PAPAYAS IN HAWAII

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THE AUTHORS

The authors of **Papayas in Hawaii** are or were actively associated with the development and well being of the papaya industry in Hawaii. They are all members of the College of Tropical Agriculture, University of Hawaii.

The aim of the bulletin is to bring our wealth of knowledge of papayas to the grower or potential grower in order that he may grow papayas with the latest available information.

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PAPAYAS IN HAWAII

INTRODUCTION

The papaya (**Carica papaya** L.) is a very large, herbaceous plant native to tropical America. The exact place of origin is not known, but wild or semi-wild naturalized forms are often found in the tropical lowlands of Central and South America. Spanish and Portuguese sailors are credited with disseminating the papaya to other tropical and subtropical countries. Today, distribution of the papaya is said to extend to 32 degrees north and south latitude of the equator. Commercially producing areas are less extensive.

The date that the papaya was introduced to the Hawaiian Islands is not known. Some authorities say that it may have been brought in between 1800 and 1823 by Don Marin, the Spanish horticulturist who settled in Hawaii. Others believe that it came to the islands via Asia and the South Sea islands before the Europeans appeared here.

The papaya is a rapid-growing, hollow stemmed, short-lived perennial. It belongs to the family Caricacea, which includes four genera and more than 20 species of Carica native to tropical and subtropical America from Mexico to Bolivia. The tree can attain heights of 25 feet or more under favorable climatic conditions. It is usually single-stemmed and bears a crown of palmately lobed leaves. The base of the stem may grow up to a foot in diameter. Fruits are formed at the leaf axils and remain in place until after the lower leaves have fallen off. **C. papaya** is the only species that has attained commercial importance. None of the others is palatable as fresh fruit, although some species are cooked, stewed, or candied.

Table 1. Annual acreage planted to papaya, by islands and total State, 1956–1969[1]

Year	Hawaii	Kauai	Maui/ Molokai	Oahu	State[2]
1956	270	5	30	440	740
1957	410	7	45	390	850
1958	480	5	40	310	840
1959	630	3	35	230	900
1960	560	4	40	240	840
1961	600	6	50	240	900
1962	660	21	65	180	930
1963	830	50	55	130	1,060
1964	1,020	60	70	210	1,360
1965	890	55	65	160	1,170
1966	930	85	50	80	1,140
1967	1,110	130	65	80	1,380
1968	1,230	110	95	70	1,500
1969	1,240	90	100	65	1,500

[1]Source: Hawaii Crop and Livestocking Reporting Service, Honolulu, Hawaii.
[2]Sum of island estimates may not add to State totals due to rounding of State total.

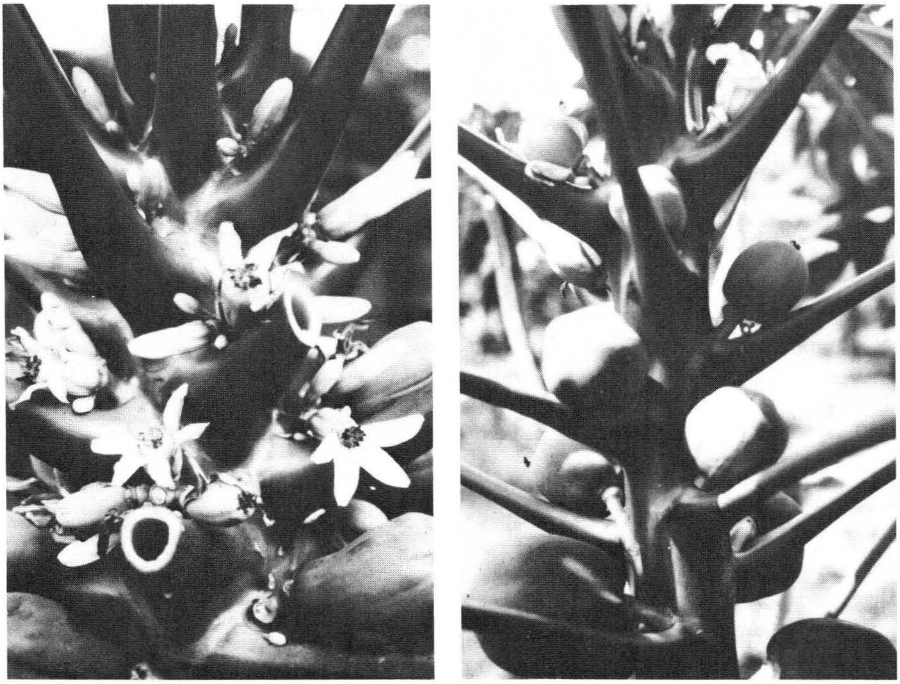
The first papayas introduced to the islands were the large-fruited types. Introduction of the Solo papaya from Barbados and Jamaica, on October 7, 1911, (accession no. 2853) by Gerritt P. Wilder resulted in a complete transformation of the Hawaiian papaya industry. This small papaya, which was named Solo in 1919, replaced the earlier large-fruited forms, and by 1936 the Solo was the only variety grown commercially.

The papaya is cultivated on all of the major islands of Hawaii (Table 1). The principal commercial producing area is Kapoho in the Puna District along the eastern coast of the Island of Hawaii. The Kapoho plantings are in areas at elevations from a few feet to about 300 feet above sea level. Before 1957, the center of papaya production was the Island of Oahu. The shift in production to Hawaii may be attributed to (1) the urbanization and the high cost of tillable land on Oahu, (2) ineffective control of diseases on old papaya farms, and (3) the availability of low-cost lands in Kapoho with fairly favorable growing conditions. In 1969, about 1,500 acres were in cultivation in the State. Since the beginning, the growth of the papaya industry has been slow, but the trend is towards continual expansion.

PAPAYA PRODUCTION

Varieties and Breeding

Solo is the predominant papaya variety grown by home gardeners and commercial growers in Hawaii. It produces two types of trees, the hermaphroditic or the perfect tree (Figure 1a) and the female tree (Figure 1b). The hermaphroditic tree produces the relatively small, pear-shaped fruit that is preferred by the grower and the consumer. The female tree produces round fruits and under Hawaiian environmental climatic conditions it is less productive than the hermaphroditic tree. The female trees may be found growing in home gardens but never in commercial orchards, where they are cut and removed. The fruits of the two kinds of trees are shaped differently, but the taste is the same.



(a) **(b)**

Figure 1. Common types of Solo papaya trees: (a) Hermaphroditic tree with young, elongated fruits and flowers; (b) female tree with young fruits and flowers.

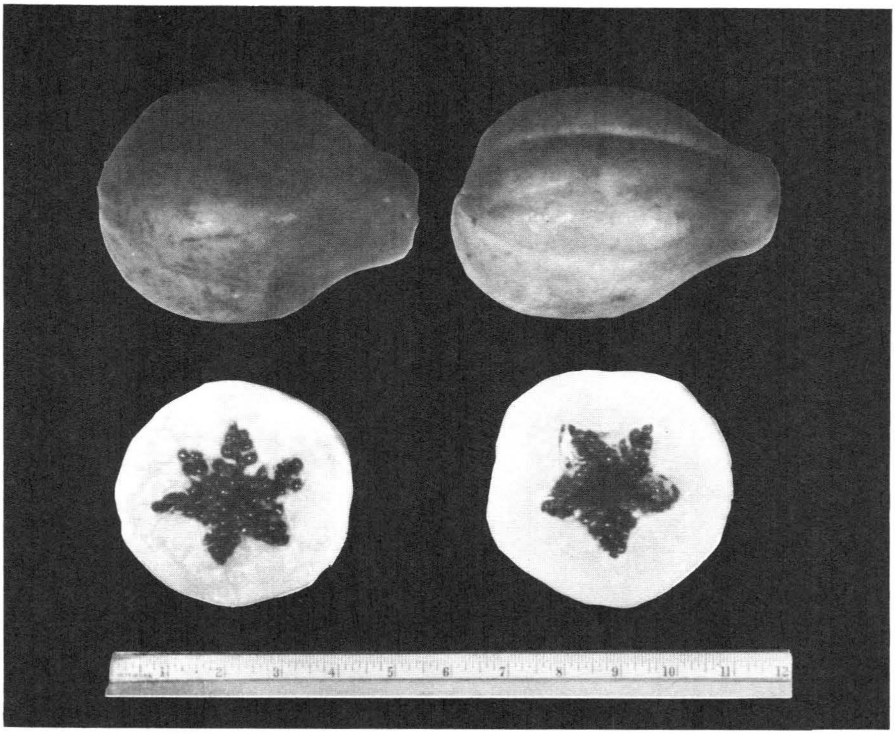


Figure 2. Major papaya strains: Line 8 and line 5.

Varieties

The Solo papaya is propagated from seeds that are largely self-pollinated. Breeding tests have shown that over 99 percent self-pollination occurs under Hawaiian field conditions. The continual selection of self-pollinating Solo strains has facilitated the production of seeds giving uniform progenies. In commercial Solo plantings, the absence of male trees of other papaya varieties eliminates the danger of cross pollination.

The seeds of the Solo variety are produced in a ratio of 66⅔ percent hermaphrodites or plants with pear-shaped fruits, and 33⅓ percent females or plants with round-shaped fruits. Thus, all commercial growers plant two or more plants in each hole. As soon as the flowers appear on the trees and the sex of the trees can be determined, one hermaphroditic tree is selected to grow and the rest are removed.

Various strains of Solo have arisen as a result of selections made in commercial orchards. These strains are adapted to specific locations or to areas with similar environmental conditions, such as rainfall and temperature. Planting a strain in a different ecological setting can result in severe sterility, catfaces or carpellody, or change of fruit size.

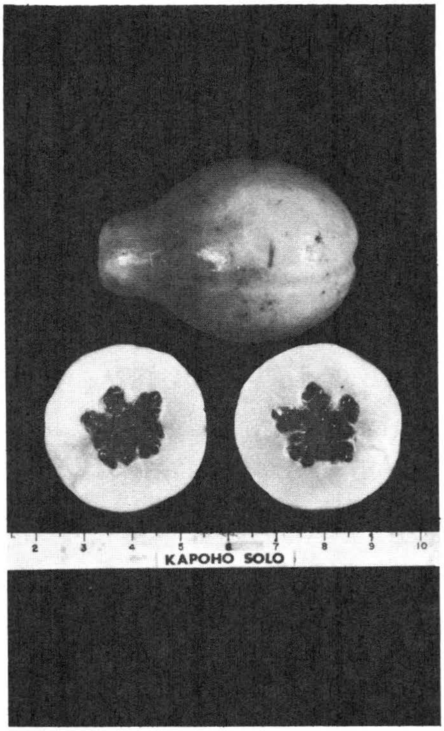


Figure 3. Kapoho Solo strain.

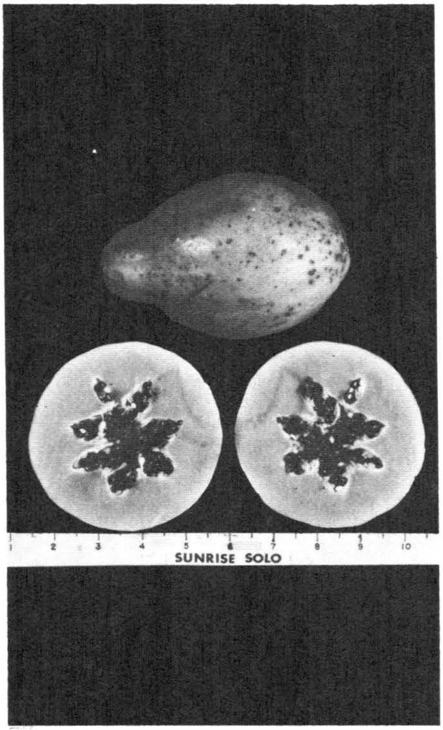


Figure 4. Sunrise Solo strain.

The major strains being cultivated are:

Line 5 and Line 8 (Figure 2). These are improved Solo strains selected on Oahu by researchers of the Hawaii Agricultural Experiment Station at the University of Hawaii. Line 5 was released to the public in 1947-1948, while Line 8 was distributed to the growers in 1954. Both are highly inbred Solos with desirable plant characteristics and fruit of high quality and uniformity. The fruits range in weight from 16 to 32 ounces and have a star-shaped seed cavity. Line 8 fruits are smoother and less furrowed than Line 5 fruits. Both strains produce large and soft-fleshed fruits suited for the local market. Flavor and flesh quality are excellent. Plantings of these strains are limited.

Kapoho (Figure 3) **and Masumoto Solo.** These are Solo strains with small fruits 14 to 28 ounces in weight. They were selected for producing firm, small fruits suitable for export to distant markets. These strains were developed on Hawaii and are grown primarily in the eastern part of the island where the annual railfall averages more than 100 inches. The seed cavity is round to star-shaped and the fruits are fairly smooth. When planted in dry areas, the fruits are exceptionally small. Kapoho is the most widely grown strain in the islands.

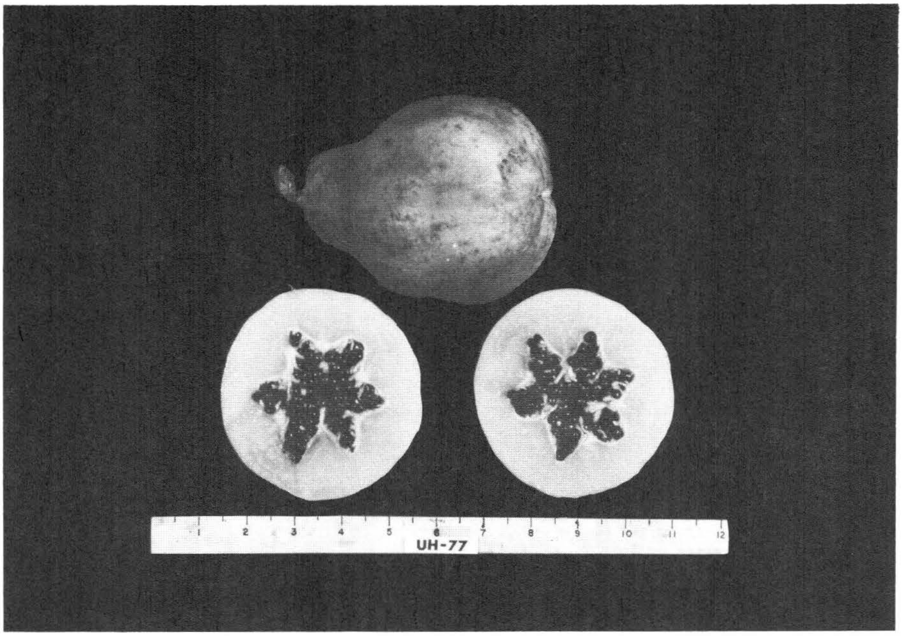
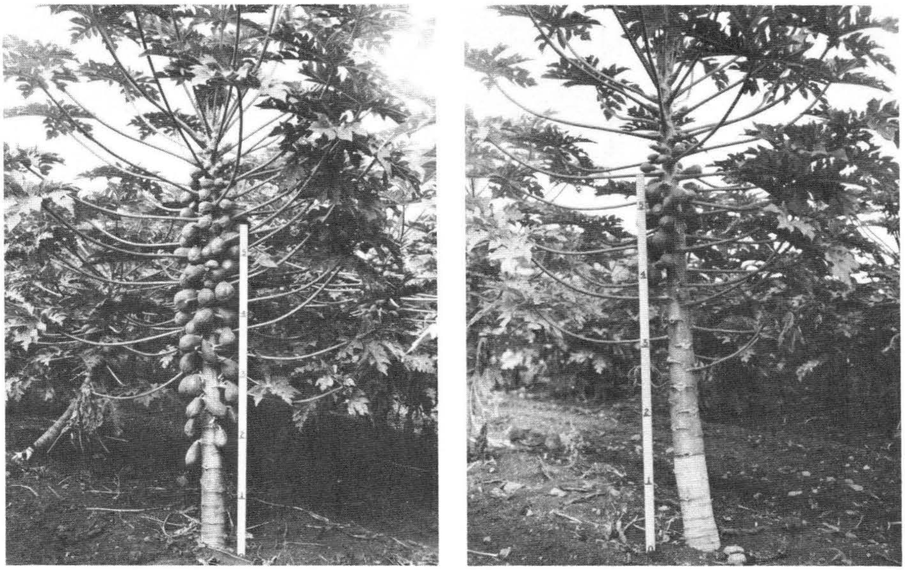


Figure 5. Waimanalo strain, with orange-yellow flesh.

Line 10. This is an inbred Solo strain producing small fruits averaging 19.7 ounces in weight. Line 10 was was released in Pahoa, Hawaii, for trial plantings because of the exceptionally uniform size of its fruit and its bearing behavior. Carpelloid fruits are seldom produced and sterile periods (skips in production) have not occurred when cultivated in Pahoa. The fruits are similar to the Kapoho Solo and are therefore recommended for planting in areas with a similar environment.

Sunrise Solo (Figure 4). The Sunrise Solo is a new, improved, high-quality selection with reddish-orange flesh. It is an inbred strain resulting from a cross between Line 9 or Pink Solo with the yellow-fleshed 'Kariya' Solo strain of Oahu. The fruits produced at the Poamoho and the Malama-ki experimental farms averaged 15 and 22 ounces respectively. The fruits are sweeter than Line 9, smooth in appearance, firm, and pear-shaped.

Waimanalo (Figure 5). This is a newly bred, high-quality variety with orange-yellow flesh, resulting from crosses between the Betty variety of Florida and the Line 5 and Line 8 Solo strains. The fruits are round with a short neck. When grown at the Waimanalo Experimental Farm the average height to the first flower was 32 inches compared to 60.7 inches for Line 8. Waimanalo fruits range in weight from 16 to 39 ounces; they are smooth and



(a) (b)

Figure 6. Bearing height of 10-month-old trees: (a) Low-bearing experimental strain; (b) Line 8 Solo tree.

shiny and have a star-shaped cavity. The flavor is good and the flesh is thick and firm. It has been grown on Oahu for the last six years and has replaced most of the other commercial strains.

Breeding

The breeding of improved papaya strains in Hawaii has been directed toward developing varieties suitable for the export fresh fruit market and for processing. In addition to flesh texture and sugar content, size is the major difference in the breeding criteria of these two types. The fresh fruit market prefers a fruit size from 16 to 25 ounces, while the processing industry prefers a large size from 32 to 48 ounces.

Factors considered in breeding are high yield, uniformity in fruit size and shape, thickness and firmness of flesh, attractiveness of flesh and skin color, small size of cavity, high sugar content, freedom from unpleasant odors, absence of carpellody and sterility, and resistance to diseases.

Besides incorporating desirable attributes into a variety, the breeding program is aimed at removing undesirable traits. Perhaps the most difficult characteristics to reduce or eliminate are carpellody and sterility. "Carpellody" refers to the abnormal development of the stamens into carpel-like, fleshy structures. In other words, the stamens become part of the fruit. This results in misshapen "cat-face" fruits, which are unmarketable (Figure 7).

Figure 7. "Cat-face" or misshapen fruits. Proper selection of seeds can reduce this problem.

Often, carpellodic fruits may resemble female fruits. Carpellody appears to be influenced by environment. It occurs especially in strains that are produced in areas with warm temperatures, then replanted in areas of cool temperatures.

"Sterility" refers to that phenomenon in which normally productive hermaphroditic trees change into a condition of maleness. Instead of producing hermaphroditic flowers, only male flowers are produced. Warm and dry weather appears to encourage this expression of sterility.

Different strains of papaya possess different degrees of sterility and/or carpellody. The removal of these undesirable characters by breeding is difficult. The Solo variety has a lower degree of both factors than many other varieties because of the many years of selection and inbreeding. Under field conditions, carpellody and sterility can easily be increased by a poor selection of trees for seeds. Hence, the growing of heavy-bearing trees with good-quality fruits depends on the individual grower's ability to select the best seed trees.

Ecological Factors

Soil

The papaya tree is able to grow on many different soils. The most important requirement is that the soil should have good drainage and be properly prepared before planting. At present, 90 percent of the papaya in the State is grown in rocky, volcanic soil called **aa**, a type of soil in the Lithosols group. **Aa** is composed primarily of porous lava with a limited amount of volcanic ash and weathered rock material and some organic matter. The casual observer would consider these lands very rocky and infertile. However, the **aa** soils in the Kapoho area are cultivated because of their loose and porous characteristic and because of the favorable growing climate of the area. Kapoho has environmental factors conducive to good growth, such as warm temperatures the year 'round, good exposure to sunlight, mild winds, and rainfall of 100 inches or more which is fairly well distributed during the year. Generally, the favorable ecological factors plus a well-managed fertilization program can make the **aa** lands of Kapoho highly productive.

The low humic latosols found on all islands are also farmed extensively and considered excellent for papaya production. With an economical source of irrigation water and good cultural practices, areas with low humic latosols are well adapted for growing high-quality fruit. These soils are red or reddish brown and are located in areas with annual rainfall ranging from 15 to 60 inches a year. They occur from sea level up to about 2,000-foot elevations. It is a common mistake of new papaya growers and many home gardeners to overlook the value of preparing and keeping these soils well aerated and free of compaction. This is necessary for normal tree development so that the root system has ready access to water and nutrients.

The Catano loamy sand, a mixture of alluvial material and sand, has been used for papaya production in the past. A typical section is Kailua on the Island of Oahu. Excellent crops of papayas have been harvested in these areas. Normal production in this soil group requires the constant use of organic material, such as barnyard manure, and the addition of minor elements, such as iron, zinc, and copper, as plant nutrients. Also, frequent irrigation is needed to prevent the trees from wilting because this soil has a low moisture-holding capacity and moisture in the soil is rapidly lost through evaporation.

Most soils in which papayas are grown are acidic, with a pH factor ranging from 4.5 to 6.0. As a result, liming is recommended to raise the soil pH to 6.5 to 7.0 and to supply calcium to the plant. Liming affects the composition of the soil such that the soil is less acid and nutrients that are fixed in the soil become more readily available. It also lessens the toxic effects of manganese in high-manganese soils, stimulates the decomposition of organic matter, and often increases crop yield. Because soils differ in the amount of lime needed to obtain a given change in pH, the soil should be tested. In Hilo and Pahoa, Hawaii, the quantity of lime needed may range from 1 to 3 tons per acre. In Waimanalo and Kaneohe, Oahu, the amount recommended may range from 0 to 2 tons per acre.

Water

The moisture required to grow papaya differs in each location, depending on the ecology of the area. Rainfall, temperature, light, wind, soil type elevation—all of these environmental conditions play an important role in determining the amount of moisture needed to keep the papaya tree in good productive condition. The age of the tree is also important in determining moisture requirement. Young papaya seedlings need more moisture than older trees, which can maintain normal growth with little moisture because of their slower rate of vegetative growth. In addition, the root system of older trees is more extensive and the tree is able to absorb available moisture more readily. In irrigated orchards, young papaya seedlings are irrigated about once or twice a week, whereas older bearing trees may be irrigated every other week.

Research shows that young bearing papaya trees in Waimanalo, Oahu, can utilize about 2½ acre-inch of water (1 acre-inch=27,000 gallons) every 10 days during the summer and fall of the first year and every 14 days during the following year. The long interval between irrigations was feasible partly because the dark magnesium clay in the area has a high moisture-holding capacity.

Although bearing papaya trees do not need water as critically as small seedlings, it is important that the tree has ample water at all times. Lack of moisture over any prolonged period will slow down growth and encourage the production of a number of male or sterile flowers. The result is that fewer fruits are set on the tree.

The papaya is adapted to a wide range of rainfall conditions. On the parts of Oahu where the industry was concentrated in the past, the annual rainfall is less than 60 inches. In Puna, Hawaii, where the industry is now concentrated, the annual rainfall is more than 100 inches. Papayas are able to grow well in high-rainfall areas like Puna because of the highly porous nature of the "**aa** soils."

In the high-rainfall and humid sections of the State, the fruits produced are larger than those grown in the low-rainfall sections. The Kapoho Solo fruit averages about 21 ounces when grown in Puna. The same strain grown at Puunene, Maui, or at Waimanalo and Ewa, Oahu, averages less than 16 ounces. Similarly, new papaya strains selected at Waimanalo for their small size have produced fruits that are too large for the market when grown in Puna.

Temperature

All commercial plantings of papaya are now located in areas that are considered warm, mainly on lands from a few feet to 500 feet above sea level. The papaya can grow and produce fruit at higher elevations where the temperature is lower, but fruit quality is usually poor. Also, the sugar concentration of papaya fruits in the winter months is lower than in the summer months. The refractometric dry solids present, an indication of sugar content, showed as much as 3.5 percent difference between seasons at Waimanalo.

The temperature of a locality influences the type of flowers and fruits formed on a tree. With some commercial Solo strains, a decrease in temperature results in a decrease in the amount of marketable fruits produced. Research has shown tremendous differences in a papaya plant's response to temperature. At Kainaliu, Hawaii, at 1,500-foot elevation where the mean minimum and the mean maximum temperatures were 59.9 degrees F. and 76.1 degrees F., respectively, a Solo strain produced 99 percent deformed or carpellodic fruits. In Waimanalo, Oahu, at 100-foot elevation where the mean minimum and the mean maximum temperatures were 69.7 degrees F. and 80.8 degrees F., respectively, the same Solo strain produced only 12 percent carpellodic flowers and fruits, all of which occurred during March to July. Since temperature changes can affect papaya fruiting so greatly, a Solo strain adapted to one area may not be recommended for production in another unless ecological conditions of the two locations are similar.

Wind

Papaya trees can withstand winds up to 50 miles an hour if the tree has a deep, well-developed root system. Nevertheless, windbreaks are necessary where strong winds prevail and can damage leaves, thus hampering growth and fruit production. Wind accompanied by rains can loosen and break roots sufficiently to cause the papaya trees to fall, resulting in severe losses to the commercial grower.

In Kapoho, Hawaii, wind protection is provided by natural tree borders of ohia lehua **(Metrosideras collina),** which are allowed to grow between papaya fields (Figure 8). Growers in Waimanalo and Kahaluu, Oahu, have used windbreaks of the seedy banana **(Musa balbisianum)** or the Brazilian banana. The coral hibiscus **(Hibiscus schizopetalus)** is often used as a supplementary windbreak. The Cunningham ironwood **(Casuarina cunninghamiana)** is well adapted to papaya-growing areas of low rainfall and should serve as good windbreaks in large papaya orchards. New strains of koa haole **(Leucaena glauca)** (Figure 9) such as K-28 or K-8 are also effective in impeding air movement.

The distance between windbreaks varies with the location. Where winds blow horizontally across the orchard, a common rule of thumb is to have the strips of windbreaks spaced at distances of 20 to 30 times the height of the windbreak trees. For instance, trees attaining a height of 10 feet can give protection to a 200- to 300-foot strip of land. Where winds come in different directions and angles, it may be necessary to have windbreaks half as close. The individual's knowledge of the area is the best guide in determining the spacing between windbreaks.

In general, a good windbreak acts as a permeable rather than a solid wall against winds. A permeable windbreak allows some of the air to pass through it. The result is less wind eddying on both sides of the windbreak and a lower velocity of air movement through the orchard.

Figure 8. Brush and ohia lehua (Metrosideros collina) left as a windbreak in Hawaii papaya orchard.

Figure 9. Koa haole (Leucaena glauca) is used as windbreak at Waimanalo, Oahu.

Growing Papaya Trees

Field Preparation

Undeveloped **aa** lands in the Kapoho area on Hawaii are usually forested. Before planting, the land must be cleared of ohia, guava, fern trees, and other vegetation. Bulldozers are used to clear and grade the land, then a heavy roller is pulled over the **aa** to level the surface. This is followed by making furrows with a two-way plow, a line-cutter, or similar equipment attached to a tractor. One-foot-wide holes or basins are made in the furrows for the papaya seeds or seedlings. In fields with too many rocks, furrows cannot be made. Here, direct seeding in the field may proceed without furrows.

The preparation of an orchard with soil other than **aa** follows a pattern similar to that of cultivated orchards on **aa.** The field is cleared of vegetation, leveled, then plowed and harrowed. This is followed by making furrows in the field with a two-way plow for the papaya seedlings and for irrigation. Holes are then dug alongside the furrows for the papaya seedlings.

Planting

Papaya plants are usually started with seeds from the ripe fruit that have been dried. The seeds are planted in the field, in seed flats, or in individual pots. Fresh seeds can germinate within 10 or 14 days if there is adequate moisture and heat. Tests have proven that if the gelatinous envelopes (sarcotestae) surrounding the seeds are removed, germination is better and faster. Seeds not to be planted immediately are kept in a cool, dry room. There are about 27,000 seeds per pound, which should be sufficient for 10 acres or more depending upon the seeding practice. One tablespoon contains about 200 seeds.

Orchards in Kapoho and in similar locations with **aa** soil are started by planting the seeds in the prepared field. Five or more seeds are placed in a planting hole or a shallow basin formed by removing some of the rocks. The seeds are then covered with ¼ inch or more of the very dark brown or almost black silt or silty clay loam soil that is present. In some locations there is very little soil present, so soil is brought and placed in the holes where the seeds are to be planted. A large number of seedlings is grown in each hole to insure against losses that may occur because of damage from birds, cutworms, mice, and slugs. Old orchards that are replanted usually harbor a large number of these pests. About two months after sprouting, seedlings are thinned to two or three plants.

Aa lands are seeded directly because the soil is rocky and porous, which makes present methods of transplanting difficult. If seedlings were removed from the usual metal containers and transplanted into the orchard, the lack of frequent showers following transplanting could result in the plants drying up before they have a chance to establish themselves. Recent trials by the University has shown that papaya seedlings can be successfully transplanted and established in **aa** soils if the seedlings are grown in peat pots. The peat pots are not removed at transplanting, so the roots of the seedlings are not damaged in transplanting and the plants are in better condition to withstand short, dry periods. This technique eliminates some of the early field maintenance costs and pest problems encountered in direct seeding of orchards. An additional benefit is that in a replant field where root diseases and the digging of basins for the seedlings are not major problems, growth is more uniform in a transplanted than a direct-seeded orchard.

Many growers on Oahu, Kauai, and Maui start their papaya seedlings in a seed flat or in individual containers. The seed flat may be 12 inches wide, 15 inches long, and 3 inches deep. The flat is filled with soil to about 1 inch from the top, and seeds are broadcast or spread out over the soil. A layer of soil ¼ inch or more thick is spread over the seeds to cover them. A week after the seeds have germinated, the seedlings are transplanted into individual pots or cups.

Growers may plant papaya seeds in individual containers, using paper cups, empty beverage cans, or any other container of appropriate size. Two or more seeds are placed into each container filled with soil. After the seeds have germinated, the plants are thinned to allow one seedling to grow.

Soil that is used for germinating seeds should be steam-sterilized or treated with a chemical such as methyl bromide to destroy disease-causing organisms that may affect seedling growth. In place of soil, vermiculite has been used successfully for germinating seeds by growers who do not have access to a steam-sterilized soil or do not wish to work with chemical sterilants.

Planting Distances

Planting distances depend on contour of the land, location, and climate. The degree of mechanization in the orchard and the size of fruit desired are other factors determining planting distances. Close spacing results in smaller fruits. In most instances, spacing between trees is closer within rows than between rows. Some of the more widely practiced planting distances and the approximate number of trees per acre are:

Distances	No. of Trees/Acre
6 feet within rows, 9 feet between rows	806
7 feet within rows, 9 feet between rows	691
7 feet within rows, 11 feet between rows	565
8 feet within rows, 10 feet between rows	544
9 feet within rows, 10 feet between rows	484

Trees may be planted in blocks with 12-foot or wider roadways between the blocks to facilitate the movement of harvesting, spraying, or fertilizing equipment. The blocks may consist of any number of sections of two, three, or four rows.

Transplanting

When transplanted from seed flat to individual pots, the seedling should be at the first two-leaf stage or about one week old. Young seedlings are best transplanted because they tend to produce a better root system and do better after field transplanting. Fifty percent or more shade should be provided to keep the newly transplanted seedlings from wilting before becoming established in the pots. The shade may be removed in stages two weeks after transplanting. Two or three weeks after the shade is removed the seedlings should be ready for field planting.

If the soil is dry, the furrows should be irrigated two or more days before transplanting the seedlings into the orchard. This allows the soil in the furrow to settle and provides enough moisture for the seedlings at the time of transplanting. Holes are dug alongside the furrow to accommodate two or three seedlings. The seedlings are then placed in the hole at a level slightly deeper than they were in the pots and set into the soil as firmly as needed to keep the plants in place. A small handful of general fertilizer should be spread in a circle on the soil surface about 4 to 5 inches from the main stem of the plant. As soon as transplanting is completed, the newly set seedlings should be irrigated. For fertilizing directions, see "Fertilization" below.

Thinning

The seedlings of papaya planted directly in the field are thinned from one month to six weeks after seed germination. All except two or three of the strongest seedlings in the hole are pulled out. The plants that are saved are those that are spaced far enough from one another to allow minimum competition for sunlight and nutrients.

The second and final thinning in the field occurs as soon as the papaya flowers appear and are large enough to determine if the tree is hermaphroditic or female (Figure 10). At this stage the trees are about five months old. Only one hermaphroditic papaya tree is selected to grow per planting hole. If all the seedlings in a planting hole develop into female trees, they are removed and new seedlings are transplanted there.

Fertilization

Factors such as soil type, rainfall, location, cultural practice, and age of plant influence fertilization practices. In **aa** soil fertilization begins when the seeds are planted in the field. A small handful (2 to 4 ounces) of a complete fertilizer, such as 10–10–10, either in the granular or pelleted form is spread in a circular band around the seeds. Other formulations of complete fertilizer such as 2–24–2 are also used. About 35 pounds per acre is applied at this time. As the papaya seedlings grow larger, more fertilizer is applied. A survey of farms in Kapoho showed that growers use 40 or more pounds per acre during the second month, 75 or more pounds during the third to fifth month, and 300 pounds or more per month thereafter.

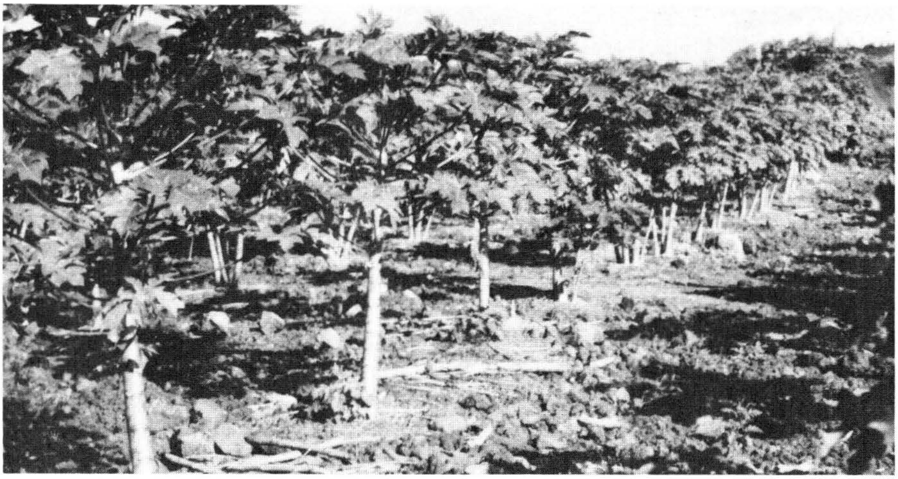


Figure 10. Foreground: Five-month-old seedlings grown in aa soil being thinned to one plant per hole as soon as sex of the trees is determined. Background: Unthinned section of orchard.

Research by the Hawaii Agricultural Experiment Station shows that in Kapoho, the 10–10–10 formulation applied at the rate of 1 pound per tree per month is desirable for continual high production of bearing trees. If the grower wishes to decrease the amount of fertilizer used, 1 pound per tree may be given for the first six months after the sex of the tree has been determined and ½ pound per tree per month thereafter.

Fertilization in soils other than **aa** may begin by applying ½ to 1 pound of superphosphate or any comparable phosphate fertilizer in the planting hole. The fertilizer is mixed with the soil at the bottom of the hole before the papaya seedlings are transplanted. Finally, about 4 ounces (a small handful) of a complete fertilizer such as 10–10–10 or 10–20–20 is spread on the soil surface in a circular band placed about 3 to 5 inches away from the seedlings to prevent injury. The more cautious grower would wait about five or more days after transplanting before applying the complete fertilizer.

The frequency of fertilization varies with the individual farmer, ranging from monthly applications of 1 pound of a complete fertilizer per plant to 2 pounds per plant every two or three months. In a bauxitic[1] soil that has never been planted into crops, it may be necessary to broadcast and plow in phosphorus initially because of the low level and high rate of fixation or immobilization of phosphorus. As much as 500 pounds per acre of elemental phosphorus may be necessary to obtain normal tree growth. The County Extension Agent should be consulted and the soil analyzed before planting.

[1]A soil high in aluminum oxides common in the latosolic soil groups with high phosphorus-fixing capacities. Phosphorus is fixed or immobilized by reacting with the soluble aluminum to form highly insoluble aluminum phosphates.

The use of plant tissue analysis to determine the fertilizer requirements of the papaya tree is not a widespread practice yet. Research studies are being conducted at the University to determine the optimum needs of the papaya tree through this method. Tissue analysis of plants from one of the most productive papaya orchards of Kauai (in Kapahi) showed the petioles or leaf stems taken from the most recently opened flower to be composed of: Nitrogen, 1.30; phosphorus, .164; and potassium, 5.20 percent on a dry-weight basis. The soil pH in this orchard was 5.9. Analysis of the most recently matured petiole of papaya trees grown in the gray hydromorphic soil of Waimanalo shows that approximately 1.28 percent nitrogen is needed for maximum yields. In the **aa** lava soil of Puna, 0.25 percent phosphorus gave the best yields. The best time for sampling of the petiole is from June through September.

Thinning Papaya Fruits

Papaya fruits are thinned at the time of harvesting or when time is available. The undersized and the deformed fruits are removed as soon as possible. Thinning is especially necessary in orchards where fruit tend to pack tightly on the stem or where trees have a tendency to produce carpellodic fruit. Trees with long fruiting peduncles have less of a fruit removal or thinning problem than those with short peduncles because there is more room for full development of the fruit. The amount of thinning or removal of fruits varies with the strains of papaya grown. Hence, it can be reduced to a minimum by proper seed selection.

Weed Control

Weed control in papaya orchards consists of pre-plant, pre-emergence, and post-emergence treatments. Pre-plant treatment is the application of herbicide on the field before the crop is planted. Pre-emergence treatment is the application of herbicide before the weeds have emerged from the soil. Post-emergence treatment is the application of herbicide after the weeds have emerged from the soil.

Pre-plant weed control in **aa** orchard is done by spraying 60 to 80 gallons of paraquat spray mix per acre or other approved herbicides about five weeks after the land has been prepared for seeding. In five weeks the weed seeds near the surface germinate and are killed by this first spray application. Where the soil can be tilled, pre-plant treatment with chemicals is not practiced but weed control is obtained by plowing and harrowing. After the first plowing and harrowing, the field may be left unplanted until the weed seeds germinate. Then the field is plowed and harrowed again, after which the papaya rows are made and seedlings planted. Some growers plow and harrow the field a third time before transplanting the papaya seedlings into the field.

Pre-emergence weed control in papaya orchards is not commonly practiced in Hawaii. However, research at the University of Hawaii and in Queensland, Australia, has shown that reasonable weed control can be obtained with a pre-emergence herbicide treatment for as long as six months without much damage to the papaya plants. It is anticipated that pre-emergence weed

Figure 11. Post-emergence weed control in a papaya orchard with a knapsack sprayer containing an herbicide.

control will become standard practice as soon as the appropriate herbicides are cleared for use in papaya orchards by the Food and Drug Administration of the U.S. Department of Agriculture.

Post-emergence weed control in bearing orchards is a standard cultural operation (Figure 11). Until recently, aromatic oil or an aromatic oil emulsion made with pentachlorophenol was used on weeds in papaya orchards. These spray materials have been discontinued as a post-emergence spray. In its place, Paraquat with a surfactant such as X-77 or Tergitol is being used. One to two quarts of Paraquat with about 8 ounces of a surfactant in 80 to 100 gallons of water per acre is sprayed to emerged weeds. The dilution rate for home gardeners is 2 to 4 teaspoons of Paraquat to ½ teaspoon surfactant in one gallon of water. Paraquat spray can cause injury to the green, immature trunks of papaya trees so it should be used with caution, especially on windy occasions. The interval between sprays is approximately 5 to 6 weeks. A knapsack sprayer or a power sprayer is used to apply the weedicide. Twenty to 40 pounds per square inch of pressure should be adequate for effective application. Since small papaya seedlings are very sensitive to chemical sprays, the weeds close to the papaya seedlings are not sprayed but are pulled out by hand or removed with a hoe. In areas with distinct wet and dry seasons, the time interval between sprays may be as long as two months during the dry season.

Harvesting

Harvesting is a simple operation when the papaya trees are short and the fruits may be reached by hand by an individual on the ground. All fruits showing a tinge or more of yellow at the apical end of the fruit are picked and placed in a picking bag, a plastic container, or a galvanized pail. They are then hauled to the packing shed by trucks. During the cool months when the fruits ripen slowly, the papayas can be left on the tree to develop more color before harvesting to obtain optimum flavor development without causing additional post-harvest handling problems. Fruits that are left on the tree with more than ⅓ color have a shorter shelf life and are more susceptible to fruit fly infestations.

As soon as the papaya trees grow tall enough that the picker cannot reach the fruits from the ground, harvesting aids must be used (Figure 12). A modified plumber's helper, which is used by most growers, a step ladder, and a bin or enclosed platform are the aids used.

The plumber's helper is modified by taking off the handle and replacing it with a bamboo pole about 8 or more feet long. The picker places the rubber cup against the bottom of the papaya and pushes the pole upward with one hand. This action snaps the papaya from its stem causing the fruit to fall. The fruit is caught with the other hand as it falls and placed in the galvanized pail or the picking bag. Using this method, an experienced picker can harvest about 800 to 1,000 pounds a day.

The bin method of harvesting is used in conjunction with the tractor and requires a tractor driver and one or two pickers (Figure 13). A bin or enclosed platform is built, large enough to hold one or two men and several boxes of papayas. The tractor furnishes the power to lift the bin to the fruiting level of the tree so the harvester in the bin can pick the papayas easily. This method is used only on level or gently sloping land.

The step ladder is also used to reach the high papaya fruit by some of the small growers. It is a tedious, time-consuming, and costly method of harvesting.

Yield

In commercial orchards, the papaya tree is usually cultivated for three years. After three years the trees are usually too tall for economical harvesting. However, the development of new harvesting methods can extend the production cycle a year or two longer, thereby increasing the total yield of an orchard before it is abandoned.

Papaya trees begin to produce marketable fruit before the end of the first year after planting the seed. Estimated figures from Kapoho growers show an average potential yield of 38,000 pounds per acre the first year of production and 25,000 pounds the second year. Estimated figures from growers in other areas are about 20 percent lower, attributable to the use of marginal lands, unfavorable climatic factors, poor cultural practices, and the build-up of diseases in soil that have continuously been planted to papayas.

Figure 12. Harvesting fruits with a modified plumber's helper in Kapoho, Hawaii.

Figure 13. Harvesting fruits with a raised platform in Waianae, Oahu.

Experimental yields on new fields in Kapoho, Hawaii, and in Wailua, Kauai, show that 50,000 pounds or more can be harvested during the first year of production.

Cost of Producing Papayas

The cost of growing papayas varies considerably among growers due to many factors. Climatic and physical factors determine to a large extent the expenses required to clear the land, the amount of weed control required, and the optimum amount and kinds of fertilizer to be applied. Such factors as management and cultural practices also affect fruit yield and thus contribute to the differences in gross returns to growers.

The management and cultural practices used by growers are more uniform for papaya production than for many other crops, but they still vary to some extent from farm to farm. In the last 10 years, the number of large plantings has increased. In general, large farms have lower overhead costs per unit output, since their capital costs are spread over a larger number of acres and a larger volume of fruit. The small growers appear to have a certain cost advantage in that management and labor on the farm are performed by one person. However, what the small producer often considers net returns from growing papayas also includes returns to management.

The presence of both large and small producers in the papaya industry makes it difficult to describe typical costs. The costs shown here depict the situation as it might exist on a 10-acre farm located in an area such as Puna. The cost pattern described below is based on cultural practices recommended by the University of Hawaii College of Tropical Agriculture.

COSTS OF GROWING PAPAYAS[2]

Per acre	
$ 45.00	Lease rental on land for 3 years
237.90	Interest and depreciation on buildings and equipment

Depreciation Straight Line	Interest Av. Invest-ment @ 6%		
$ 30.00	$ 18.00	Building:	400 sq. ft. used for packing fruit and storing supplies. Rough wood construction. Life: 20 years. Cost: $600.
300.00	90.00	Trucks:	½ ton pickup, (old used) 2½ ton. Life: 10 years. Cost: $3,000.
325.00	30.00	Equipment:	150 crates, 4 knapsack sprayers, miscellaneous hand tools. Average life: 3 years. Cost: $975.
$655.00	$138.00		

Total interest and depreciation on a 10-acre farm for one year $793. Interest and depreciation per acre, per year $79.30. Interest and depreciation per acre for 3 years (normal life of planting) $237.90.

75.00	Indirect and miscellaneous costs: gasoline, oil, lubrication of machinery, bookkeeping, stationery, obtaining supplies
180.00	Land clearing and rolling: done on contract for $180 per acre.

[2]All costs and returns per acre are for a 3-year period, the normal life of a papaya planting.

OPERATIONAL COSTS—LABOR AND MATERIALS

Per acre	
$ 40.00	Layout orchard and dig holes: 25 man-hours @ $1.60 per man-hour
32.00	Plant and mulch: 20 man-hours @ $1.60 per man-hour
25.60	Thin seedlings: 16 man-hours @ $1.60 per man-hour
12.80	Plant thinning: 8 man-hours @ $1.60 per man-hour
383.20	Weed control:

Man-hours for weed control

(a) Preplanting spraying = 6 man-hours

(b) Spraying every two months 1st through 33rd spraying @ 6 man-hours (17 applications) = 102 man-hours

(c) Time spent preparing materials and equipment = 4 man-hours for crop

Total man-hours weed control: 112 man-hours

Cost: 112 man-hours @ $1.60 = $179.20

Materials for weed control

(a) Preplanting spraying = 60 gallons of Paraquat spray mix

(b) Spraying every two months 1st through 33rd spraying (17 applications) of 60 gallons

Total gallons of paraquat mix sprayed: 1,020 gallons

Cost: 1,020 gallons @ 20 cents per gallon = $204.00

624.09 Fertilizing:

Monthly Application No.	Man-hours	Pounds 10–10–10
1st	9	35
2nd	8	40
3rd	7	75
4th	6	75
5th	5	75
6 through 33rd	112 (4 hrs./time)	8,400 (300 lbs./time)
Total 33	147	8,700

Labor cost: 147 man-hours @ $1.60 = $235.20

Material cost: 87 cwt. of 10–10–10 @ $4.47 = $388.89

Per acre	
$ 980.88	Pest control: Three sprayings per month starting with the 6th month of growth. Spraying consists of 5 pounds of wettable sulfur and 2 pounds of Dithane M45 per 100 gallons of water. Fifty gallons of mixed spray are used per application. **Man-hours for pest control** 95 applications, 5 man-hours per application Total man-hours 475 @ $1.60 per man-hour = $760.00 **Materials used for general pest control** (does not include pest infestations): Sulfur 2½ pounds per application, 93 applications = 232½ pounds @ $ .15 = $34.88 Dithane M45 2 pounds per application, 93 applications = 186 pounds @ $1.00 = $186.00
800.00	Harvesting: Yield 63,000 pounds of papaya (life of planting: 3 years) 500 man-hours @ $1.60 per man-hour
310.40	Packing (field): Yield 63,000 pounds of papayas 194 man-hours @ $1.60 per man-hour
$3,746.47	TOTAL COST of production per acre for 3 years
.059	Cost of production per pound of fruit produced

PAPAYA MARKETING

The State of Hawaii produced 19 million pounds of papayas in 1969. The principal market for the papayas is Honolulu. A gradual change is taking place in papaya marketing with an increasing amount of fresh fruit being shipped to the mainland United States.

The Honolulu Market

During the past few years, Honolulu has used about 12 million pounds of fresh papaya annually. Most of this fruit comes from the Island of Hawaii to Honolulu in 25-pound lugs. The volume that reaches the market fluctuates with the season and is larger during the late spring and summer months and shorter during the fall and winter months. Correspondingly, the price decreases with an increase in fruit supply and increases with a decrease in supply. Papayas are channeled into the market by the producer or his representative (1) through the jobber to the wholesaler, then to the retailer; (2) through the wholesaler[3] then to the retailer; or (3) through direct sales to the retailer. The sales to wholesalers by the producers have been on a consignment basis but there is a movement towards outright cash sales. The normal commission charged by handlers is 20 percent.

Honolulu is the only market in the state capable of handling a large volume of fresh papayas. As a result, the wholesale price of papayas is largely determined by the wholesale market in Honolulu. Prices reach a peak during the late winter when production is low and competition from season fruits such as peaches, plums, and cantaloups is also low.

The cost of transporting papayas to Honolulu from the neighbor islands differs with method of shipment, volume of shipment, origin of shipment, and carrier. Air freight costs per pound of fruit are 3 cents from Hilo to Honolulu for shipments over 500 pounds and ½ cent for shipments over 10,000 pounds. Maui and Kauai shipments to Honolulu are 2.25 cents for a load of 500 pounds or more and 1.85 cents for a load over 10,000 pounds. Ocean freight rate from Hawaii is about $7.65 per pallet and the rate from Maui and Kauai is $7.36 per pallet. The net fruit weight of a pallet of 56 lugs is approximately 1,400 pounds.

The Mainland Market

Before 1948, shipments to mainland markets were negligible (Table 2). In 1952, 5 percent of the fruits produced was shipped to the mainland. In 1969, 31 percent or about 7.6 million pounds were exported. In the first quarter of 1970, roughly 3 million pounds were exported. Exports are expected to continue to increase because of improved transportation facilities, lower freight rates, new markets, improved handling practices, better marketing methods, and increased demand for papayas on the mainland. Initially, ocean shipment was the only means of transporting fruits to the mainland United States. In 1961, curtailment of ocean shipments because of disturbances in the maritime industry forced producers and shippers to use air cargo services

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[3]The wholesaler may also be a jobber to accommodate other wholesalers during periods of shortages or surplus.

Table 2. **Shipments of fresh papayas to the mainland United States from Hawaii, 1948–1969**[1]

Year	Ocean Shipments	Air Shipments	Total
	1,000 pounds		
1948	2	..	2
1949	28	..	28
1950	286	..	286
1951	313	..	313
1952	331	..	331
1953	774	..	774
1954	1,853	..	1,853
1955	955	..	955
1956	1,568	..	1,568
1957	2.457	..	2,457
1958	2,430	..	2,430
1959	2,125	..	2,125
1960	1,059	..	1,059
1961	1,816	907	2,723
1962	95	3,209	3,304
1963	22	3,164	3,186
1964	88	4,342	4,430
1965	76	4,823	4,899
1966	337	4,971	5,308
1967	702	6,522	7,224
1968	150	7,726	7,876
1969	12	6,020	6,032

[1]Source: Market News Service, Hawaii State Department of Agriculture, United States Department of Agriculture, Honolulu, Hawaii.

as an alternative. Since then most shipments of fresh fruit have been sent via air freight.

Air shipments have stimulated papaya exports and decreased the time lag between the producer and the consumer. Faster delivery service has resulted in high-quality fruit, less spoilage, and a longer shelf-life at the retail market.

Currently, most papayas are shipped in 10-pound cartons to mainland markets. The number of fruits in the carton varies from 9 to 13. A 15-pound carton is also being used by the shippers. The papayas are shipped directly from Hilo or from the neighbor islands to Honolulu and then transshipped to the mainland United States. Direct air shipments from Honolulu or Hilo to the West Coast is 6 cents per pound for shipments of 15,000 pounds or more. In comparison, surface shipment rates are about 2½ cents for 14,000 pounds or more and 1¾ cents for 24,000 pounds or more.

Fruits marketed on the mainland are much smaller in size than those sold in Hawaii. They are sold by the piece and average 12 to 16 ounces in weight.

On the other hand, in the islands papayas are usually sold by weight and weigh as much as one or more pounds, although a few stores are now selling papayas by the piece. According to a recent mainland study papaya sales at the retail stores are affected to a greater degree by such factors as available supply, condition of the product, shelf position in the store and display rather than price changes. Current retail prices in the West Coast cities ranged from 29 to 79 cents apiece, with 39 cents each the prevailing price.

The Japanese Market

After four years of negotiation, exports to Japan were initiated in April 1969. Approximately 73,000 pounds were shipped by air and 7,000 pounds by ship. Air freight cost was 30 cents per pound. The retail price of fruits was about $2.00 per pound. This was brought about principally by the high import tariff which raised the C.I.F. (cost-insurance-freight) of papayas.

Processed Papaya Products

The sale of processed papaya products has been limited with little change in the volume of sales during the past 10 years. The quantity shipped out of the State to the mainland U.S. and foreign countries amounts to a million pounds annually. Canned nectar comprises 65 percent of the processed products exported. Frozen papaya puree, juice, nectar base, canned balls, chunks, and slices make up the remainder of the products exported.

Papain, the proteolytic enzyme from the green papaya, is being sold as a meat tenderizer. However, it is not being manufactured in Hawaii because of the high cost of labor, the low yields of 50 to 70 pounds dried papain per acre, and competition from other proteolytic enzymes such as bromelin. Moreover, the Solo papaya, grown primarily for the fresh fruit market, is a poor variety for papain production.

Papayas can be used in canned tropical fruit mixes. Processors in the Philippines, Australia, and Taiwan have been selling products of this type. A similar product was processed in Hawaii, but the high cost of raw materials made it uneconomical to continue its manufacture.

Treating and Packing Papayas

Fresh papayas must be treated to destroy the fruit flies that may be present in the fruits before being shipped out of the State. This is a quarantine regulation necessary to prevent the insects from infesting and damaging mainland crops. Two approved disinfestation methods are now used for export fruits: vapor heat and fumigation. More papayas are fumigated than vapor heat-treated.

The quarantine requirement for vapor heat treatment is that the temperature in the center of the papaya fruit must be brought up to 117 degrees F. under saturated conditions (100-percent relative humidity). When this temperature is attained, the treatment is considered concluded with no stipulation as to time required to reach this temperature. However, to obtain postharvest disease control, a minimum time of four hours is recommended.

Figure 14. Packing papayas for shipment to the U. S. mainland after hot water and fumigation treatments. (Photograph courtesy Mr. Papaya.)

Since papayas do not tolerate the treatment well, they should be "pre-conditioned" just before treating to increase tolerance to the vapor heat. The pre-condition treatment is not a quarantine requirement. It consists of subjecting the fruits to dry heat (about 40-percent relative humidity) at about 110 degrees F. for 6 to 8 hours.

After the vapor heat treatment, the fruits are cooled with circulated air, then packed in a corrugated carton with shredded paper in a screened area to prevent reinfestation. The packed and sealed cartons are then trucked to the ship and loaded into the ship's reefer, or they may be loaded into a refrigerated container for surface shipment at about 50 degrees F., or they may be shipped by air. If it is necessary to hold the packed fruits before shipping, they are held in storage at about 50 degrees F.

In the fumigation method, the fruits, packed in open field-lugs, are fumigated with ethylene dibromide at a dosage of ½ pound per 1,000 cubic feet of fumigation chamber space for 2 hours at a minimum fruit temperature not lower than 70 degrees F. This is done under the supervision of a quarantine official. The treated fruits are then packed with shredded paper in a corrugated carton and sealed in a screened area (Figure 14). Whether shipped by surface transportation immediately or held in a reefer the packed cartons should be held at about 50 degrees F.

Before fumigation, papayas are immersed in hot water at 120 degrees F. for 20 minutes, then cooled in running tap water for 20 minutes (Figure 15). This hot water treatment, developed by the College of Tropical Agriculture, helps control storage diseases. It is a post-harvest operation not required by quarantine regulations. However, tests have shown that the

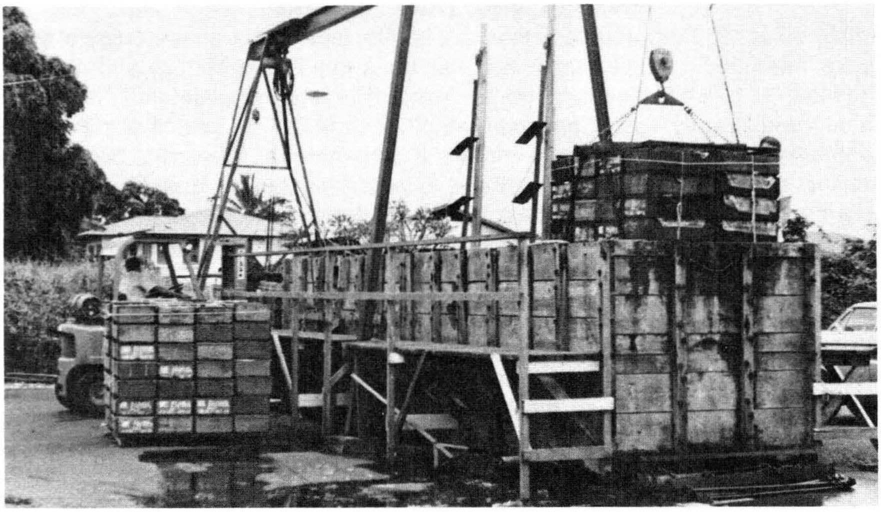

Figure 15. Hot water treatment of papayas to control storage decay (Photograph courtesy Mr. Papaya.)

hot water treatment can reduce storage decay to about 5 percent when the orchard infection rate by diseases such as anthracnose is higher than 25 percent and to 0 percent when the orchard infection rate is less than 25 percent. Aroma and taste are not affected by the treatment.

Irradiation

Gamma irradiation with radioactive cobalt at a dose of about 25 krad[4] has been found very effective in controlling fruit flies in Solo papayas. When combined with the hot water treatment to control storage decay, irradiation at a range of 75 to 100 krad increases the marketable life by about three days. Studies are now in progress to obtain clearance from the U.S. Food and Drug Administration that gamma-irradiated papayas are safe for consumption. If approved this treatment may replace the current disinfestation treatments for export fruits.

Controlled Atmosphere Storage

The shelf-life of papayas can be extended further by controlled atmosphere storage in which the concentration of oxygen in the storage container is kept at a low level by mixing nitrogen with air. Storage in 1- to 1.5-percent oxygen during the surface transit period will give the hot-water-treated fumigated papayas an additional salable life of at least one day. Similarly, the shelf life of hot-water-treated irradiated fruits will be extended about two days if stored in 2- to 4-percent oxygen.

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[4]Krad or kilorad is a unit of measurement of absorbed dosage of gamma irradiation.

DISEASES AND THEIR CONTROL

Plant diseases comprise a major economic factor in papaya culture and require adequate control measures that must be intensified as production increases. In Hawaii, diseases are an especially serious problem. They can reduce yield greatly and impair marketability of fruit. The principal diseases of papayas are caused by fungi, viruses, and nematodes. Diseases of papaya were the subject of Hawaii Agricultural Experiment Station Bulletin 136. The following is a brief, up-to-date discussion of the major diseases of papaya.

Fungus Diseases

Anthracnose

If uncontrolled, anthracnose can be the most serious disease affecting papaya in Hawaii (Figure 16). In this disease, the fungus **Colletotrichum gloeosporioides** attacks not only the fruit on which it causes the most damage, but also the petioles of the low, older leaves that begin to turn yellow.

The first symptoms of anthracnose usually are small, round, water-soaked areas on ripening portions of the fruit. As the fruit ripens, these spots enlarge rapidly, forming circular, slightly sunken lesions. These lesions enlarge as the fruit matures and may become 2 inches in diameter. The fungus frequently produces large, light-orange or pink masses of spores in the center of the lesions. Sometimes, the spores are produced in concentric rings, giving the lesions the appearance of a bull's eye. In addition to producing this surface damage, the fungus also advances into the fruit. In the early stages the affected portion can be lifted from the healthy fruit as a hemispherical plug. Later the tissue rots, becoming soft and somewhat dark-colored.

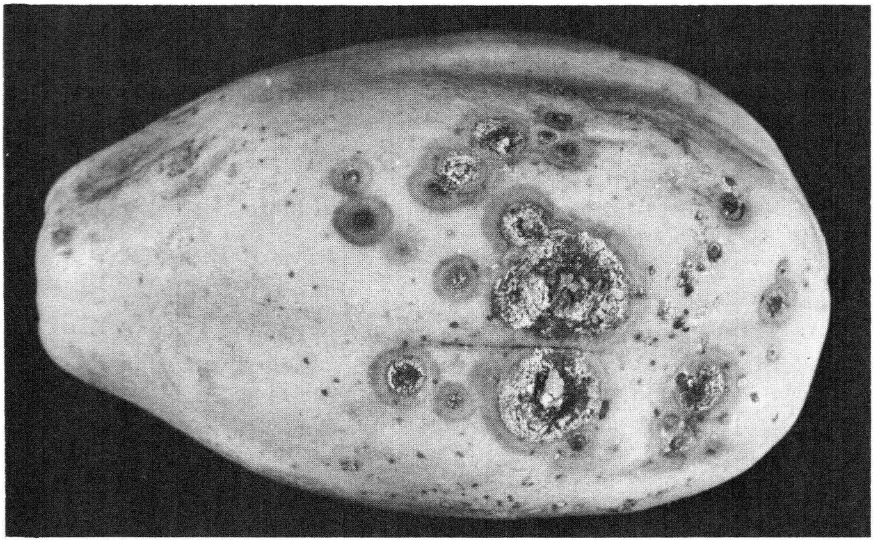


Figure 16. Anthracnose disease caused by Colletotrichum gloeosporiodes.

Occasionally green portions of the papaya may become affected with anthracnose. The disease first appears as small, water-soaked lesions. Soon after the fungus penetrates the fruit, the latex in the papaya oozes out in sticky mounds or horns. These lesions enlarge very slowly and rarely become larger than ½ inch in diameter as long as the fruit remains green.

The fungus causing anthracnose on fruit also attacks the petioles of lower leaves as they begin to die and are shed from the plant. Infections on these petioles are important since they may act as a source of inoculum for infection of fruit.

Control

Control of anthracnose can be achieved only by means of a thorough and continuing spray program. How frequently the papaya must be sprayed depends on the amount of disease present and the weather. Ten-day spray intervals usually gives good control, but when weather conditions are favorable for disease development—that is, high temperatures coupled with high rainfall—, it may be necessary to spray every seven days. Dithane M-45 at the rate of 2 pounds per 100 gallons of water or 4 teaspoons per gallon water gives excellent control. Fungicides containing copper also give good control. (However, copper may be injurious to the fruit.) A spreader-sticker, such as Triton B-1956, should be added to the spray.

Papayas grown in drier areas are usually not as badly affected with the fungus than those planted in high-rainfall areas. Decay occurring in storage after harvest can be materially reduced by the hot-water treatment as shown in Figure 15.

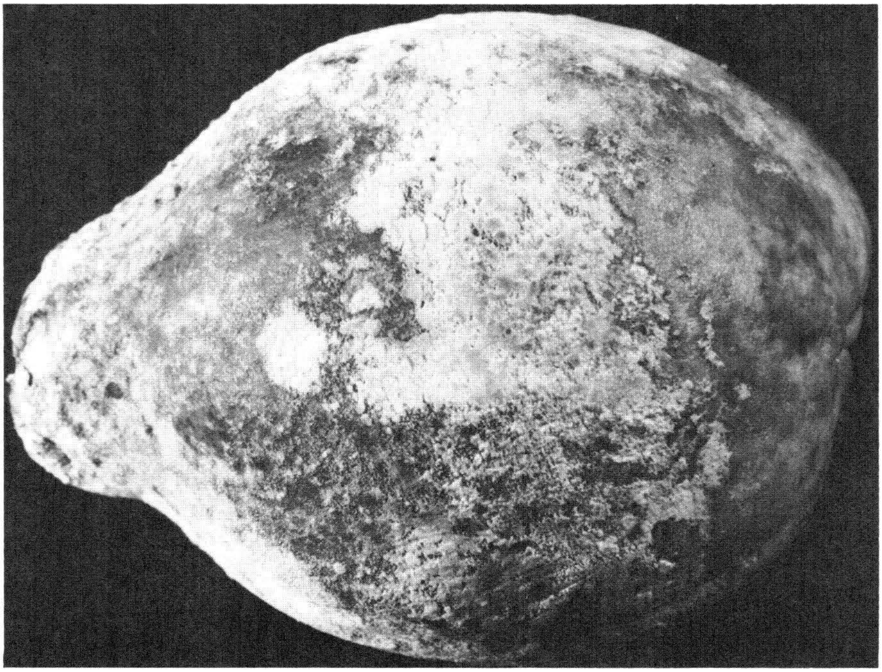
Phytophthora Blight

Phytophthora blight of papaya, caused by **Phytophthora palmivora,** was first identified as a serious fruit- and stem-rotting disease in Hawaii in 1940 (Figure 17) and is still one of the most serious problems in all papaya-producing areas in Hawaii. The fungus usually parasitizes the above-ground portions of the papaya plants, but it may also cause root rot, damping-off of young seedlings, and cankers of the stem at the soil line.

The most common symptoms associated with Phytophthora disease are found on the stems and fruit. Small, water-soaked, discolored spots may occur anywhere on the stem around fruit or leaf scars, but they are found primarily in the region of fruit production. These infected areas enlarge and often completely girdle stems of young trees. Green fruit are resistant to infection but can be invaded through wounds or through the peduncle from stem cankers. Mature fruit may become infected with **Phytophthora** as the fruit hangs on the tree. As the disease progresses, the fruit shrivels, turns dark brown, becomes mummified, and falls to the ground. Mummified fruits are a reservoir for the fungus and a source of inoculum for further infection.

A whitish fungal mass develops on the rotting fruit and stems in which large quantities of specialized spores, known as sporangia, are found. Rain or wind carry these sporangia to healthy parts of the plant where, in the

(a)



(b)

Figure 17. (a) Phytophthora blight of tree caused by Phytophthora palmivora infecting the root system. (b) Phytophthora blight of fruit caused by Phytophthora palmivora.

Figure 18. Powdery mildew caused by Oidium caricae growing on the undersurface of leaves. Note the powdery material near the large veins of the leaves.

presence of water, they germinate and produce large number of swimming spores, known as zoospores, which start the disease. These zoospores may infect and invade non-injured leaf tissue, stems, or fruit.

Control. Immediate removal and destruction of infected plants and fruits from the orchard will aid the control of this disease. Protectant sprays of 2 to 4 pounds of basic copper sulfate per 100 gallons of water during the wet seasons will help reduce the incidence of this disease. Dithane M-45, used as for anthracnose control, may be sprayed also. Planting of papayas in dry areas is also helpful in lowering the extent of injury by this fungus.

Powdery Mildew

Powdery mildew of papaya is caused by **Oidium caricae** (Figure 18). This fungus does not penetrate the fruit but is found on the undersurface of leaves, withdrawing nutrients from the cells of the leaf surface by specialized absorbing structures, known as haustoria.

Patches of whitish, powdery material found on the underside of diseased leaves are the main body of the fungus, and they are associated with the discolored spots found on the upper surface of the diseased leaves. At the infection spot, the leaves show blotches of yellow or pale green, usually near the veins, surrounded by normal-colored tissue. Early, less conspicuous symptoms consist of tiny, pale-yellow spots near the veins. These spots look somewhat water-soaked. The fungal mass growing on the underside of the leaf produces chains of spores which are carried by wind to healthy leaves. These spores germinate, send haustoria into the leaf, develop a fungus vegetative body, and reproduce the disease cycle. Occasionally, the fungus may attack the stems and petioles of young seedlings that are growing under reduced light. The stems have the typical powdery growth, and under severe attacks the top portion of the seedling may die.

Control. Powdery mildew may be controlled by spraying wettable sulfur at 5 to 6 pounds per 100 gallons of water. Caution should be taken in hot weather, since sulfur may injure papaya at temperatures above 90 degrees F.

Replant Problem

Planting papayas repeatedly in the same field in Hawaii presents a disease problem that has loosely been termed "the papaya replant problem." Papayas planted in fields for the second or more time may decline slowly or, in severe cases, die or fail to start. The difficulty in establishing papaya in old papaya land is a particularly serious problem. Experimental data collected implicate fungi, such as **Phytophthora palmivora** and **Pythium aphanidermatum.** When high populations of the fungi exist in the soil they easily parasitize the roots of the new plants and reduce the vigor of the plants.

Frequently, factors other than diseases may cause a replant problem in directly seeded orchards. Examples are improper cultural practices, lack of moisture in the soil, excessive moisture in the soil, and damage by insects on young seedlings. These factors are often confused with the replant problem caused by fungi.

Control. The effectiveness of corrective measures on soils when the replant problem exists varies. Crop rotation or fallowing, field sanitation (removal of papaya residue), and planting orchards in new areas have been the principal means of avoiding the replant problem. With the exception of planting new orchards, none of these methods has been entirely successful or applicable to all situations, and better control measures are needed. The use of fungicides in the soil such as captan has not been found effective in the aa soils of Kapoho, Hawaii, where most of the papayas are planted. Presently, the addition of virgin soil to planting holes shows promise as a means of reducing loss in the Kapoho area.

Black Spot of Papaya

Black spot of papaya is caused by **Cercospora papayae.** The leaf spots are grayish-white, roughly circular to irregular in shape, from 1/16 to ¼ inch in diameter. Heavily infected leaves turn yellow and dry up. The fruit spots start as tiny, water-soaked spots which turn black and enlarge to 1/32 to ⅛ inch in diameter. The tissue just beneath the epidermis of the fruit becomes corky; the spot does not develop into a fruit rot.

Since black spot causes leaves to drop, it results in a significant reduction in yield. Fruit spots, even when the incidence is high, do very little damage to the fruit. However, they detract from the appearance of the fruit and thereby affect marketability.

Control. Unlike anthracnose, black spot of papaya fruit cannot be controlled by dipping the picked fruit in hot water at 120 degrees F. A spray program to control **Cercospora** in the field is imperative. (See section on Anthracnose for field control methods.)

Damping-Off of Seedlings

Damping-off disease is a condition in which the tissues of the papaya seedling stems at the soil-line become water-soaked and collapse due to the growth of fungus in these tissues. The emerging young seedlings rapidly dry out and die. Young seedlings are very susceptible to damping-off and become resistant to this disease as they become older. A number of fungi, including **Pythium aphanidermatum, P. ultimum, Phytophthora palmivora,** and **Rhizoctonia** sp., can cause damping-off of papaya seedlings. These fungi live in the soil. The disease is particularly severe in warm, wet weather and is more severe when seedlings are crowded.

Control. It is important to know that the fungi causing damping-off are found in most soils and that the disease is favored by certain conditions. High temperature and wet weather have already been mentioned as conditions favorable to the disease. Other conditions encouraging development of damping-off include wet soils, poor drainage, deep planting of seeds. thick planting of seeds, poor soil aeration, and high levels of available nitrogen in the soil. Any practice to minimize these conditions will help control the disease. Once damping-off has started in a bed, little can be done to save the infected plants. Thus, the soil must be treated before planting to rid the soil of the fungi that cause damping-off. This may be accomplished by sterilizing the soil with steam at 180 degrees F. for 30 minutes or by fumigating the soil with methyl bromide at 1 pound per cubic yard of soil.[5]

Rhizopus Fruit Rot

Fruit rot caused by the fungus, **Rhizopus stolonifer,** differs markedly from that due to the fruit-rot fungus, **Phytophthora palmivora. Rhizopus** invades injured mature fruit only and does not usually cause rot in sound uninjured immature fruit. **Phytophthora** on the other hand, has the ability to invade and cause disease in uninjured tissue of fruit of all ages. **Rhizopus** causes a soft water rot and under conditions of high relative humidity produces masses of visible black sporangia. **Phytophthora** causes a firm rot and there is no leakage of cell fluids from the rotting fruit as is common with **Rhizopus infection.** The sporangia of **P. palmivora** produced on the rotting fruit are not visible except with a microscope.

Control. Since uninjured fruit is not affected by **Rhizopus,** caution should be used during picking, transporting, and packing operations so as not to bruise or otherwise injure the fruit. Hot-water dip at 115 to 120 degrees F. for 20 minutes described in the section Treating and Packing Papaya has been shown to be effective in killing the fungus on lightly-infected fruit. The sporangia of the fungus are killed by the high temperature of the water used in the dip. Rotting fruit in the packing sheds should be removed and destroyed. They are a source of spores which are windblown and settle on healthy fruit to start infection.

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[5]Manufacturers' recommendations on exposure and aeration should be adhered to rigidly.

(a)

(b)

Figure 19. Papaya mosaic, a virus disease. Note (a) fruit and (b) leaf symptoms.

Stem-End Rot

Stem-end rot is a disease of old or mature fruit. It usually occurs after picking and is primarily a post-harvest problem. A dry, firm, dark rot extends into the fruit starting at the stem end. **Ascochyta** sp. and other fungi have been shown to be the causes of the disease.

Control. Control measures to date have not been successful but it has been observed that fruits picked with part of the peduncle attached to the fruit do not become diseased.

Virus Disease

Two virus diseases identified in Hawaii are papaya mosaic and papaya ring spot. Papaya mosaic causes more damage than ring spot, is prevalent on Oahu, and is a constant threat to the growers.

Papaya mosaic

An outbreak of the papaya mosaic virus disease was first encountered in 1959 in Waimanalo, Oahu. By 1961, the disease had spread rapidly and had restricted papaya growing in many commercial orchards on Oahu. Presently, the mosaic disease is very destructive; losses ranging from 5 to 20 percent are common in many orchards but losses as high as 75 percent have occurred. The disease has also been found on the Island of Hawaii.

Symptoms. Initially, the leaves develop a rugose appearance. The undersides of the leaves show thin, irregular, dark-green lines which appear to etch the borders of cleared areas along the veins. The younger leaves of the crown are generally stunted and severely chlorotic with veins banding or transparent oily areas are found scattered over the leaf or along the leaf veins. In mature leaves, the chlorotic pattern frequently is a light color between the veins, accompanied by numerous small rings ranging from transparent yellow to tan in color (Figure 19a). In severely affected trees, defoliation progresses upwards until only a small tuft of leaves remains at the crown (Figure 19b).

Stem and petiole. On the stems of infected plants are found pinpoint-sized, water-soaked pimples. As the infection progresses, these water-soaked spots may develop into linear or, in some instances, distinctly concentric ring patterns which become more intense in color and larger. On the petioles the water spots are more irregular in distribution, lineal in shape, and at times more elliptical than on the stems. They are also generally lighter in color than those of the stem. In severe infections petioles are stunted and may bend downwards.

Fruits. Distinctive symptoms occur in all stages of fruit maturity, although fruits infected at approximately one-half maturity or more usually do not exhibit conspicuous symptoms. Small, dark-green ringspots, 1/16 inch in diameter, have been observed on fruits as young as about two weeks old. Typically, rings appear either on the stem or blossom end. The rings at first may be incompletely closed and irregular. As the fruit develops, target-like spots develop and increase in diameter from 1/16 inch, consisting of only one ring, to about 1 inch, with as many as eight or more distinct, slightly raised, concentric, brownish rings with a green outside ring. On ripe fruits there is no mottling of colors as found in papaya ringspot disease.

Transmission. The papaya mosaic disease is readily transmitted mechanically at a rate of 70 to 80 percent. The mosaic disease is also readily transmitted by the green peach aphid, **Myzus persicae.** Symptoms of the disease normally appear 18 to 24 days after inoculation. Plant species susceptible to papaya mosaic virus are primarily in the family Cucurbitaceae, including cantaloupe, cucumber, squash, pumpkin, and watermelon, although in India a mosaic virus of papaya has been transmitted to **Impatiens,** the common nasturtium, and sunflower.

Control. At present, it is not possible to obtain complete control of papaya mosaic. The only satisfactory way of controlling mosaic is by destroying the source of the virus, a difficult accomplishment because the disease is widespread. Once infected, a tree will always remain infected. Complete recovery from the disease does not occur. Partial recovery is only apparent and temporary. A roguing program including the following steps may be helpful:

(1) Spray all infected trees with an insecticide so that aphid carriers are destroyed.
(2) Cut all infected trees and remove them from the growing area of papaya and cucurbitaceous plants, so that the disease cannot spread and all infected plant parts will dry out and die.
(3) Avoid nearby cultivation of all cucurbitaceous plants since the virus is found naturally in several species in this plant family.
(4) Control aphids with pesticides since they are the disease carriers.

Nematode Diseases

Two nematodes recognized as pathogens of papaya are the reniform nematode **(Rotylenchulus reniformis)** and the root-knot nematode **(Meloidogyne** sp.). Root-knot nematodes have not been found to limit Hawaiian papaya production.

Reniform Nematode

The reniform nematode is a serious pest where papaya is grown on soil other than in lava. Stunting of the trees as well as yield reduction has been noted in the field.

Symptoms. Unlike the root-knot nematode, the reniform nematode does not cause swelling or retardation of the root. The presence of the nematode in the root may be detected by observing the small grains of sand-like

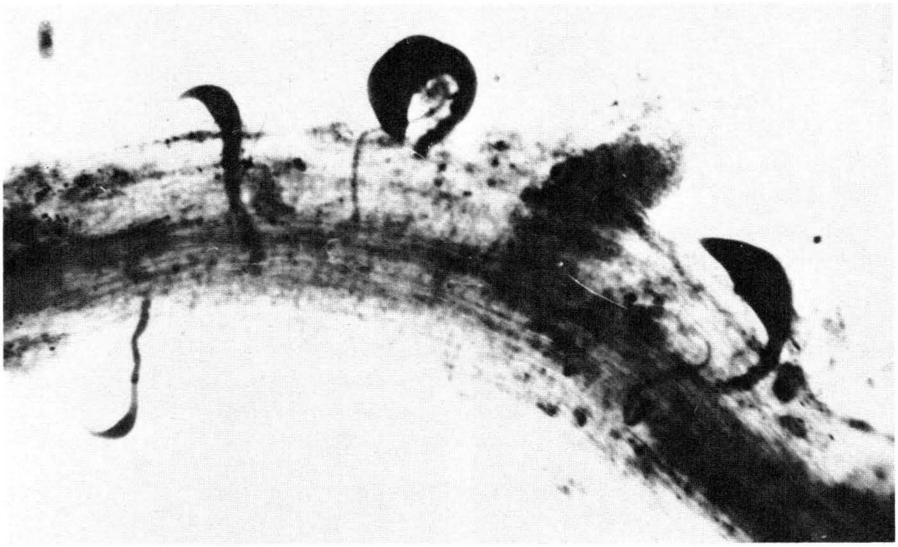


Figure 20. Reniform nematodes parasitizing a papaya root.

bodies (Figure 20) which remain attached when the root system is carefully washed.

In heavy infections the above-ground symptoms are similar to those of root-knot nematode on papaya. The trees of infected plants are sensitive to stresses and wilt more readily than non-infested ones. Fruits are smaller and may be tasteless.

Causal agent and life history. Nearly 100 host species for the reniform nematode **(Rotylenchulus reniformis)** have been reported. Many cultivated plants as well as weeds are hosts for this worm. The larvae are able to move short distances in undisturbed soil, cultivation and surface water aid the spread of the larvae in the field. Larvae of the reniform nematode are less than 1/50 inch long. The young females penetrate the root, after which they do not migrate. The portion of the body which remains outside the root enlarges until it resembles a kidney (Figure 20). After the female matures she secretes a gelatinous substance about her body in which are laid about 100 eggs. A complete life cycle is possible in about 25 days.

Control. Chemical control which is economically feasible has been obtained by using 1,2-dibromo-3-chloropropane (Fumazone or Nemagon) at 35 to 70 pounds per acre, a mixture of dichloropropane and dichloropropene (D-D) at 200 pounds per acre, dichloropropene (Telone) at 200 pounds per acre, and ethylene dibromide (EDB) at 72 to 96 pounds per acre. Presently, no field soil fumigant has been cleared by the Food and Drug Administration for use on papaya.

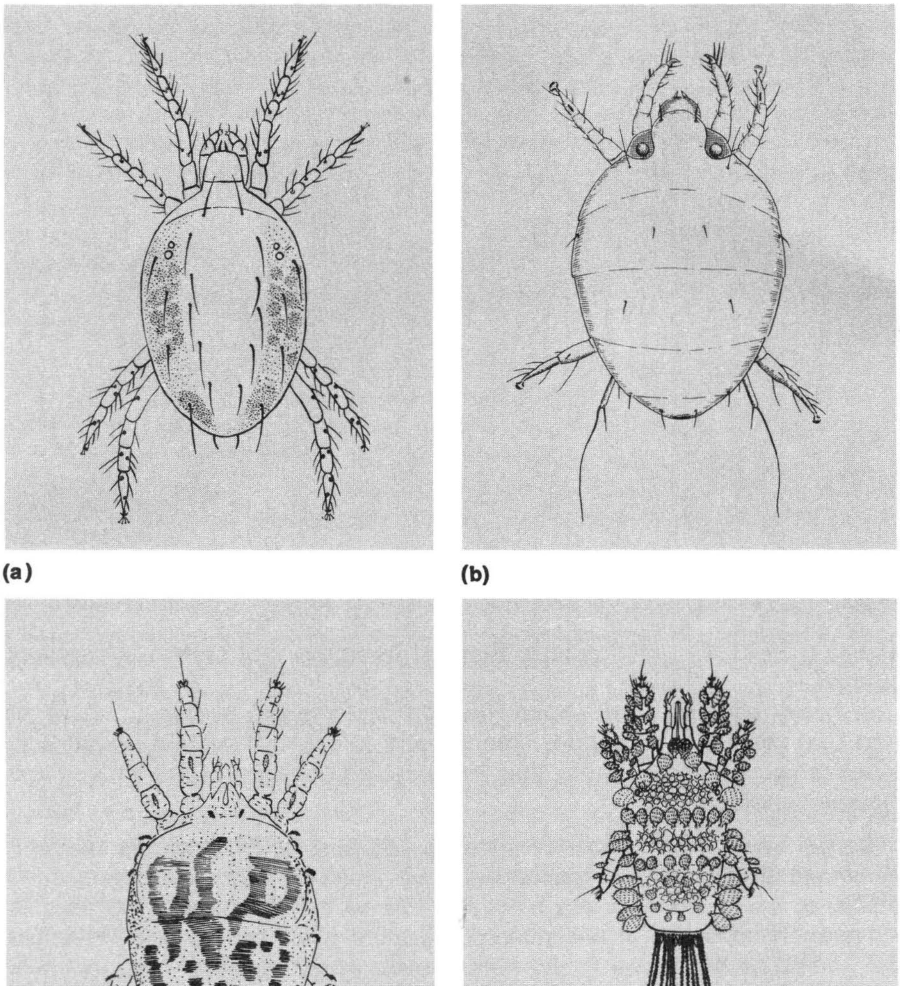


Figure 21. Mites that infest papaya in Hawaii: (a) Carmine mite (Tetranychus cinnabarinus); (b) broad mite (Hemitarsonemus latus); (c) red and black flat mite (Brevipalpus phoenicis); (d) tuckerellid mite (Tuckerella pavoniformis).

Mites and Insect Pests and Their Control

Several species of mites and insects have been reported infesting papaya in Hawaii (Tables 3 and 4). Only a few, however, are destructive pests. Mites are among the most serious pests of papaya, while insects are of relatively minor importance. Because of their minute size, less than ⅛ inch in length, the presence of mites on papaya often escapes detection until these pests are extremely abundant and plant damage become obvious. It is important to recognize the different pests as soon as possible so that the best control measures can be instituted against them.

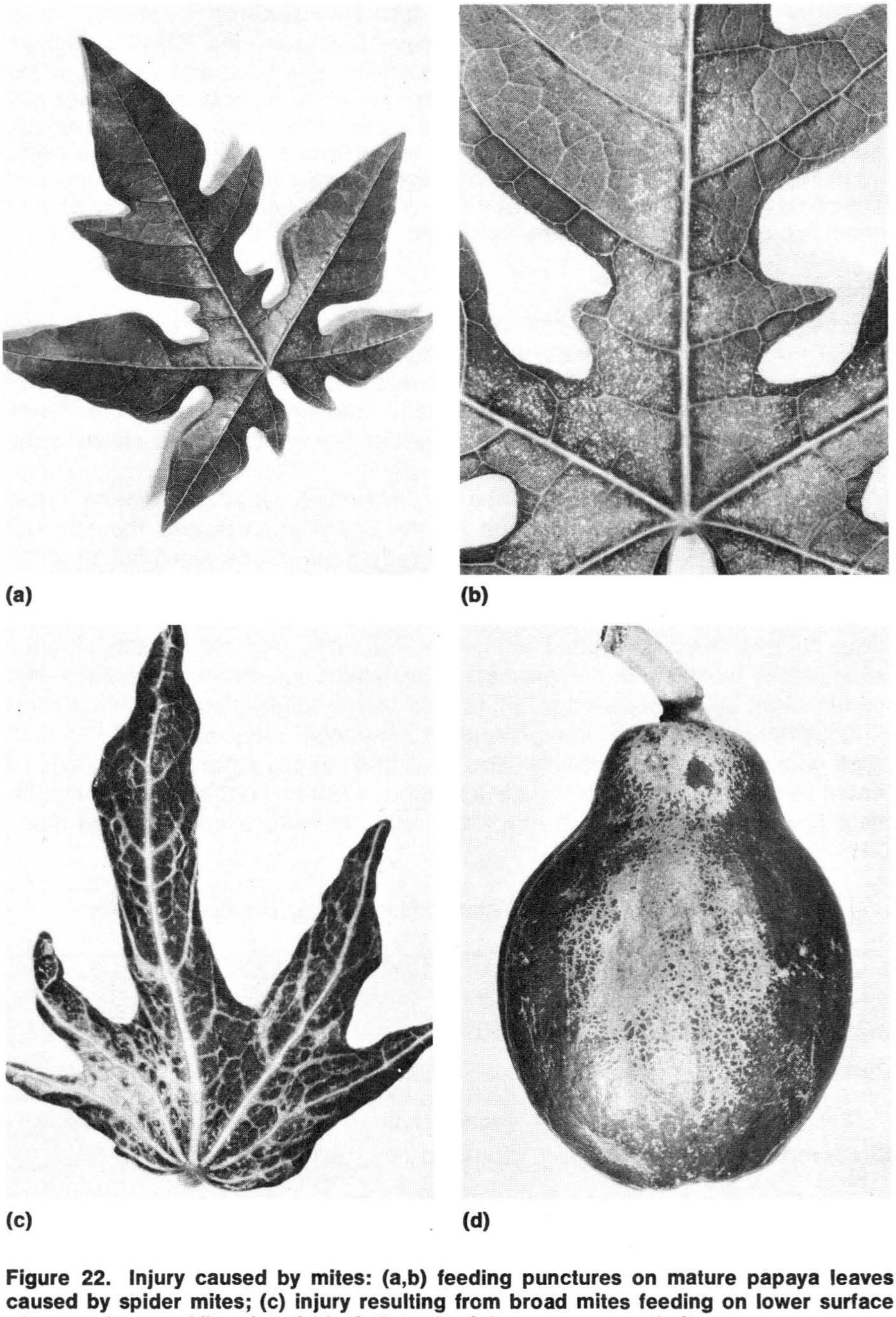
Mites

Seven species of mites colonize on different parts of the plant and feed on the plant, causing premature leaf drop, reduced tree vigor, and external blemishes on the fruit that reduce its market value. Mites puncture the plant tissue with their needle-like mouthparts and feed on the juices of the tissue. Some of them multiply prolifically throughout the year and can cause widespread damage in a very short time.

Three species of spider mites feed on the mature, older leaves—the Texas citrus mite and the citrus red mite on the upper surface and the carmine mite (Figure 21a) on the lower surface. Feeding punctures resemble stippling and are visible on the upper surface of infested leaves (Figure 22, a and b). In heavy infestations, the entire leaf surface is bleached with feeding punctures. Leaves become matted with webbing when infested by the carmine mites, while webbing is not prominent on leaves infested by the other two spider mites. All stages—eggs, six-legged larvae, eight-legged protonymphs, deutonymphs and adults—are present on the leaves. Only males emerge from eggs deposited by unmated females and both sexes emerge from eggs of mated females. Spider mite adults are about 1/50 to 1/60 inch long. The female has a plump, oval, sac-like body and the male a cone-shaped body.

Table 3. Some differentiating characters of the spider mites

Species	Body Color		Egg	
	Female	Male	Shape	Color
Carmine mite	dark red	translucent with two dark green spots	globular	translucent white to light brown
Citrus red mite	velvety red	light red	spheroid with long dorsal stipe	red
Texas citrus mite	tan to light green with variable dark green markings	tan	disc-like with short dorsal stipe	greenish-yellow



(a) (b) (c) (d)

Figure 22. Injury caused by mites: (a,b) feeding punctures on mature papaya leaves caused by spider mites; (c) injury resulting from broad mites feeding on lower surface of young leaves; (d) red and black flat mite injury on papaya fruit.

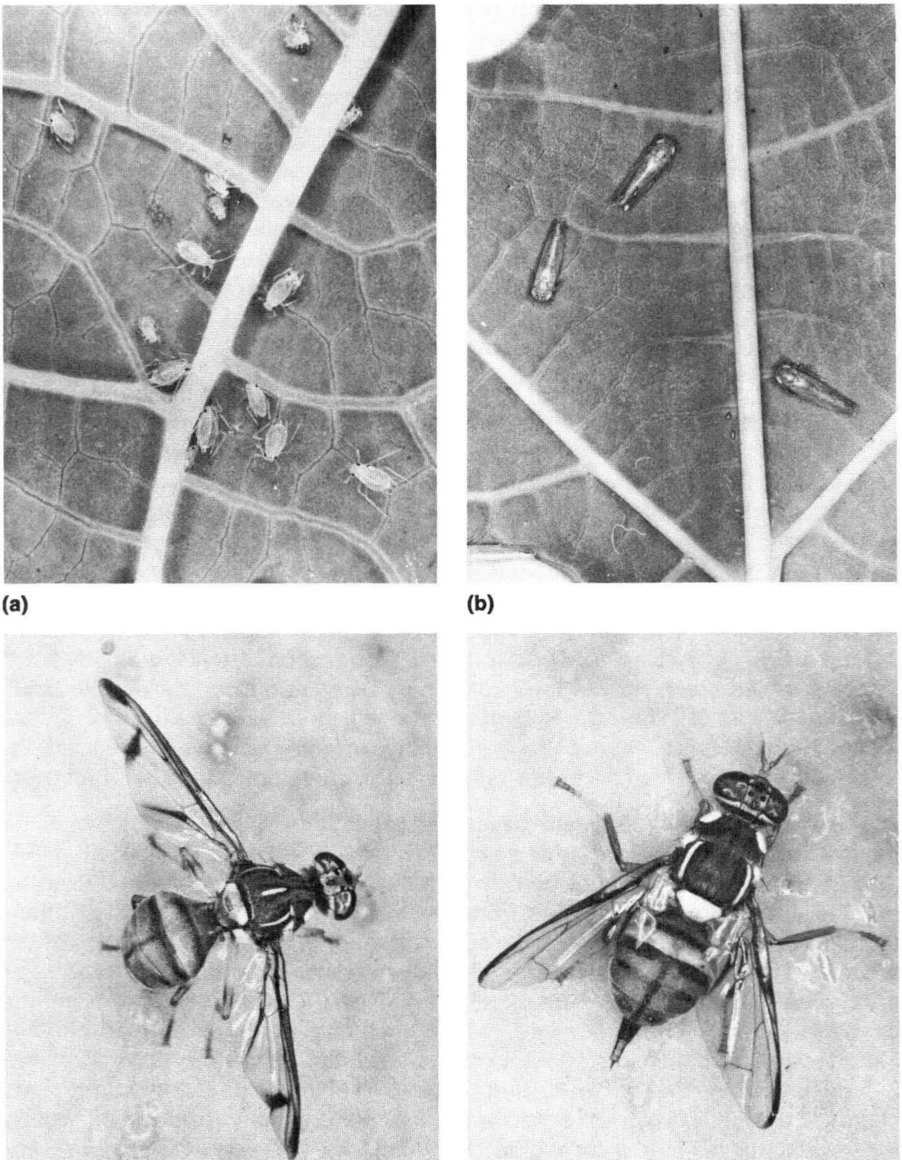
The immature stages are shaped like the adults but are smaller and lighter in color. Besides occupying different parts of the leaves, these spider mites are different from each other in the characters shown in Table 3, which may be seen with the aid of hand lens capable of magnifying 10X.

The life cycle of the spider mites is greatly influenced by temperature. At an average temperature of 85 degrees F., a generation is completed in 7 to 10 days, but under cooler conditions 20 or more days are required. The carmine mite is a more serious pest of papaya than the other two species. It occurs in all papaya-growing areas and reproduces throughout the year on many kinds of plants besides papaya. The citrus red mite and the Texas citrus mite are more limited in their distribution and host range, and outbreaks of them occur only periodically, usually during the fall.

The broad mite (Figure 21b) is very damaging to seedlings and young plants. It feeds on the lower surface of tender, young leaves and causes them to become stunted and distorted (Figure 22c). In extremely heavy infestations, the growing tips are aborted. This species is difficult to see even with the aid of a hand lens. The adults are oval, less than 1/140 inch long, and straw-colored. Unlike many other mites in the family Tarsonemidae, males of this species are very common and frequently seen carrying on their backs the white "female" pseudopupae. At an average temperature of 70 degrees F., the life cycle, which includes eggs, larvae, pseudopupae, and adults, is completed in 4 to 5 days. Mating takes place soon after the emergence of the females. Each female lays from 18 to 24 eggs during a short life span of about 2 weeks. The egg is ovate, flattened, and translucent, and it has several white, raised spots on the upper surface, which give the egg a speckled appearance. The broad mite is more prevalent during cool months.

The red and black flat mite (Figure 21c) is one of the major pests of papaya for it causes scarring of fruit which greatly reduces its market value. The females are about 1/95 inch in length, flattened in profile, and oval in outline. Their body color ranges from red, red with various patterns of black pigmentation, to black. Males are red, flattened, wedge-shaped, and rather scarce. Reproduction is primarily without fertilization. About 50 to 70 reddish-orange, elliptical eggs are laid singly during the life span of about a month by each female. The life cycle, which includes eggs, six-legged larvae, eight-legged protonymphs, deutonymphs, and the adults, is approximately 3 weeks during the summer and 4 to 5 weeks during the winter. All stages are found during all seasons on the stem, usually at the level where the lowest leaves are attached to the plant. As the population increases, the mites gradually feed upwards on the stem and outwards onto the leaf petioles and fruits, leaving a large, conspicuously damaged area behind them. The affected area is slightly sunken, tan, and has a corky appearance (Figure 22d).

The tuckerellids (Figure 21d) are of minor importance as pests of papaya. They feed on the trunk of old plants, usually below the level occupied by



(a) (b) (c) (d)

Figure 23. Insects affecting papayas: (a) Aphids feeding on underside of leaf; (b) Southern green leafhopper feeding on underside of leaf; (c) melon fly; (d) Oriental fruit fly.

the red and black flat mites. The symptoms of the feeding injury are very similar to that caused by the red and black flat mites. The tuckerellids are very ornate mites, about 1/60 inch in body length, oval in outline, flattened in profile, and bright red. The body has 44 white, fan-like hairs on the upper surface and 10 to 12 long flagellate hairs on the posterior that are equal in length to the body. These flagellate hairs are raised up and down in unison when they are disturbed. The life cycle, which includes eggs, six-legged larvae, eight-legged protonymphs, deutonymphs, tritonymphs, and adults, is more than 45 days. The flat, scale-like, red eggs, which have several white, parallel ridges on the dorsal surface, are deposited singly in crevices on the stem and hatch in about 14 to 18 days at 85 degrees F. The immature stages are very similar in shape to the females, except they are smaller and lighter red. Males are not present. Since the females lay only a few eggs and since the life cycle is very long, many months are required before they become noticeably abundant.

Insects

Papaya is not a preferred host of the species of insects which have been reported infesting it (Table 4). Many of them are infrequent or unimportant visitors and damage by them is negligible. Aphids, leafhoppers, and thrips do not thrive on papaya. Usually they multiply on weeds and when the weeds begin to dry up, they migrate in mass onto papaya. Older plants are able to tolerate fair numbers of them; however, young plants immediately after being transplanted can be severely damaged unless control measure is instituted promptly.

Aphids (Figure 23a) are soft-bodied, about 1/12 to ⅛ inch long, with long antennae and legs. They have a pair of tubes called cornicles on the posterior part of the abdomen and are green, yellow, or black. Both winged and wingless adult forms are present. Aphids injure the plants by sucking the juices with their long piercing-sucking mouthparts. They feed on the underside of leaves and cause them to become curled and crinkled. Petioles of heavily infested leaves droop downward. Aphids also excrete a honeydew which attracts ants and promotes the growth of sooty mold. Although male aphids occur in other parts of the world, they are not produced under Hawaiian conditions. An unfertilized female during her life span of about a month gives birth to 60 to 100 nymphs which mature in about a week.

Besides causing damage directly by feeding, some aphids are important as vectors of virus diseases. The green peach aphid, the cotton aphid, and the cowpea aphid have been implicated in the transmission of papaya ringspot. The green peach aphid has recently been shown to be a vector of papaya mosaic virus.

The onion thrips is a slender insect about 1/25 inch long. The adults are yellowish and the immature stages, which include two nymphal changes in form (instars) and two resting stages, are white. Males are wingless and very scarce. Females have four slender, feather-like wings and reproduce usually by parthenogenesis in Hawaii. The white, bean-shaped eggs are inserted into

Table 4. Insects and mites reported as feeding on papaya in Hawaii

Scientific name	Common name	Reference	Pest status*
INSECTS:			
Aphids			
Aphis gossypii Glover	Cotton or melon aphid	Proc. Haw. Ent. Soc. 12:100	2
Aphis craccivora Koch	Cowpea aphid	Proc. Haw. Ent. Soc. 12:102	3
Aphis middletonii Thomas	Erigeron-root aphid	Proc. Haw. Ent. Soc. 12:102	3
Hyperomyzus lactucae (L.) (=**Amphorophora sonchi** (Oestlund))	Sonchus aphid	Insects of Hawaii 5:103	3
Macrosiphum euphorbiae (Thomas)	Potato aphid	Proc. Haw. Ent. Soc. 12:104	2
Neomyzus circumflexus (Buckton)	Crescent-marked lily aphid	Proc. Haw. Ent. Soc. 12:105	3
Myzus persicae (Sulzer)	Green peach aphid	Proc. Haw. Ent. Soc. 5:456	1
Rhopalosiphum maidis (Fitch)	Corn leaf aphid	Proc. Haw. Ent. Soc. 12:99	3
Beetles			
Exillis lepidus Jordan	Fungus weevil	Proc. Haw. Ent. Soc. 10:361	3
Rhabdoscelus obscurus (Boisduval)	New Guinea sugarcane weevil	Proc. Haw. Ent. Soc. 11:99	3
Flies			
Ceratitis capitata (Wiedemann)	Mediterranean fruit fly	Proc. Haw. Ent. Soc. 6:367	3
Dacus cucurbitae Coquillet	Melon fly	Proc. Haw. Ent. Soc. 9:200	2
Dacus dorsalis Hendel	Oriental fruit fly	Proc. Haw. Ent. Soc. 13:25	2
Chrysomya megacephala (Fabricius)	Oriental blowfly	Proc. Haw. Ent. Soc. 7:252	3
Neoexaireta spinigera (Wiedemann)	Blue soldier fly	Proc. Haw. Ent. Soc. 7:252	3
Volucella obesa (Fabricius)	Green syrphid fly	Proc. Haw. Ent. Soc. 7:252	3
Stink Bug			
Nezara viridula (L)	Southern green stink bug	Haw. Coop. Econ. Insect Rep., Sept. 13, 1968	2
Leafhopper			
Empoasca solana Delong	Southern garden leafhopper	Insects of Hawaii 4:27	2
Moths			
Agrotis ipsilon (Aufnagel)	Black cutworm	Haw. Coop. Econ. Insect Rep., Aug. 1, 1969	2
Heliothis hawaiiensis (Quaintance and Brues) or	Hawaiian budmoth	Proc. Haw. Ent. Soc. 14:173	3
Heliothis zea (Boddie)	Corn earworm	Proc. Haw. Ent. Soc. 14:173	3
Scales			
Aspidiotus destructor Signoret	Coconut scale	Haw. Coop. Econ. Insect Rep., Dec. 26, 1968	2
Coccus elongatus (Signoret)	Long brown soft scale	Insects of Hawaii 5:300	3
Coccus hesperidum Linnaeus	Brown soft scale	Insects of Hawaii 5:301	3
Howardia biclavis (Comstock)	Mining scale	Proc. Haw. Ent. Soc. 8:95	2
Mealy Bug			
Pseudococcus obscurus Essig	Obscure mealybug	Previously unrecorded	2
Thrips			
Thrips (Thrips) tabaci Lindeman	Onion thrips	Proc. Haw. Ent. Soc. 10:253	2
White Fly			
Trialeurodes vaporariorum (Westwood)	Greenhouse whitefly	Previously unrecorded	3
MITES:			
False spider mites			
Brevipalpus phoenicis (Geijskes)	Red and black flat mites	Proc. Haw. Ent. Soc. 14:16	1
Spider mites			
Eutetranychus banksi (McGregor)	Texas citrus mite	Proc. Haw. Ent. Soc. 17:320	2
Panonychus citri (McGregor)	Citrus red mite	Previously unrecorded	2
Tetranychus cinnabarinus (Boisduval)	Carmine mite	Haw. Agr. Exp. Sta. Bien. Rep. 1960-26:51	1
Tarsonemid mite			
Hemitarsonemus latus (Banks)	Broad mite	Proc. Haw. Ent. Soc. 12:12	1
Tuckerellid mites			
Tuckerella ornata (Tucker)	Ten-tailed tuckerellid	Previously unrecorded	2
Tuckerella pavoniformis (McGregor)	Twelve-tailed tuckerellid	Haw. Agr. Exp. Sta. Bien. Rep. 1960-62:51	2

* 1=major pest.
2=minor pest.
3=occasional pest.

the plant tissue. The complete life cycle is about 3 weeks. Thrips scarify the leaf surface and suck the liberated juices. Leaves that are infested when young become distorted and show silvery, whitish sunken areas where the thrips have fed. Several species of thrips, including the onion thrips, are known to transmit spotted wilt, a virus disease which infects papaya, tomato, pineapple and others.

The Southern green leafhopper (Figure 23b) is light-green, wedge-shaped, and about ⅛ inch long. Adults are winged but usually use their legs in jumping from one part of the plant to another. After mating, the females insert the small, whitish, elongate eggs into the petioles of the main veins of the leaves. These eggs hatch into wingless but very active nymphs which characteristically move sideways when disturbed. The life cycle is about 4 weeks. Both nymphs and adults feed on the underside of leaves, sucking out the sap and cause the leaves to have a white, speckled appearance.

Fruit flies can infest papaya when fruits are allowed to ripen on the tree beyond the recommended picking stage. Fruits harvested in the mature-green stage are not infested because the milky substance they exude, occurring as soon as the fruit surface is punctured, prevents oviposition. Soft, ripe fruits are very attractive ovipositional sites. The white, spindle-shaped eggs are deposited in clusters inside the pulp. They hatch in about 1½ to 2 days and the maggots feed and develop rapidly from microscopic size to a length of about ⅜ inch. The maggots along with rot organisms decompose the fruit to a liquid mess in a few days. The creamish-white maggots leave the fruit and pupate in the soil. Transformation into adult flies occurs about 3 weeks after the eggs have been deposited.

The melon fly (Figure 23c) and the Oriental fruit fly (Figure 23d) occur more commonly in the papaya-growing areas than the Mediterranean fruit fly.

Control

Aphid, leafhopper, and thrips outbreaks can be controlled to a large extent by keeping the orchard relatively free of weeds. Fruit fly infestations can be prevented by harvesting all fruits at the mature-green stage, before they become attractive ovipositional sites. All soft-ripe and infested fruits should be picked and disposed of promptly to prevent fruit fly reproduction within the orchard.

Predaceous arthropods such as ladybird beetles, spiders, mites, and lacewing and syrphid larvae are commonly found on papaya plants. They undoubtedly do much to keep down some of the pest populations.

Chemical control of mites and occasionally of insects is a necessary part of papaya culture. Many chemicals or pesticides are available on the market today; however, their use is governed by both federal and state laws and they should not be applied on papaya unless they have been cleared for use. Among the pesticides registered for papaya are chlordane, ethylene dibromide, ferbam, malathion and methyl bromide. Of these, chlordane and malathion are available in garden shops to control some of the insect pests.

Besides the above insecticides, there are other pesticides that have been exempted from the requirement of formal tolerances since they are fairly safe to man when applied in accordance with good agricultural practices. Of these, rotenone, pyrethrum, and ryania are claimed as effective against some species of aphids, thrips, leafhoppers, and mites on papaya. Application of these pesticides is permitted fairly close to harvest date on many crops. The phytotoxicity of the various concentrations of these pesticides has never been tested on papaya. When it becomes necessary to apply any of these pesticides, each formulation should be tested on a few plants, both on foliage and fruits, for possible injurious reactions before spraying the whole orchard. In general, the wettable powder formulations are less phytotoxic than the emulsions.

Some chemicals have been declared safe and do not come under the pesticide regulations. One of them is sulfur. Sulfur is one of the best and most economical materials for the control of most species of mites on papaya, except for the carmine mite which is somewhat tolerant to it. When sulfur is applied regularly as a preventive or to control mite populations that are still small, even the carmine mite can be kept to fairly low population levels. Wettable sulfur applied at the rate of 5.7 pounds of actual sulfur (6 pounds of sulfur, 95 percent wettable powder) in 100 gallons of water is recommended for use on papaya.

Since several species of insects and mites do occur simultaneously on papaya and since no one pesticide can control them all, combinations of pesticides are often used to eliminate the necessity of separate applications. Care must be exercised in combining pesticides for not all chemicals are compatible with each other. A pesticide that is not injurious when applied singly may cause plant injury when combined with another. A suggested combination spray is 4 pounds of 95 percent wettable sulfur and 2 pounds of 25 percent malathion in 100 gallons of water. This combination does not harm the papaya and is effective against practically all of the pests on papaya, including the carmine mite. The sulfur-malathion combination should not be applied within 30 days of harvest because of the 30-day limitation established for malathion. Malathion is not injurious when it is applied singly as a suspension of wettable powder or as an emulsion or when it is applied in combination with sulfur as suspensions of wettable powders. However, foliar injury can result when the emulsifiable formulations of malathion and of most pesticides are applied in combinations with wettable sulfur.

WARNING

Many pests and diseases of papayas are controlled by using pesticides or chemicals. The U.S. Department of Health, Education and Welfare under the provisions of the Pesticide Chemicals Amendment to the Federal Food, Drug, and Cosmetic Act, has established criteria governing the use of each chemical to which clearance for use has been given. Growers should always check the current status of any pesticide with their County Extension Agent or the local representative of the Food and Drug Administration.

The term "pesticide chemical" refers to any substance that is an economic poison under the Federal Insecticide, Fungicide, and Ratinocide Act, that is used in the production, storage, or transportation of raw agricultural commodities.

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