries where passion fruit is grown commercially. Many of the recommendations made in this circular may be changed later, as growers and researchers discover better procedures.

The ultimate success of a passion fruit industry in Hawaii will depend upon the co-operation and co-ordination of the efforts of growers, research workers, and Extension Service personnel. The work of those persons who contributed to this circular is heartily appreciated.

BARON GOTO
Associate Director
<table>
<thead>
<tr>
<th>CONTENTS</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Botanical Relations</td>
<td>7</td>
</tr>
<tr>
<td>History</td>
<td>7</td>
</tr>
<tr>
<td>Varieties</td>
<td>8</td>
</tr>
<tr>
<td>Flowering and Fruit Setting</td>
<td>10</td>
</tr>
<tr>
<td>Propagation</td>
<td>11</td>
</tr>
<tr>
<td>Trellising</td>
<td>13</td>
</tr>
<tr>
<td>Training</td>
<td>14</td>
</tr>
<tr>
<td>Pruning</td>
<td>15</td>
</tr>
<tr>
<td>Fertilizing</td>
<td>15</td>
</tr>
<tr>
<td>Insect Pests and Diseases</td>
<td>16</td>
</tr>
<tr>
<td>Selection of Fruit for Processing</td>
<td>19</td>
</tr>
<tr>
<td>Harvesting</td>
<td>21</td>
</tr>
<tr>
<td>References</td>
<td>22</td>
</tr>
</tbody>
</table>
Figure 1. Purple passion fruit, PASSIFLORA EDULIS, the variety most extensively cultivated in other countries.
BOTANICAL RELATIONS

The passion fruits belong 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 to be found as cultivated fruit or ornamental plants in home gardens, or as naturalized wild plants along roadsides, on 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 one 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* (fig. 1): purple passion fruit or lilikoi. Cultivated to a limited degree as a home 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* (fig. 2): yellow passion fruit or yellow lilikoi. Cultivated in home 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, waterlemon, 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 cultivation in home gardens at elevations from near sea level to 1,500 feet.
- *P. mollisima*: 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 home gardens on lowlands up to an elevation of 1,500 feet.

Species and varieties which may be encountered in cultivation as ornamentals in home gardens or as wayside plants are: *P. suberosa*, *P. pulchella*, *P. manicata*, *P. vitifolia*, *P. seemanni*, *P. maliformis*, *P. incarnata*, *P. coerulea*, *P. foetida*, *P. foetida var. gossypifolia*, *P. subpeltata*, *P. Pfordti*, and *P. princeps-coccinea*. Many of these bear fruits which may be eaten, although they can hardly be considered palatable.

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 Australia 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 began to appear in the wild and soon became widespread in the district. The name of the district soon became attached to this particular species of passion fruit.

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 by some unknown person. 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 home after 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.

VARIETIES

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

Passion fruit production in Australia, New Zealand, South Africa, and other
countries is almost exclusively of the purple variety. Usually, strains selected for
the particular growing conditions of the country are grown. The purple variety
tends to grow better in the uplands than in the lowlands of Hawaii. Because no
selection work has been done with the variety, the fruits tend to be small, and the
vines are less productive than the yellow variety. In the opinion of some persons
the purple variety has better flavor than the yellow variety, especially for eating
out-of-hand.

The yellow variety is best adapted to the lower and middle elevations in Hawaii.
In general, the fruit is larger than that of the purple variety, and the vines tend to
be much more vigorous and prolific. The pulp and juice are more tart than those
of the purple variety.

Brief descriptions of the two varieties follow.

P. edulis

The plant is 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 3-lobed with finely toothed edges and a cordate
or heart-shaped base. The flowers, which occur one at each node on new growth,
have five whitish sepals, five whitish petals, and two rows of thread-like rays, called
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 egg-shaped, 1½ to 2 inches in diameter, and deep purple in color 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 naturally 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 may be distinguished by the suffusion of reddish,
pinkish, or purplish color in stems, leaves, and tendrils. The leaves resemble those
of the purple variety but usually are somewhat larger, and the bases of the corona
filaments are a much deeper, brighter purple. The fruit averages slightly larger than
the purple variety and has a bright, canary-yellow rind. The pulp is somewhat more
acid, and the seeds are dark brown rather than black.
Figure 2. Yellow passion fruit, PASSIFLORA EDULIS f. FLAVICARPA, the variety best suited to commercial production in Hawaii.
FLOWERING AND FRUIT SETTING

When grown under favorable conditions, passion fruit vines grow rapidly and may flower within a year after they have been started from seed. The flowers are borne singly in the axils of the leaves on new growth.

There are two fairly distinct periods of flowering and fruit setting. The first period of flowering occurs in late winter or early spring, and the fruit matures in midsummer. The second period of flowering occurs in early fall, and the fruit matures in midwinter. It has been noted that, although flowers may be produced continuously along a long section of branch, the last produced may not develop into fruit even when pollination has been done by hand. The reason for this behavior has not been determined, but is very probably related to the physiology of the plant. After a certain number of fruits have set along the branch, something inherent in the plant seems to inhibit further fruit setting for a time. After the first-set fruits have begun to mature, setting of the flowers may resume for the remainder of the flowering period. The effect on a single, long branch, following a period of flowering, is to have two or three sections on which fruit has set, with blank spaces in between.

The flowers of the purple variety open early in the morning, usually around dawn, and close before noon. The flowers of the yellow variety open about noon and close about 9 or 10 o'clock at night. It is probably because there is little or no overlapping of the functional periods of the flowers that not much crossing takes place between the two varieties. In Hawaii an instance of a natural hybrid originating from a cross between the yellow- and purple-fruited types has recently been confirmed, whereas in Queensland this cross has also been made with the object of combining the most desirable qualities of both types.

When the flowers first open, the stamens hang down and the anthers dehisce on the undersides, exposing the pollen. The style branches remain erect, and there is no stickiness to the stigmatic surfaces. As time goes by, the style branches gradually bend down until the stigmatic portions are at a level below that of the stamens and become receptive of pollen. When the flower begins to close after its few hours of functionality, the style branches return to an upright position.

The flowers are fragrant when open. Nectar is secreted at the base of the pistil stalk, and the pollen is heavy and sticky. These features, in conjunction with the position of the anthers when the pollen is exposed and the functional position of the stigmas, suggest that the flowers are adapted to pollination by insects rather than by wind. In Hawaii, the principal insects which visit the flowers are the honeybee (Apis mellifera) and the carpenter bee (Xylocopa varipuncta). It is doubtful whether the honeybee is effective in pollinating the flowers because of its small size. The carpenter bee, on the other hand, is large enough so that, in moving around the flower to obtain nectar, its back brushes along the anthers and stigmas, transferring pollen from one organ to the other. It is not uncommon to see big, black carpenter bees moving from flower to flower and vine to vine with their backs dusted yellow with pollen, doing a good job of pollination.

The carpenter bee nests in wood, and its presence as a pollinating agent should be encouraged by placing wooden posts through the vineyard. The posts may be redwood, kukui, or some other suitable, soft wood.

Honeybees may actually be a cause of unfruitfulness of the passion fruit. In some areas where honeybees are plentiful, it has been observed that they visit the flowers as soon as they have opened. The bees remove the pollen from the anthers and carry it back to the hive. By the time the style branches have moved into position where their stigmas can be pollinated by carpenter bees, the pollen may
be entirely gone. Unless the carpenter bees have some pollen still on their backs from early visits to the flowers, pollination is entirely precluded and failure of fruit setting results.

Whether cross pollination between flowers of different vines is necessary for maximum fruit setting has not been determined. The problem has never come up in commercial plantings in Hawaii because these have consisted almost entirely of seedlings. It might become a problem if a superior strain is selected and propagated by cuttings for planting an entire vineyard, particularly if the strain should have a low order of self-fertility. Seedlings vary in their degree of self-fertility. Many isolated vines set what appear to be good crops through natural pollination, but it is not known whether these crops approach the maximum potentialities of the vines. Other isolated vines set little or no fruit.

It would seem wise to plant several selected strains in a vineyard to enhance the possibility of cross pollination and to minimize crop losses which might occur from planting with a single strain that proved not to be highly self-fertile.

**PROPAGATION**

Passion fruit is propagated either by seeds or cuttings. In countries where this fruit is grown commercially, the usual method of propagation is by planting seeds. Whenever propagation of a particular strain or horticultural variety is desired, cuttings 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 subsequently planted.

If a greater delay in planting is necessary, the fruit may be held at a temperature of 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. Temperatures below 55°F. tend to delay the sprouting of the seeds. Freezing the fruit kills the seeds. Seeds removed from the fruit but not separated from the pulp keep satisfactorily at 55°F., provided mold growth does not set in.

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 85 percent after a storage period of 3 months at room temperature in an experiment which is incomplete as yet. In another incomplete experiment, 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. Thus it seems that, if seeds are to be dried for storage, the drying and subsequent storing should be done at room temperature.

How long passion fruit seeds will maintain their viability remains to be determined. Neither is it definitely known whether dormancy exists in these seeds. If it does exist, methods of breaking the dormancy must be determined.

PROPAGATION BY CUTTINGS

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, very frequently shoots 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 readily develop from the same leaf axil. For this reason the older part of the vine of passion fruit makes inferior cutting material. This is in contrast to the behavior of other plants in which adventitious shoots readily develop from the same leaf axil after the main bud is destroyed.

Cutting material obtained from the region where the vegetative bud is sound and unextended into a branch is too immature for rooting because of its position near the actively growing tip of the vine. Between the old and the immature regions of the vine is a region where the buds are fully extended into branches, each of which has its first vegetative bud near the leaf axil. Reliance is placed upon this bud to develop into a shoot. From the standpoint of root and shoot development, it seems that the best cutting material is obtained from this region. The best time to obtain cuttings is when the vines are actively growing and not bearing fruit. In Hawaii this seems to be between the summer and winter crops and 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 node 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. So far no root-inducing chemicals seem to be effective.

HANDLING SEEDLINGS AND ROOTED CUTTINGS

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 should be transferred to individual containers. In transplanting, care should be exercised not to injure the delicate
roots. When the shoots and roots are well established, the cuttings should be set out in the field.

PLANTING AREA AND DISTANCES

The planting area should be located in sections where there is good drainage, especially when vines are grown in wet areas. Another desirable feature of the planting area is that it be sheltered from strong winds. Where land is being cleared, natural growth may be retained, or if this is not possible windbreaks may be planted.

A suitable planting distance depends upon a number of factors. Among them are the vigor of the vines in a given location, the variety planted, the type of trellis used, and the amount of mechanization possible. When these factors are known, the distance is increased or decreased correspondingly. Some of the planting distances which have been recommended are as follows:

- 10 feet between rows and 20 feet in rows — 215 plants per acre
- 12 feet between rows and 14 feet in rows — 256 plants per acre
- 10 feet between rows and 16 feet in rows — 270 plants per acre

TRELLISING

There are many different systems of training vine crops on various types of vertical and horizontal trellises. Any attempt to describe in detail the merits and disadvantages of the many trellising arrangements in use would probably be more confusing than helpful to prospective passion fruit growers. The following general considerations should be helpful, however.

Unlike the fruit of most other vine crops, passion fruits are harvested from the ground after they have matured and fallen from the vine. Because of this, the so-called clothesline or T-type trellis seems to be an advantageous and desirable arrangement for growing and harvesting operations. When properly constructed, the T-trellis facilitates harvesting. It is not difficult to train the vines to grow satisfactorily on this type of trellis. A number of modifications of the upright, fence-type trellis are also possible and have been used for growing passion fruit. Posts 5 to 8 feet high are generally used, with from two to as many as eight wires strung between them. The main disadvantage of the fence-type trellis is the fact that the wires often interfere with weeding and harvesting operations under the plants.

Posts for a T-type trellis may be of any available material which is resistant to decay and strong enough to carry the weight of the vines. If wooden posts are used, the part in contact with the ground should be treated to prevent decay. Wherever available, posts made of coconut trunk, hau, redwood, or any other type of wood in which the carpenter bee nests are desirable. The upright posts should be about 6 inches in diameter and the end posts approximately 10 inches in diameter. Posts should be 8 or 9 feet in length so that at least a 5-foot clearance is allowed under the cross pieces of the trellis when the posts are set 3 feet deep in the ground. Cross pieces should be wooden beams or posts 4 to 5 feet in length and 3 to 5 inches thick. Cross pieces should be nailed firmly to the top of the upright posts.

Two or three 8- or 9-gauge galvanized-iron wires are strung parallel to each other between posts and stapled firmly to the cross pieces of the trellis. The wires should be stretched tightly to prevent excessive sagging with the weight of the vines. On a 5-foot cross piece, one wire should be in the center and the other two near the ends. This would allow the three wires to be spaced about 2½ feet apart. If two wires are used, the crossbars should be 3 to 4 feet long. The upright posts
should be set firmly in the ground at a depth of at least 3 feet. In addition, end posts must be braced firmly with guy wires or some other type of bracing to assist in supporting the heavy weight of the vines. This type of T-trellis, with modifications to fit the individual grower’s needs, is suggested for commercial passion fruit growing in Hawaii.

A good arrangement is to space the posts twice as far apart as the vines in the row. Thus, if vines are spaced 12 or 14 feet apart in the row, the posts would be placed 24 or 28 feet apart. At spacings of 24 or 28 feet, two vines may be planted between successive posts.

On fertile soil with ideal growing conditions, the growth of yellow passion fruit vines may be so rapid that even wider spacing between plants would be justified. It has been observed that the vine growth of the yellow passion fruit at elevations below 1,500 feet in Hawaii is considerably more vigorous than that of the purple type cultivated commercially in other countries. Individual vines of the yellow passion fruit have remained in a vigorous and productive condition for 10 years or more in favorable locations. On the other hand, the purple-fruited type is considered by a number of authorities in various countries to have a maximum productive life of not more than 5 or 6 years. It is possible that spacing as wide as 20 feet between plants in the row may prove suitable for the yellow passion fruit under the best growing conditions in Hawaii.

At the wider spacing of 16 to 22 feet between plants, it would be necessary to have only one plant per trellis post because of the weight of the vines. This would of course result in more posts per acre and increase the initial cost of trellising. Since trellising is one of the largest initial expenses in passion fruit growing, this point should be carefully considered.

The distance between rows depends on the width of disc harrows or other tillage implements necessary in keeping down weed growth. Ten to 12 feet is suggested as a logical distance between rows, provided this allows access for necessary implements and machinery. With a spacing of 12 feet between rows and 14 feet between plants, 256 plants can be planted in an acre, whereas 10- by 20-foot spacing allows 215 plants per acre.

**TRAINING**

Some training of young passion fruit plants is necessary to start the vines growing along the trellis wires. In training the vine, put in a supporting stake of bamboo or other suitable material beside each plant. This stake should be long enough to reach up to the trellis wire. A single stem or leader without side branches is trained along this support so that it reaches the trellis wire as soon as possible. Stakes are necessary when the plants are spaced between trellis posts, but not when plants are set in beside the posts.

If vines are spaced the same distance apart as the trellis posts, stakes are not necessary since each plant can be set in beside a post. The post can be used to support the vine until it grows long enough to reach up to the trellis wire. The vine should then be attached to one of trellis wires by means of raffia or string wrapped several times around a leaf petiole and a tendril and tied in place. It is not advisable to tie around the stem proper as this may result in injury to the vine.

The growing tip is next pinched off to force out several new side branches. Three to five of the side branches or canes are allowed to grow. Some of the canes are placed along the wires in such a way as to encourage their growth in one direction along the trellis wires. The remainder are arranged so that their growth is directed along the wires in the opposite direction.
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 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 year 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."

In young, healthy plantings, pruning may be expected to reduce the total yield of fruit. Since fruit for processing purposes is commonly sold by weight or measure without grading, the total yield has a direct bearing on the income per acre and is an important factor for the grower to consider.

Evidently the necessity for pruning depends upon 1) the need for spraying and 2) the necessity of forcing out new growth when vines begin to lose vigor and produce little new growth. The necessity for spraying cannot be predicted until growers determine whether or not insects or diseases attacking passion fruit in Hawaii will do sufficient damage to justify the added cost and labor required for spraying. Disease and insect problems will probably vary from island to island and from season to season, and the necessity for pruning depends largely on insect and disease problems encountered by individual growers.

When grown at low or medium elevations in Hawaii, the yellow-fruited passion fruit is considerably more vigorous in growth habit than the purple-fruited type. Because of this, and because the climate in Hawaii usually permits the vines to grow throughout the year, it is doubtful whether pruning to force new growth would be necessary if soil fertility is satisfactory and good cultural practices are followed.

Five or 6 years has been the maximum profitable life of the purple variety in commercial plantings in Australia, New Zealand, and South Africa. If the yellow passion fruit vines remain healthy for longer than this, considerable thinning out of lateral branches would probably be necessary to reduce the weight of vines on the trellis. It may also be advisable to thin out some of the canes to let in light and permit better air circulation, especially if there is a dense, tangled growth of vines.

If and when pruning becomes necessary to force growth, vines should be cut back on lateral branches rather than to the main stem. If spraying becomes necessary, or other developments make it advisable to prune passion fruit vines, the work should not be done during a drought or when the soil is very dry. If this precaution is not observed, pruning may kill or seriously injure the vines.

At present there seems no valid reason to recommend carrying out specific pruning practices except when it becomes necessary to facilitate spraying and harvesting or to force new growth.

FERTILIZING

The fertilizer recommendations given here for passion fruit will be tentative. They are based on observations of scattered fertilizer trials 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, with the second choice being a 10–10–10 analysis of fertilizer or fertilizers having a similar ratio. In newly transplanted orchards, the application should be a pound 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 growth. This will probably be in the month of February. The rate should be 2 pounds per plant.

The question of subsequent application of nitrogen will have to be determined by rate of growth of vines and general appearance of plants. If, in March or April, the plants are not making a vigorous growth, a pound of ammonium sulfate per plant should be applied. From our present knowledge it is believed that nitrogen fertilizers should not be applied after May 15.

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, lime has proved beneficial on very acid soils low in available calcium. In areas with pH below 5.5, where soil has a very low calcium content, lime should be applied. It can be worked into soil in a strip along the planting row or spread in a circle where plants are to be set and worked into soil. One pound per 10 square feet of area is recommended.

INSECT PESTS AND DISEASES

Insects and diseases which cause serious damage to the passion fruit are not numerous in Hawaii. The most troublesome pests are a red spider mite, Brevipalpus

Figure 3. Passion fruit vines damaged by red mites.
the Oriental fruit fly, *Dacus dorsalis*; the melon fly, *Dacus cucurbitae*; and the Mediterranean fruit fly, *Ceratitis capitata*. There are also a few other insects of minor importance. The only known serious disease of the passion fruit is one caused by a fungus, *Alternaria*.

**RED MITES**

The red spider mite is usually most damaging in areas of low rainfall and during prolonged dry seasons. Its effects first became evident in yellowing, shriveling, and falling of the leaves. With heavy or prolonged infestation, leaf fall increases and the vine has the appearance of dying back (fig. 3). At the same time, developing fruit may begin to shrivel and fall prematurely from the vine. Close examination will reveal the presence of mites as scattered reddish patches on the surface of fruit, particularly around the stem end and along the midrib and veins of the leaf, especially on the undersurface.

Unless damage from the red spider mite is checked, the vine may eventually die. The recommended control measure is to spray with wettable sulfur at the rate of 5 pounds per 100 gallons of water to which a proprietary sticker-spread has been added in the amount recommended on the label. When DDT is used for fruit fly control, which is discussed later, sulfur may be included in the DDT spray. Spraying should be done about every month as a preventive measure rather than only after damage has become apparent. If a first spraying is done because of an obvious infestation, two or three additional sprayings at intervals of about 10 days might be necessary to control mites hatching later.

**FRUIT FLIES**

The Oriental, melon, and Mediterranean fruit flies puncture the fruit while the rind is still tender. As the fruit enlarges, a woody area develops around the puncture. 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 continue on 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 does not impair the quality of the pulp. 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.

The relative importance of each of the three species of fruit fly appears to vary with the location of the vineyard. Rearing made from young passion fruits collected at Kahaluu, Oahu, yielded 64 adults which were all melon flies. However, fruit samples obtained at Waimanalo, Oahu, yielded 64 adults of which 75 percent were Oriental and 25 percent melon flies. The Mediterranean fruit fly was not observed in the field or reared from passion fruits from Kahaluu or Waimanalo. In view of its scarcity at the present time, it seems that this fly would not be a passion fruit pest in the lowland areas. It must be regarded as a potential pest, however, if the passion fruit is cultivated in high-elevation areas where this fruit fly occurs in numbers sufficient to cause damage.

One of the most important steps in controlling fruit flies is the elimination of overripe papaya, tomato, and other fruits in which the flies breed and on which the adults feed. The adults may be destroyed by use of various insecticides. DDT at the rate of 4 pounds of a 50 percent wettable powder (or parathion at $1/2$ to $3/4$ pound)
pound of a 25 percent wettable powder) per 100 gallons of water may be used. For best results these materials should be applied with a power sprayer. 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 fruit flies. The frequency of application varies with the abundance of flies. When adults are numerous, applications might be necessary twice a week during the period when fruits are young. In general, however, such frequent treatments may not be necessary. Treatments once a week or once in 10 days should be adequate. Experiments on the use of bait sprays containing protein hydrolysate and toxicants such as parathion or malathion are currently being carried out by the U.S. Department of Agriculture, Bureau of Entomology and Plant Quarantine. Promising results are being obtained. These will be made available in the near future in the form of recommendations to growers.

HONEYBEES

In some areas the honeybee (*Apis mellifera*) might be considered a pest in that it robs the flowers of pollen before the carpenter bee can effect pollination and thereby causes some unfruitfulness. At present it is not known how important this problem is. No recommendations have as yet been forthcoming as to how honeybees might be prevented from robbing flowers of their pollen.

APHIDS

Aphids are known to attack the passion fruit vine, although they seldom cause serious damage. Nevertheless, at least two species of aphids, *Myzus persicae* and * Macrosiphum solanifolii*, must be regarded as potentially important insects. These aphids, which are present in Hawaii, are vectors of the passion fruit woodiness virus disease in Australia. Fortunately, this virus disease does not occur in Hawaii.

CONTROL OF PESTS

In the control of insect pests which attack passion fruit we are confronted with two basic problems: first, the creation and preservation of conditions favorable to the carpenter bee, whose function in pollination is of vital importance to fruit set; and second, the destruction of insects which attack the plant. The problem becomes complicated because both beneficial and destructive insects are so closely associated with the plant. The timing of spray applications so that they are not made at the time when the passion fruit flowers are open and the carpenter bee is active is of importance in preserving the pollinating insects. Because the flower of the purple variety opens during the morning hours, for example, it might be desirable to spray during the afternoon hours at a time when the carpenter bee would less likely be found on the plant. In the case of the yellow variety, morning treatments might be of value because its flower opens during the afternoon hours and closes at night.

DISEASES

A fungus disease of passion fruit has been reported in Hawaii. Fruits affected by the disease have reddish-brown surface spots. The spots may be small or large and may or may not be sunken. Leaves may also be marked with spots 1/8 to 1

---

2 Precaution: Parathion is very toxic to humans and should be used with extreme care. It should not be applied with hand equipment as the hazard to the operator is very great. Refer to Extension Bulletin 57 for further precautionary measures.
inch in diameter. This disease, which is caused by a species of *Alternaria*, is thought to be the same as the brown spot disease of passion fruit in Australia. In Hawaii it is prevalent only during the rainy season. Australian horticulturists recommend spraying the vines with a 4-3-50 Bordeaux mixture. The Plant Pathology Department of the Hawaii Agricultural Experiment Station suggests that 2 pounds of Tennessee tribasic copper sulfate to 100 gallons of water plus a suitable sticker-spreader would probably give as effective control as Bordeaux mixture.

These are the insect and disease problems of the passion fruit. At present fruit flies and the red spider mite are the most serious pests. Fruit flies are the pests most difficult to control. However, they can be controlled, and there is no reason to believe that the presence of fruit flies will seriously limit passion fruit production.

**SELECTION OF FRUIT FOR PROCESSING**

By growing passion fruit to suit the processor’s requirements, the farmer will serve his own interests best. Buyers will want the fruit for juice extraction mainly and not for sale as fresh fruit.

The processor is paying for the amount of juice he gets. He wants high quality and quantity. Quality is measured in terms of flavor, color, sugar, acid and vitamin content, and other standards. Under laboratory conditions of partial hand extraction, 30 to 40 percent juice yields from whole fruit have been recovered.

Select and propagate fruit strains which tend to meet these standards. Detailed selection work requires considerable time and effort, but, when done well, insures a profitable crop. Following are some suggestions which will help in selection. Other factors will be given in the future when known.

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

3. Select first for flavor, or for characteristics such as size, thinness of rind, well-filled cavity, and yield of juice. It is considered best to select for flavor first, then for characteristics. 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. We hazard a guess that only about 5 percent of the vines will show these unusually desirable taste characteristics. The farmer should select and mark them.

4. Of those few vines selected according to the above suggestions, the farmer should choose those which show the best characteristics of growth. Observe a vine for several seasons, remember that pounds of juice recovered is the first criterion of choice, and select on that basis. A vine which sets heavily but produces little juice should not be selected.

5. Finally, having made the selections, make further plantings from cuttings and seeds. Cuttings are best for small acreages, seeds for the larger. Propagate several strains, not only one proved selection.

The work on selection for desirable strains is a never-ending one. The farmer, ever mindful of processors’ requirements, should continuously improve his stock with new selections.
Washing and grading of fruit. Spoiled fruit is discarded and underripe fruit is set aside for ripening.

Cutting of fruit and scooping out of juice and seeds from shell. Machines are being designed for these operations.
HARVESTING

In the management of a vineyard the harvesting of the crop is an expensive undertaking. The planning of the vineyard should be such as to minimize this cost. There are no data as yet on harvesting methods and cost, but our observations over 2 years on this particular problem will be given nonetheless, especially in relation to processors' requirement.

Generally, the practice of allowing the fruit to fall to the ground and of gathering it once a week seems to be a sensible one. A rake can be used effectively to collect the fruit in the drier regions and where the ground is not rocky. In wet regions it may be wiser to collect twice a week and keep the ground under the vines as clean as possible. Fruits that lie in wet grass for several days tend toward surface spoilage, which sometimes extends to the juice cavity. Fruits that have been subjected to surface spoilage present large problems to the processor who has to grade out the very bad ones and trim away the damaged areas. It is an important processing requirement that the fruit be clean and sound. In the harvesting, spoiled fruit should not be included with sound fruit, nor should half-ripe fruit be picked from the vines, because of the woody off-flavor of its juice. There will be some dropping of half-ripe fruit. The processor will have to grade these out and allow them to ripen. Green fruit should not be included, because these will not ripen normally. The dropping of green and half-ripe fruit may be a physiological problem. If fruit is picked from the vines, it is better to leave the stem intact on the fruit. If the stem is pulled away from the fruit, there is great danger

Oval fruits are 40 percent juice, round fruits are 30 percent juice.
Some of the passion fruit products with commercial possibilities. In foreground, frozen juice packed in polyethylene bags. In background, 6-ounce cans containing frozen passion fruit nectar base. On the right, fresh nectar consisting of juice, sugar, and water. Passion fruit juice may also be used in blends with the juices of pineapple, papaya, orange, grapefruit, and apple and in making sherbets and ices.

of fruit spoilage from mold and insects which enter the fruit cavity during storage. The processor may find that wash water has entered the fruit through the small opening made by the removal of the stem.

The fruit may be stored in wooden crates or bags and kept in a well-aerated, cool, and dry area. Fruit that comes in wet from the field should be given a chance to dry before being stored. It is not necessary to refrigerate the fruit that is to be held only a week or so. If refrigeration is necessary to hold the fruit for longer periods, we recommend storage temperature of 50-55°F. The fruit should not be stored wet, otherwise rapid mold spoilage may occur. Fruit stored at room temperature will, after a few days, begin to shrivel due to the drying out of the rind. There is no apparent damage to the juice, but there will be a significant loss in weight. There may be differences between the processor’s weight and the farmer’s weight of fruit because of this drying out. In one small experiment there was a loss of from 4 to 8 percent in weight in 4 days in fruit scored in closed paper sacks. Greater losses in weight may be expected in fruit stored in open crates or porous bags and held for longer periods.

REFERENCES

PARSONS, T. H. 1945. The cultivation of fruits in Ceylon with cultural details, VIII. CEYLON DEPT. AGR. LEAFLET 69: 1-8. (Revised 1945.)
Separating the juice from the seeds by use of a commercially available pulping machine.
University of Hawaii
College of Agriculture
Agricultural Extension Service

GREGG M. SINCLAIR
President of the University

H. A. WADSWORTH
Dean of the College of Agriculture and
Director of the Agricultural Extension Service

BARON GOTO
Associate Director of the Agricultural Extension Service