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GUAVA (*Psidium guajava* L.) IN HAWAII– HISTORY AND PRODUCTION

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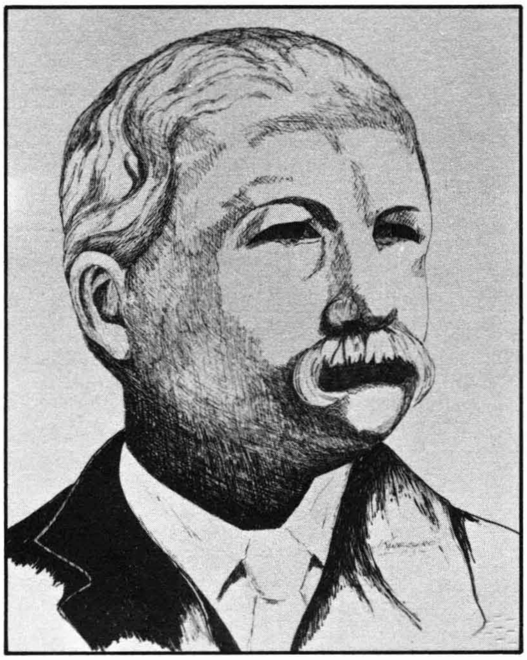
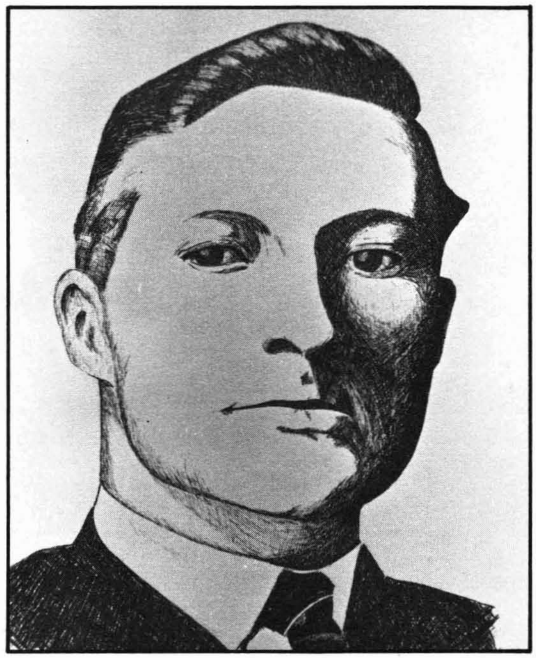


Robert Rycroft (1843–1909) emigrated to the United States from Leeds, England, when he was 16 years old. After serving 16 months in the U.S. Cavalry during the Civil War, he arrived in Honolulu. Failing in the restaurant and saloon business on Fort Street in Honolulu he went to Brisbane, Australia, to establish an ice works and was nearly successful in establishing his system on steamers to carry frozen mutton to Europe. Failing in this venture he returned to Honolulu and finally to Pohoiki to start a coffee plantation. He returned to Honolulu in 1899 after the coffee boom ended.



Walter S. Rycroft (1885?–1968) was Robert's son, who studied at Punahou. Presumably he remained in Pohoiki after his father returned to Honolulu to look after the business then developing in guava.

After a short period in guava, the Rycroft holdings in Puna were sold to Hackfeld & Co., the current Amfac.

GUAVA (*Psidium guajava* L.) IN HAWAII–HISTORY AND PRODUCTION

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INTRODUCTION

The plantation production of guava (*Psidium guajava* L.) for export of processed products from Hawaii now has become a definite possibility. When visitors, particularly American and Japanese, return to their respective domiciles they raise questions as to why guava and its processed products are not sold in their markets. Promotional and market development efforts along with consumer demand and production interest have all steadily increased. In keeping with this continuing change in guava prospective, this bulletin has been prepared. It provides much of the production information now available in order to promote an orderly development of the industry and contribute to an increase in the economic base in the Islands (*22*).

HISTORY

Guava, a native of the tropical Americas, has long been in the Islands as an important food source for the native Hawaiians and early immigrant families. Don Francisco de Paula Marin, an expatriate Spaniard who came to Hawaii in 1791, has been credited with the introduction; however, Gast and Conrad (*21*), in a thoroughly researched biography of Marin, state:

> "the truth is that most of the important food plants now grown in Hawaii were first brought in by others, some of them were widely grown before Marin came and [he] turned to the soil as an avocation, as well as a source of part of his income. . . . It was in his use of plants rather than in introduction of plants that Marin made his greatest contribution to early Hawaiian agriculture."

Marin also served as a royal physician, counselor, interpreter, and distiller to King Kamehameha I. It was during this time that Marin developed his vineyard and garden in Honolulu in the general area now bounded by River, Kukui, and Vineyard streets and the Pauoa Stream drainage. Vineyard Street was named after Marin's then famous grape planting in the area.

Production

On the basis of old records, newspapers, and other printed matter, Robert Rycroft and his son, Walter (frontispiece), should be credited with the first commercial production of guava at Pohoiki in Puna, Hawaii.

Luther K. Makekau of Puna, Hawaii, born July 13, 1890, remembers these men working in the production of guava jam and jelly in the "coffee mill" (Fig. 1) when he was about 15 years old, suggesting a production date of about 1905. Jack Chong Lee, born in 1900 at Kalapana, Hawaii, to a native Hawaiian and her Chinese husband, also remembers seeing guava jam and jelly being made

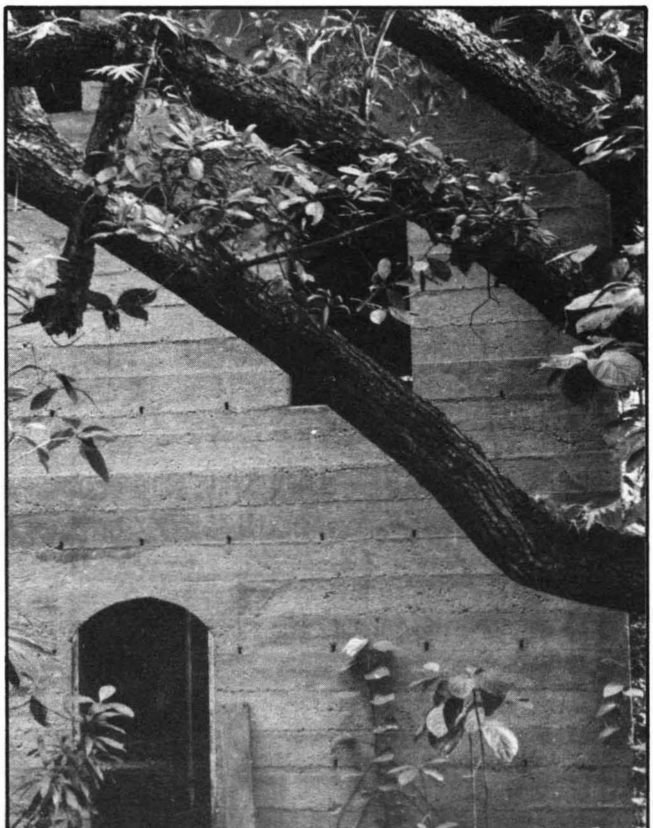

Fig. 1. The old coffee mill at Pohoiki where Robert Rycroft and his son, Walter, processed their guava jam and jelly. The building is still standing.

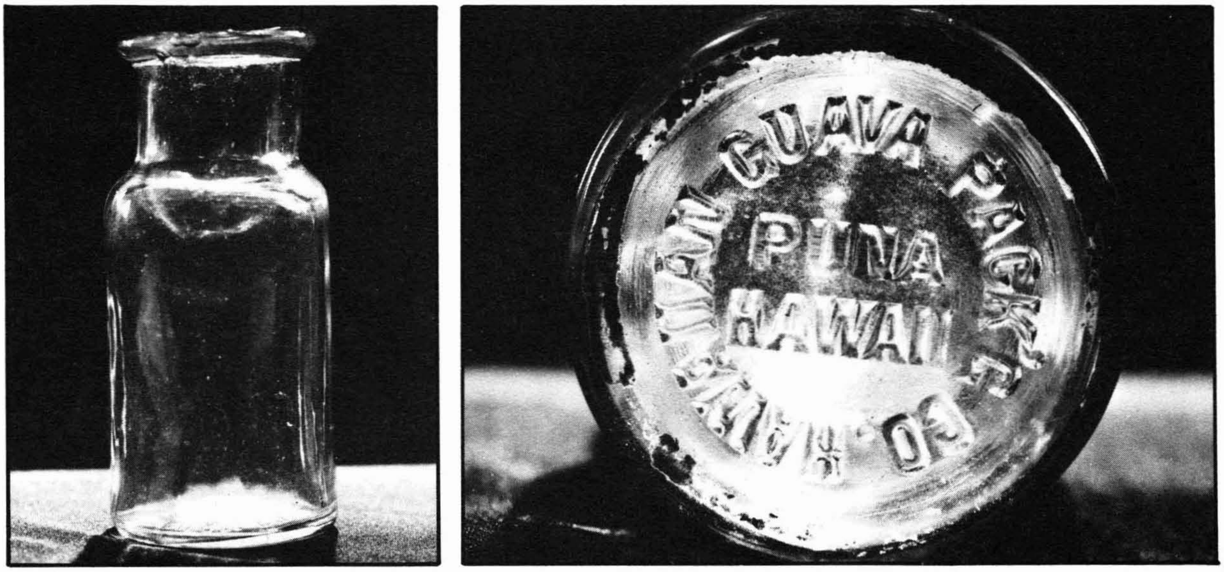

Fig. 2. An antique bottle from the collection of Harry M. Shigeura of Hilo. Probably the bottle was used by the Rycrofts.

at Pohoiki, Hawaii, when he accompanied his father from Pahoa to Pohoiki on fishing excursions. Marguerite Ooka, formerly of Kapoho, on her visits to Pohoiki in about 1925, remembers her father, James B. Campbell, pointing to the spot in the abandoned mill where the copper kettle used in the guava operations stood.

Robert Rycroft came to Pohoiki in 1877. After a period in cattle, awa roots, railroad ties, and making "ohia paving blocks" (*Metrosideros* sp., an indigenous tree) for the Honolulu market, he constructed the coffee mill in 1891 to process the coffee then being planted in Puna. However, for some unknown reason, the coffee boom ended in 1899, leaving the mill basically without a product to process. Then, probably, the Rycrofts had to find an alternate crop to process in the new coffee mill.

C. Arthur Lyman of the R. A. Lyman Estate in Puna has a lease agreement between R. A. Lyman and J. I. Kerschberg, documented and signed on January 19, 1904, and filed with the Bureau of Conveyances of the territorial government, permitting Kerschberg to pick guava on the Estate lands at Kapoho, Kula, and Puna for a period of 10 years.

Presumably, then, the Rycroft guava business in Puna was started about 1900 to use the coffee mill, and possibly was abandoned after 1910.

Figure 2 shows an old bottle from the collection of Harry A. Shigeura of Hilo. Presumably, this is one of the bottles used by the Rycrofts in their guava business in Puna.

In 1912, Chun Kee (Fig. 3) made guava jelly in a cauldron over a wood-burning stove, used cheesecloth to strain the juice, and melted paraffin wax to top the jelly. Chun Kee resided and operated on Kukui Street in Liliha. Ukichi Sako operated another guava jelly factory on Kukui Street between Liliha Street and College Walk in 1921. Mr. Sako is now (1982) about 98 years old and resides in the McCully district in Honolulu. Tomekichi Tanaka of Algaroba Street acquired the business from Mr. Sako in 1936, and operated it until 1956. Tanaka's Honolulu Jelly Company, although not manufacturing jelly now, is still in business as a wholesale distributor of sundry commodities.

The Wing Coffee Company started a jelly factory in 1925 on Kukui Street (Fig. 4, 5) and relocated to the corner of Fort and School streets in 1926, where it also began producing papaya and pineapple jams, coconut syrup, and honey. Wing applied for a trademark in 1931 and relocated to Kakaako in 1958.

In the late 1920's, Chun Hoon Markets of Honolulu packaged guava jelly in 25-pound pails for the U.S. Army. Frederick E. Haley, one of the early pioneers in pineapple production with James D. Dole, started a guava nectar and jelly operation in Kakaako in 1935. Ryoichi Tateishi, in the Lawai Valley on Kauai, extended his papaya juice operations to include guava, coconut syrup, and many other products by 1945. The Tateishi operation is still doing business as Hawaiian Fruit Preserving Company, Ltd., with sons Hiroshi, in production, and Stanley, in sales.

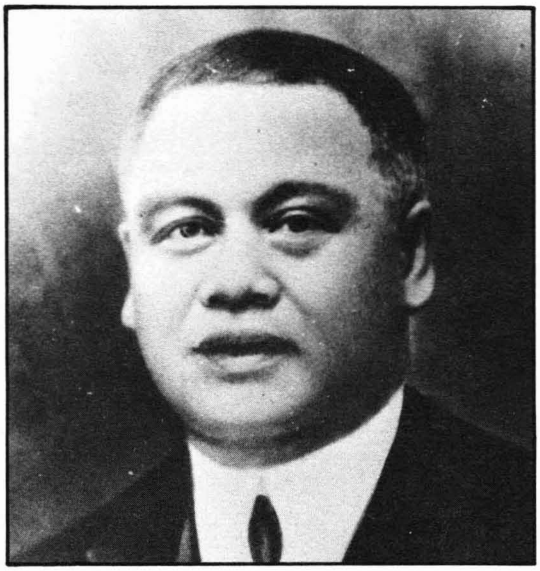

Fig. 3. Chun Kee. Photo courtesy of son, Kammy Chun.

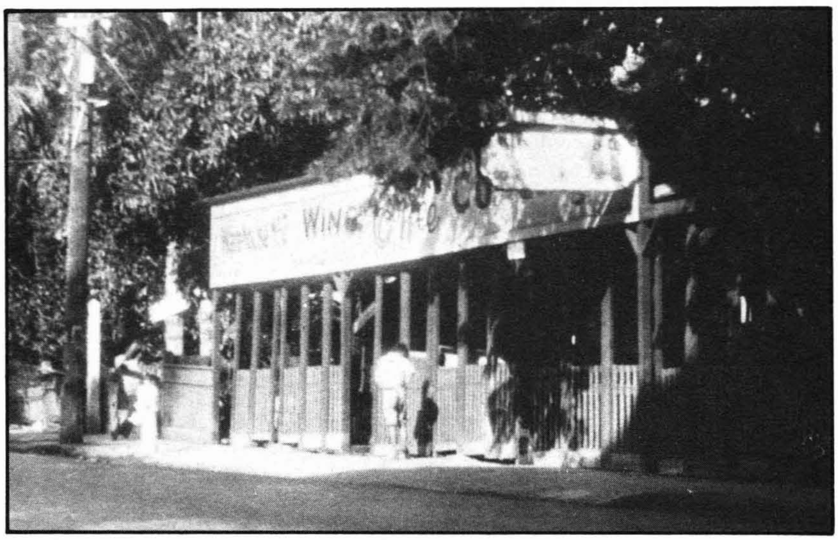

Fig. 4. Wing Coffee Company's guava factory on Kukui Street. Photo courtesy of Wing Coffee Co.

Fig. 5. Wing products made in the late 1920's. Photo courtesy of Wing Coffee Co.

George Y. Bennett started his Kaaawa Farms operations in Kalihi in 1946, where he hot-packed guava juice as Pearl Harbor brand for local sales and as Kulana brand for export sales. This firm also packed for S&W under a private label. The firm was sold in 1970 because of an inadequate supply of raw materials and the difficulty with quality control using wild fruits. The canning equipment was acquired in 1974 by Kreston Nagao of Hilo, who hot-packed the Pearl Harbor brand for a year or two, but, again because of inability to maintain quality, bad production scheduling, and insufficient fruit supply, the operation was disbanded in 1976.

During the 1946 to 1947 period there was a surge of development in Hilo. Harumi Kaneko, George Lycurgus, and Kreston Nagao started their respective operations in the Waiakea Kai and Hilo industrial areas. In 1965, George Lycurgus sold his Niolopa operations to Suisan Company, Ltd., which continues to produce the Niolopa brand products today. Norman Koshiyama purchased the Kaneko Jelly Company in 1971 and continues to produce jam and jelly. He also leased Nagao's operations in 1979 to continue processing guava puree.

In 1952, E. Braunlee Clewett started his King of the Island guava operations after a thorough study of the fruit as a possible commercial commodity (Fig. 6). Before embarking on his new venture,

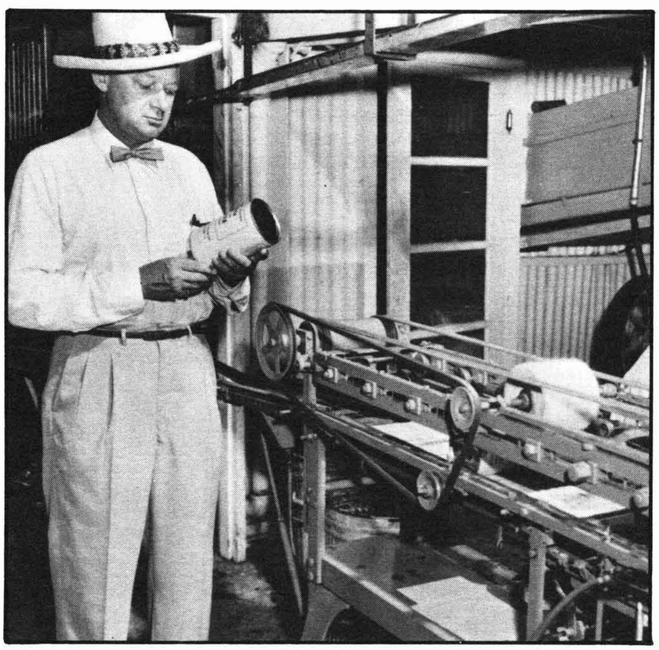

Fig. 6. E. Braunlee Clewett, pioneer in commercializing guava nectar, examining his product in his factory in the early 1950's. Photo courtesy of E. B. Clewett.

Fig. 7. G. Donald Sherman, then chairman of the Soils Department at the College of Tropical Agriculture's Experiment Station, and director, Food Processing Laboratory, stimulated and encouraged the development of a food technology laboratory at the University of Hawaii. Photo courtesy of Mrs. G. D. Sherman.

Clewett consulted with G. Donald Sherman (Fig. 7), then chairman of the Soils Department and director, Food Processing Laboratory, University of Hawaii. Clewett was encouraged to see the newly developed, sweetened fresh-frozen guava puree at the University that needed only an addition of 3 parts of water to form guava nectar. With this incentive, Clewett formed his Hawaiian Fruit Growers Exchange, Inc., in Damon Tract and started the production of guava, papaya, and passion fruit frozen concentrates in 6-ounce cans. In addition, Clewett worked with Mauna Loa Dairy under the Foremost label to package and distribute 1-quart guava juice samples free to customers on the Dairy's milk run. This promotional effort resulted in a 40,000-quart-per-month business, a major outlet for guava juice. In 1954, Clewett started his Hawaiian Punch operations and set up a factory at Kahului, Maui, where he began growing passion fruit to assure a supply of raw materials for his packaging plant. In 1962, Hawaiian Punch sold out to Reynolds Tobacco for an exchange of stock. Since then Reynolds has been operated as RJR Foods, Inc., producing Hawaiian Punch as a major item. In 1979, the Hawaiian Punch operation was purchased by Orchards Hawaii, Ltd., a corporation headed by Gordon Lent, president and general manager, with Jim Nabors and Paul and Anita DeDomenico as associates.

In 1955, Hawaiian Juice Industries (*2*) was formed by a small group of investors headed by Otto Younge and Francis Bowers, formerly of the University of Hawaii, Thomas Shaw, a trained biochemist, and Larry Matsumoto, operational manager. The company started small on Hotel Street but relocated to the Airport Industrial Park with new equipment and facilities in 1971, only to be sold to AlPac, a Seattle subsidiary of Pepsi Cola, later in 1971. AlPac, in turn, sold the business to Meadow Gold Dairies–Hawaii in 1974, again because of an inadequate supply of raw material and difficulties in quality control using wild fruits. Meadow Gold Dairies–Hawaii continues to be in business with Hawaii's Own sold locally as well as in the West Coast markets.

Suisan Company, Ltd., with Rex Matsuno, president, and Zenzo Kanai as operational manager, started guava puree operations in 1962 using wild fruits. They continued to expand in 1981 using predominantly cultivated guavas. They are now selling processed guava puree to users in Japan and the U.S. Mainland, and canned guava shells to local institutions on an experimental basis.

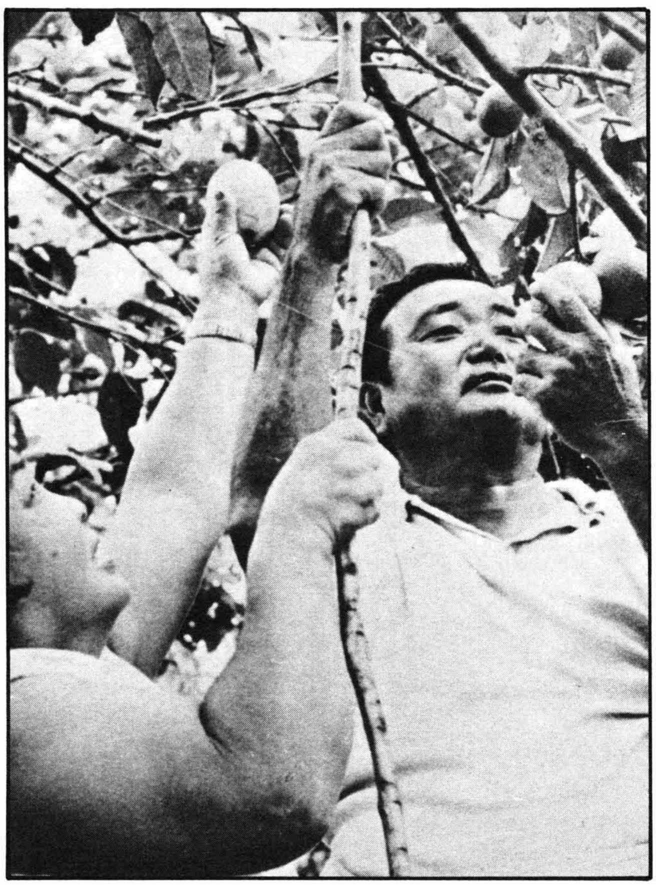

Fig. 8. Hazel and Hideo Tasaka of Waimanalo harvesting guavas in their orchard in the early 1950's.

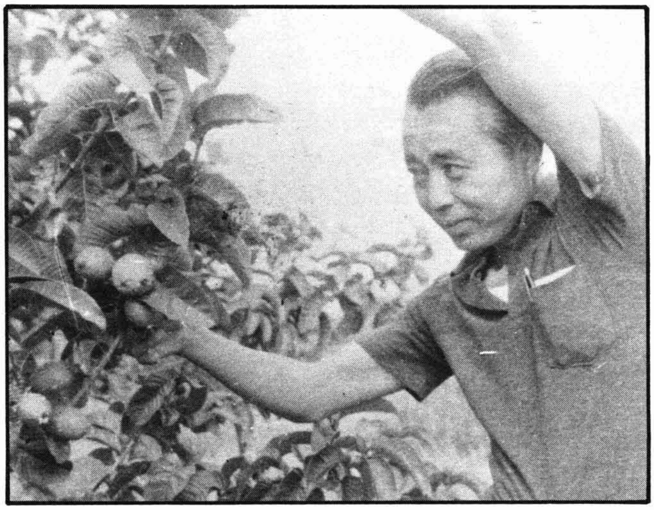

Fig. 9. Masayoshi Ikeda inspecting fruits in his orchard at Umauma on the Island of Hawaii.

In 1961, Hawaiian Sun Products, Inc., was formed by Henry Kurihara and his family on Republican Street in Honolulu. Hawaiian Sun has been marketing various fruit products in Japan and the West Coast with considerable success. Satoru Shishido started his operations as Tropical Products Packing Company, Ltd., in 1970 at Haiku, Maui, packing nectars of various mixtures of tropical fruits, including guavas. Kahuku Agriculture Company Hawaii, Inc., under Tom Yamabe II, operates at Kahuku, producing its own raw material to pack for the consumer outlets.

Farming

Concurrently with the development of processing factories, farmers in the Waimanalo area began field-planting guavas in the early 1950's (*3*). Among these were Harold T. Tamashiro, Hideo and Hazel Tasaka (Fig. 8), Isamu Gibu, Grant Hamachi, Hideki Okamura, Charles Saiki, Masanori Kunisaki, Nobuharu Kohagura, and Yajiro Ito. Masayoshi (Masa) Ikeda (Fig. 9) planted his orchard at Umauma, just north of Hakalau on the Island of Hawaii. Through their efforts these individuals demonstrated that the establishment of clonal orchards is possible and necessary to sustain overall quality control.

Research

In 1915, the Hawaii Agricultural Experiment Station published the first paper on the composition of fruits and nuts, including guava, then found in the Islands, by A. R. Thompson (*68*). In 1923, J. C. Ripperton (*50*) published Bulletin No. 47 on jelly making using Hawaiian fruits. At about this time commercial jelly making started receiving attention as a probable business. In 1936, Miller (Fig. 10), Bazore, and Robbins (*35*) published their benchmark Bulletin No. 77, *Some Fruits of Hawaii.* A surge of interest from housewives, nutritionists, and medical people necessitated a revision of the original paper as Bulletin No. 96 by Miller and Bazore (*36*) in 1945.

The 1949 Territorial Legislature passed Act 122 creating the Industrial Research Advisory Council to sponsor, supervise, and fund research and developmental projects to widen the economic base of the territory. After a survey of all reports and literature on agricultural, industrial, and economic research conducted within the Hawaiian Islands during the period 1930 to early 1952, the council accepted and funded a project submitted by the Agricultural Experiment Station, "Processing as by Canning and Quick Freezing of Hawaiian Fruits and Vegetables." With the initial grant of $104,840, the food-processing laboratory was constructed. The University provided the site for the laboratory and administrative supervision. This arrangement made it possible for the project director, G. Donald Sherman, to obtain sizable contributions from the federal government to perform specialized contract research. This cooperative effort between the territorial and federal governments resulted in early publications by Boyle et al. (*6*) and Lynch et al. (*30*) on guava products to compete with temperate-zone fruits on the grocery shelves.

Fig. 10. Carey D. Miller, formerly nutritionist at the Hawaii Agricultural Experiment Station, University of Hawaii.

Fig. 11. John H. Beaumont, formerly horticulturist and director of the Hawaii Agricultural Experiment Station, University of Hawaii.

In 1953, J. H. Beaumont (Fig. 11) reported in *Hawaii Farm Science* the work he and Francis Bowers had done in varietal selection (*4*). During this time, scionwoods and seeds from Florida, California, Brazil, South Africa, and the Philippines were introduced. Selected clones in Hawaii were identified as 'Kipapa 1', 'Halemano 1' and 'Halemano 2', 'Sacred Falls 1', etc. In 1967, Nakasone, Hamilton, and Ito published a report in *Hawaii Farm Science* (*40*) on an evaluation of introduced guava cultivars in Hawaii. In 1959, Hamilton and Seagrave-Smith (*24*) published Extension Bulletin No. 62, *Growing Guava for Processing.* In 1960, Bowers and Nakasone (*5*) assigned the name 'Beaumont' to a seedling of fruit found in Halemano, Oahu. In 1965, Wenkam and Miller published a bulletin (*70*), *Composition of Hawaii Fruits.* In 1968, Brekke (*7*) published a circular on tropical syrup production.

BOTANY

The guava is in the Myrtle family (Myrtaceae), which can be easily identified by flowers with long conspicuous stamens and yellow anthers (*44*). The Myrtaceae include many of the spices, e.g., clove, cinnamon, allspice, and nutmeg. *Metrosideros* (ohia-lehua), *Eucalyptus* (gum tree), *Tristania* (Brisbane boxwood), and *Melaleuca* (paper bark) also belong to this group. Although the genus

Psidium produces the most important fruit in the family, other genera in this family producing fruits are *Myrciaria* (jaboticaba), *Feijoa* (guavasteen), *Eugenia* (Surinam cherry), and *Syzygium* (rose apple). Neal (*44*) places *Myrciaria* and *Syzygium* in *Eugenia*.

The genus *Psidium* is composed of many species of which *P. guajava* is the most important (*49*). *Psidium cattleianum*, strawberry guava, and its botanical variety *lucidum* are of interest because the fruits are not only distinctly flavored and delicious but they are produced during a short period of time and make mechanical harvesting a possibility. The fruits can be made into jelly and juice that are very attractive. Other *Psidium* species are *P. polycarpum, P. guineense, P. aromaticum, P. friedrichsthalianum, P. molle,* and many others. A dwarf form, *P. guajava* forma *Cujavillus* (Burm f.) Degener and Degener (*16*) also needs to be listed, since this form, in preliminary rootstock trials, indicated its possibility of being used for rootstock, much akin to apple tree propagation to induce dwarfing of trees (*64*).

The guava fruit is a berry with a thick pericarp and fleshy seed cavity. The fruits are soft when ripe, making postharvest handling difficult and critical. Poor handling of the ripe fruits can result in great losses in the field and factory, where decaying and damaged fruits are discarded before processing. When these ripened fruits are further allowed to be exposed to the hot sun, the guava flesh becomes very soft and mushy. These fruits become difficult to puree in this condition, possibly due to actual chemical breakdown in the tissue. The flesh color of the fruit is becoming increasingly important as the use of coloring dyes in food products is being restricted. Fortunately, in Hawaii, the 'Beaumont', selected from the wild, has the desired pink flesh color. Flesh color of guavas from the wild range anywhere from white to yellow to salmon-orange and pink, all of which blend into an unattractive yellow-orange product. Wild guava fruits need to be blended with the pink to produce nectars with acceptable color.

CLIMATIC REQUIREMENT

The guava is a hardy shrub that has acclimated itself well to the various conditions at the lower elevations in Hawaii, where it is still considered a noxious weed (*45*). It is a serious pest in pastures, especially where no weed control is practiced.

Wind

The guava tolerates and is capable of withstanding strong prevailing winds or winds of hurricane velocities. Its root system is basically a fine mat supporting the tops and requires a tremendous horizontal wind force to uproot the tree. Also, the guava wood is strong and especially flexible and pliable, enabling the tree and its branches to bend in a whiplike fashion in a strong wind. The authors have yet to see a guava tree, except for defoliation by wind stripping, damaged by hurricane winds in Hawaii. However, growth and fruit production can be drastically reduced when the trees are grown in areas with constant prevailing winds of 10–15 miles an hour. In such situations, the trees will grow and develop away from the wind with short, stubby limbs facing the wind, these branches performing as a windbreak protecting and permitting the leeward branches to develop. When such growth is evident (*57, 58, 59*), a low windbreak that does not have much lateral growth can be used along the field edges. A larger orchard extending over 150 meters (500 feet) in length or width will benefit from the use of tall columnar or upright trees on the edges and possibly within the field.

Rainfall

In Hawaii, guava trees are found growing in the 500-centimeter (200-inch) annual rainfall belt, with continuous freestanding water, as well as in desertlike areas found at Kawaihae and Ka'u, where annual rainfall is less than 25 centimeters (10 inches). In these areas, the trees are not too productive, seemingly only surviving and demonstrating the ability to withstand extreme conditions in water supply. In areas that tend to be too dry for crops during the summer months, provisions for irrigation are advisable. Guava growing on pāhoehoe or 'a'ā lava, even in the wet Hilo area where rainfall can be 300 centimeters (125 inches) per year, will respond to additional water during brief dry periods. Since water supply throughout the production cycle from flowering to harvesting is very critical, irrigation should be included in any commercial planting of guavas.

Temperature (Radiant Energy)

Recorded air temperature at selected weather stations in most of the areas in Hawaii is often assumed and used, agronomically, as an indicator of the radiant energy received from the sun and used by crops in growth. The relationship is

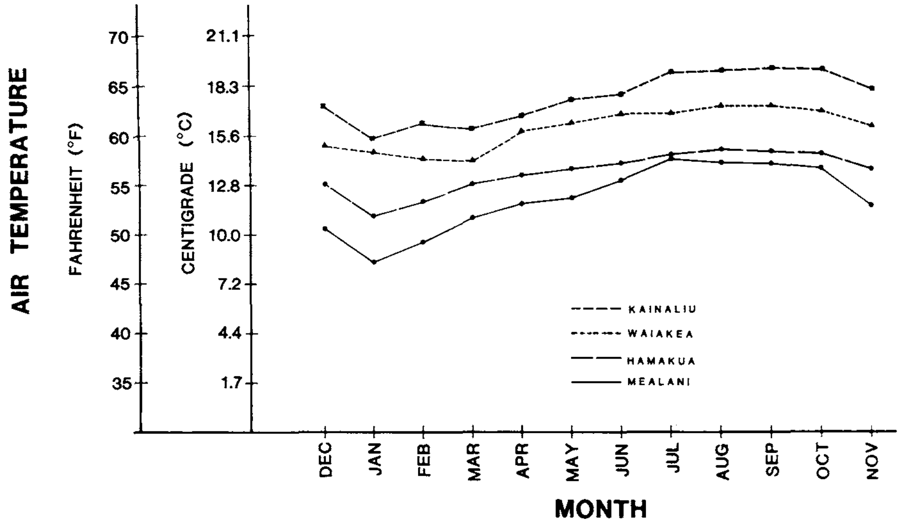

Fig. 12. Minimum temperature regimes of four areas in Hawaii obtained at different elevations.

obviously not absolute, but is the easiest to obtain and sometimes the only record available where no pyronometric records are kept. However, due to the constant trade winds and a great body of tempering ocean water surrounding the islands, the relationship between elevation, temperature, and radiant energy is constant and very highly correlated. The higher the elevation, the colder and cloudier it becomes. Assuming the physiological activities within plants are affected by elevation and its accompanying temperature and radiant energy, then it is not in error to relate tree performance, i.e., growth and yield, to elevation. In Hawaii, this relationship is much easier and more reasonably drawn, since air movement over the islands is relatively constant trade winds, and is not affected in the varying air movement usually obtained over continental land masses. Consequently, temperature, radiant energy, and elevation will be considered synonymous and interchangeable, and will be used as such in this text. Exceptions to this general rule in the Islands are land with southern exposures where cloud and fog overcast is at a much higher altitude, permitting a longer and more intense light-exposure period below to enable production at a higher elevation.

Field observations and some data now available in insular Hawaii suggest that minimum temperatures can be critical. Guava trees growing at lower elevations are generally vigorous and large with a heavy set of fruits, while those at 650 meters (2000 feet) or higher become very erratic depending on temperature differences due to cloud cover. Along the Hilo coast where cloud cover sets in at 490 meters (1500 feet), along the Kona coast at 650 meters (2000 feet), and along the Ka‘u coast at 820 meters (2500 feet)—with its southern exposure—seem to be the upper elevations where guava can set fruits. In the higher areas with cloud and fog overcast, the trees and leaves are small with interveinal tissues turning red to purplish-red during the winter months. Further preliminary evidence and field data gathered at Hamakua, Hawaii, at 640 meters (1900 feet), where recorded air temperature goes down to 7°C (42°F) in February, indicate that flowers initiated during this cold period abort before or after anthesis to result in very low production of fruits in the summer months following.

The relationship between elevation and temperature in Hawaii is shown in Fig. 12. The lower set of lines in Fig. 12 gives the minimum temperature regime at Mealani at 845 meters (2600 feet) and at Hamakua at 641 meters (1900 feet). During the winter months of January and February the monthly average minimum temperature in Hamakua is about 11°C (52°F) with low dips down to 6°C (42°F). The upper set of lines is from Kainaliu in Kona at 450 meters (1400 feet) and from Waiakea at 200 meters (650 feet), giving minimum temperature regimes of 15°C (59°F) in January and February with low dips down to 10°C (50°F).

Although the minimum temperature difference in the regimes is only 4° to 5°C during the winter months, the energy difference is substantial. Actual performance records in growth and production responses in these areas also indicate that the difference is real and distinguishable with total production much less at the lower temperature regimes than at the higher. At the Mealani elevations guavas grow and yield very sparsely.

Realistically, the guava can be economically grown at elevations in Hawaii where pineapple, macadamia, coffee, papaya, mango, and banana are profitably grown. Except for a few areas with a definite southern exposure, most of the areas above 60 meters (1800 feet) in Hawaii are not suitable for growing guavas profitably.

SOIL

Soil, per se, as a requirement of growth, is not a major consideration in Hawaii. In the State of Hawaii, guava is found growing as a weed on every conceivable soil type, from the basic ‘a‘ā and pāhoehoe lavas found in the Puna and Kona areas to land types useful only as conservation, forest reserve, or pastures. However, an improvement in management and cultural practices in marginal areas results in increased growth and production. On better arable soils, guava growth needs to be controlled by cutting with machetes or by applying herbicides to reduce its noxious competition with economic crops. Before 2,4-D was available for weed control, guava was one of the major weed control problems in the state. These hardy and versatile characteristics make the guava a plant that is difficult to control as a weed and, thus, one of the easiest crops to grow commercially; hence, commercial operations in guava can be profitable on almost any land with adequate management.

Since most of the arable land in the state is in sugarcane, pineapple, and vegetable crop production, nearly all of the early planting of guavas has been on ‘a‘ā, pāhoehoe, marginal, or abandoned lands. In the last 10 years, with a decline in the economy of growing pineapple and sugarcane, some marginal pineapple and sugarcane lands have been planted to guavas. Kilauea Agronomics, on the island of Kauai, started their first guava planting a few years ago, with acreage to be increased over the years. Other sugar plantations have been expressing interest in converting marginal sugarcane fields to guava production.

Land preparation should be minimal in the reuse of abandoned sugarcane or pineapple land, depending on the weed or brush conditions. When the area is overgrown with tall weeds the field should be plowed under for proper weed disposal. At the same time, if soil calcium or magnesium is low, calcium carbonate, calcium silicate, dolomite, or magnesium oxide can be worked into the soil at plowing. On land with a slope exceeding 15–20 percent, shallow-contour rainwater drain ditches that will not interfere with field operations should be put in. A cover crop of low grasses, clovers, or some other leguminous ground covers may be used to reduce or eliminate the need for drain ditches and to minimize weed control.

Preparation of pastureland can be handled in a similar manner to eliminate old cattle trails and ruts and to permit the safe movement of mechanical equipment. Fertilizer additives for calcium and magnesium nutrition can also be plowed in at this time.

Preparation of ‘a‘ā lava land should be more carefully handled, although clearing costs will be slightly higher. Forested ‘a‘ā lands inevitably have organic materials, formed by the years of plant growth, interlaced in the top foot or two of lava rocks. The total amount of this material is usually small, but since this is the only part of this soil type that holds water and has the cation exchange capacity (CEC) to hold on to the nutrients, it should be guarded and properly placed to permit its better utilization. Consequently, in clearing ‘a‘ā land, the organic fraction should be initially bulldozed into piles or strips, and the remaining terrain should then be brought to a reasonable level by ripping the solid rock base that is usually beneath the a‘ā. Finally, the stored "topsoil" material can then be brought back to cover the already leveled terrain to help support the growth of trees. There is no doubt that this procedure is much better than clearing land in one operation, and thereby burying the organic matter in the low hollows and beyond the reach of the new tree roots. Area cleared in the latter manner will require topsoil or cindery materials on the surface to permit better tree growth.

Pāhoehoe lava land is the least desirable and should be avoided in growing any crop, including guava. Pāhoehoe land is sheet lava that meagerly supports vegetation in the large crevices and low spots where fine cindery material may have accumulated. In the Hilo area, where rainfall is high and good friable farmland is not available at a reasonable cost, small farmers are forced to use pāhoehoe land for guava cultivation. In such situations the land is usually ripped using a heavy tractor to create trenches or areas of loose rocks of various sizes down the tree rows. The trees are then planted in these ripped strips (Fig. 13) with the addition of about a cubic foot of cindery material or potting soil. With proper cultural care the guava trees will do reasonably well in these ripped areas and produce fruits profitably. However, to support guavas ideally on pāhoehoe, the land should be thoroughly ripped throughout the area to a depth of about 2 feet, with additional cindery material to permit adequate lateral extension of the root system. The cost of such preparation will be high but will pay for itself in time.

NURSERY TREE PROPAGATION

Guava trees for eventual field planting (*42*) can be nursery propagated by grafting, by budding, by stem cuttings using succulent green stems (*24, 48, 63*), or by root cuttings.

Grafting or Budding

Seedlings for grafting or budding (*15, 23*) can be propagated using seeds of *P. guajava* from the wild or seeds from clonal trees. There is no evidence, at the moment, to indicate that seed source for the production of rootstocks is important. Fresh seeds should be obtained from clean, ripe fruits, thoroughly washed to eliminate the pulpy material clinging to the seeds, and treated with a fungicide to prevent damping-off before planting in the seedbed. If damping-off is evident as the seedlings emerge, the surface of the media and the seedlings should be treated again with a fungicide. When the seedlings are 3 to 4 centimeters (1½ inches) in height they should be planted in small containers for later nursery row planting, or they may be planted in 4-liter (1-gallon) containers for the propagation of larger seedlings for later use in budding or grafting. Whether to use the nursery row or container-grown seedlings in tree propagation is a matter of preference, convenience, and cost. The end result should be the production of healthy seedlings. Healthy, succulent, and highly vegetative seedlings thus propagated can be grafted or budded when they are about 1 centimeter (½ inch) in diameter, 25 centimeters (10 inches) above ground level. The guava can be grafted or budded using any accepted method.

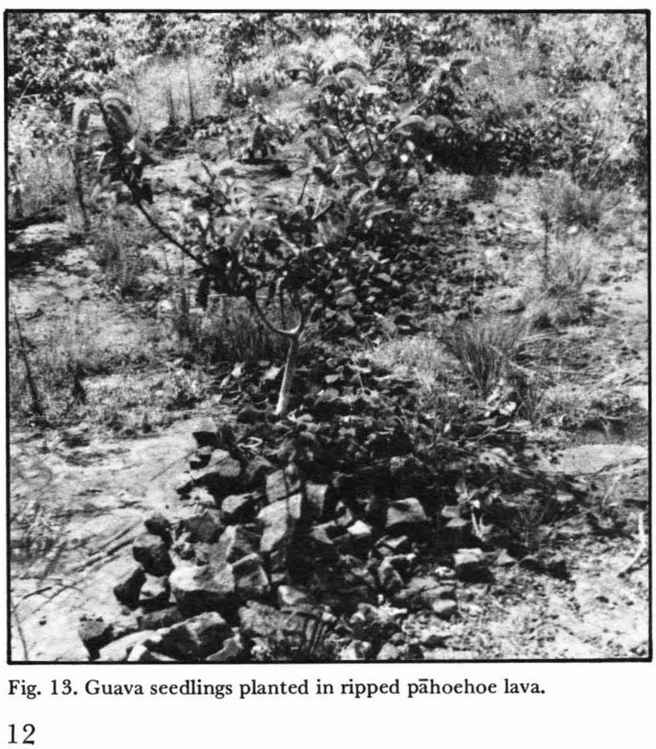

Fig. 13. Guava seedlings planted in ripped pāhoehoe lava.

The Forkert, a modified patch bud method, has been found ideally suited to guava (*23*). A patch size approximately 1 centimeter (½ inch) × 1½ centimeters (¾ inch) seems to take better than when a smaller patch or bud is used. The trees from which buds are taken should again be highly vegetative with lush, succulent growth to permit easy separation of buds from the stem. Buds on brown stems with leaf scars hard and grown over are better to use than younger buds with leaf scars still distinct and soft. In Australia, small oval punches about 1 centimeter on the long diameter are being used on macadamia and guava to remove buds that are fitted into punch-holes similarly created for a perfect match on the stock seedlings (*69*).

Green Wood Stem Cuttings

Green wood stem cuttings (Fig. 14) can be used in cutting propagation. Shigeura and Matsuyama (*63*) recommend the use of a three-node stem cutting with two leafy nodes and a basal node without leaves (Fig. 15), or a similar cutting without a basal node, in an intermittent mist chamber with bottom heat and media temperature maintained at 27°C (80°F). The cuttings thus prepared should be treated with a rooting hormone mixture of 2 percent indolebutyric acid (IBA) suspended in fine dolomitic limestone or insecticidal talc. The concentrations of IBA from 0.25 to

Fig. 14. Only strong, succulent green wood (right) should be used in cutting propagation. Two three-node cuttings can be cut from the stem to the right. Weaker stems (lower left) should only be used when cutting supply is low. Percentage takes on these are lower. Small twigs (upper left) should never be used.

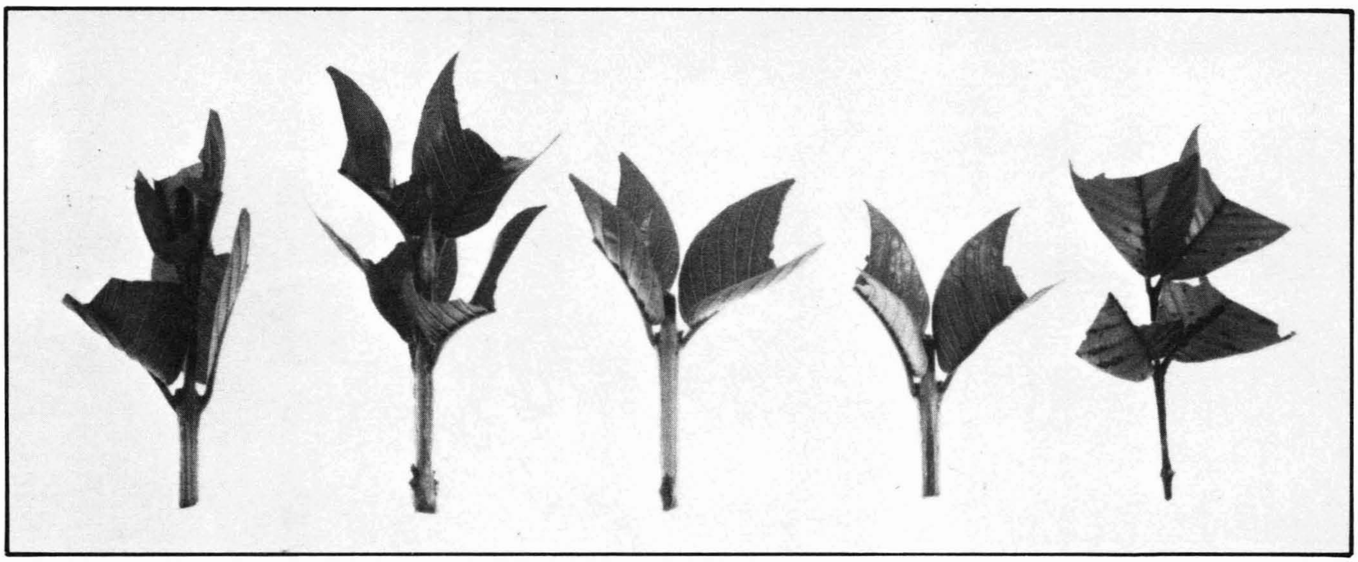

Fig. 15. Types of cuttings used in rooting trials (left to right): (1) two leafy nodes without a basal node; (2) two leafy nodes with a basal node; (3) one leafy node with a basal node; (4) one leafy node without a basal node; and (5) small twig. Cutting no. 2 (two leafy nodes with a basal node) was slightly better than cutting no. 1. Others were comparatively mediocre.

2.00 percent used in the same series of tests did not affect the rooting percentages, but the development of the root mass was significantly better with 2 percent IBA than at the lower concentrations. The cuttings should be adequately rooted for container transplanting after 6 to 8 weeks in the mist chamber. The transplant containers need to be large enough in size to nurse the cutting for about 4 to 6 months until the plants are ready for field transplant. A good well-drained potting soil should be used and water supplied adequately. The trees can be easily damaged and growth delayed when plants at this stage are mishandled.

Root Cuttings

Roots are an excellent source of propagation material from the fields since the surface roots under normal field conditions readily develop shoots when exposed to light or when slightly injured by herbicides or moving ground equipment. Trees propagated in this manner are just as good as trees propagated by any other means, but the method is applicable only if the parent orchard was started from cuttings rather than having been budded or grafted on a seedling rootstock. However, this method of propagation is quite inadequate in a large nursery operation since the material source is low.

Seedling Orchard

Although this method is not now a recommended practice, for economic reasons seedlings can be used to establish an orchard. The design of planting then needs to be different since most of the seedlings will not be like the parental type in yield, taste, and fruit flesh color. When the deficiency becomes obvious, these should be eliminated or topworked (Fig. 16) with either clonal 'Beaumont' or 'Ka Hua Kula' as early as possible.

Dwarf Trees

Dwarfing rootstock trials should be continued using the forma *Cujavillus* and strawberry guava. Preliminary trials indicate this work should be reinitiated (*64*).

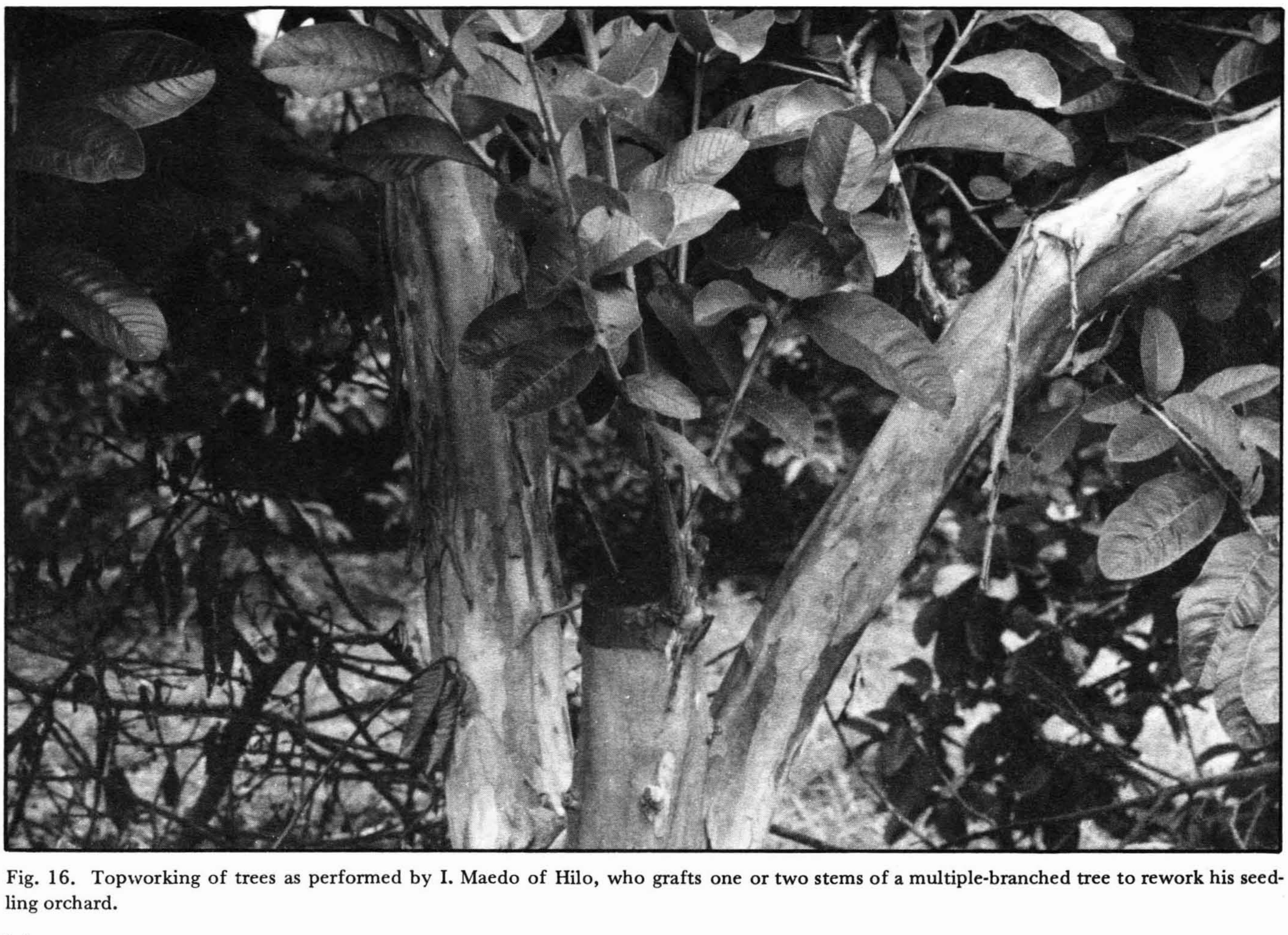

Fig. 16. Topworking of trees as performed by I. Maedo of Hilo, who grafts one or two stems of a multiple-branched tree to rework his seedling orchard.

ORCHARD MANAGEMENT

Orchard Design

Clonal orchard. The planting design of any crop should be determined only after consideration of the tree's growth habit, its response to pruning, harvesting method, and other cultural methods to be used in the care of the orchard. Fortunately, the guava can be pruned and trained to any dimension or pattern the grower wishes. It can be trained into a large, low-hanging bush to permit hand harvesting or into a small tree with a single trunk to permit mechanical harvesting. A properly pruned and trained tree can be confined to a foliage canopy approaching 4 meters (11 to 12 feet) in radius. This radius can be maintained by judicious pruning in conjunction with crop cycling. To maximize production, tree limbs must be developed to cover the land area as completely as possible. This can be done in time, by pruning and tree training; however, a better way to do this is initially to reduce the "blank" areas between trees (Fig. 17) in the orchard by planting them on an equilateral triangle (quincunx) system and at a desired distance between trees rather than on a square system. Design data given in Table 1 and layout design in Fig. 17 should help in decision making on planting.

The spacing between trees on any given farm is a decision for the individual farmer to make after he considers the production potential of his land based on fertility, availability of water, intensity of

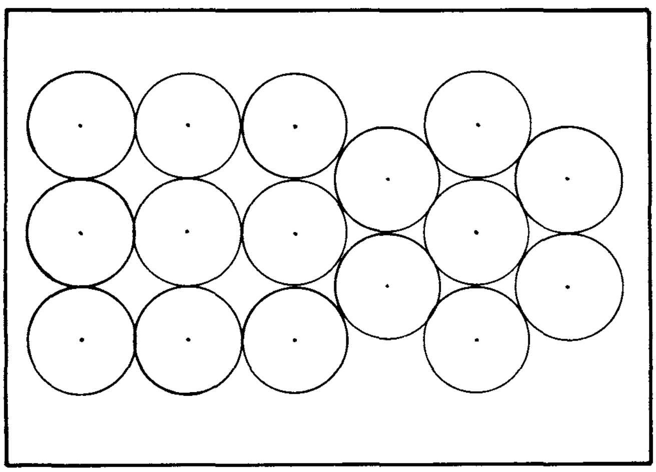

Fig. 17. Planting design to illustrate space loss between trees. Assuming a radial tree canopy extension, the loss is definitely larger with a square system of planting than with an equilateral (quincunx) design, resulting in fewer trees. At a distance of 25 feet between trees, a square system allows 70 trees per acre while the quincunx system allows 80 trees, a substantial difference in production capability.

Table 1. Equilateral triangle (quincunx) design data

Design no.	Distance (ft.) between trees in row	Distance (ft.) between rows	No. of trees per acre	No. of sq. ft. per tree
1	25′	21.7′	80	543
2	24′	20.8′	87	499
3	23′	19.9′	95	458
4	22′	19.1′	104	420

sunlight, wind exposure, etc. However, Design No. 1, with 25 feet between trees and 21.7 feet between perpendicular rows, optimizes production. If the farmer prefers, for conditions of his own, closer spacing and more trees can be used.

Seedling orchard. For economic reasons, an orchard established with seedlings should be planted with an operational area of 24 to 25 feet between rows with trees planted in-row at 8- to 12-foot spacing. The trees should be rogued out or topworked as soon as off-types develop, or as cash flow is available to expend into topworking of undesirable trees.

Fertilization

Leaf analysis as a guide to guava fertilization has been suggested by Shigeura, Silva, Bullock, and Matsuyama (*62*). Recommended leaf values are given in Table 2. The guide values are tentative and should be refined with further data. The table gives the elemental values as percentages or parts per million of the oven-dried leaf material. The index leaf is the fourth leaf in a whorl of leaves of an actively growing major terminal, counting the first expanding young leaf in the whorl as No. 1. A 10-leaf sample should be taken at random from 10 trees in an area where information is desired. If plant growth and appearance in the area are

Table 2. Tentative leaf analysis guide to guava fertilization

Element	Unit O. D. basis	Optimum value
Nitrogen	%	1.70
Phosphorus	%	0.25
Potassium	%	1.50
Calcium	%	1.25
Magnesium	%	0.25
Sulfur	%	0.18
Zinc	ppm	20.00
Manganese	ppm	60.00
Copper	ppm	8.00
Iron	—	—
Boron	ppm	20.00

uniform, one sample is sufficient. More samples from an area are suggested if differences are visible. If deficiencies are indicated by symptoms (*51*) or leaf analysis, corrective measures should be taken immediately. If not, because of the crop cycling procedure, whatever fertilizer program is suggested should be applied after the completion of the current crop for the benefit of the succeeding crop. Recent preliminary data and observations indicate that calcium is related to the firmness of fruits and blossom-end rot of matured fruits. Leaf calcium level to correct this condition appears to be 1.25 percent or higher.

The lands now used for guava cultivation are either old, marginal areas where sugarcane or pineapple was cultivated, or virgin lava forests that were considered commercially unproductive until recent times. In either case, fertility on these lands should be monitored prior to planting and if called for, calcium or magnesium should be incorporated in the soil at preparation time. The most economical calcium sources are calcium carbonate from beach sand, calcium oxide from burnt lime, and calcium hydroxide from hydrated lime. These can be plowed in before planting to supply the need for calcium. For magnesium needs, magnesium oxide or dolomite should be used.

At the present time, there are no data to indicate that soil pH obtained under Hawaiian conditions (pH 3.5 to 7.0) is a factor in guava fertilization and production. Until experimental data indicate otherwise, pH as a factor need not be considered for the soil types used to grow guava in Hawaii.

When soil analyses records are available, the values given in Table 3 (*67*) can be used to better approximate the nutritional need that must be met by the soil.

An orchard, during the first few months in the field when leaf sampling is not possible, should be adequately fertilized at a 2- or 3-month interval with a complete fertilizer including calcium, magnesium, and the trace elements to establish the basic foundation of structural branches as soon as possible. Leaf sampling should be instituted as leaves become available, and fertilizer should be applied as indicated. At the end of the 2nd year or at the beginning of the 3rd, the trees can then be put into production cycling.

Table 3. Optimum nutrient levels for Hawaiian soils (parts per million)

Element	Optimum	Conditions
P	40–50	–
	25	low
K	200	–
Ca	2000–4000	humid soil
	2000	semidry soil
Mg	1/5 of Ca	–

Pruning

Within the first 3 to 4 months after field planting, the guava tree needs to be pruned and trained to allow maximum production of fruit as soon as possible and at the lowest possible cost. Operational costs of herbicide, pruning, and harvesting can be considerably reduced when orchard trees are trained to a single upright stem with the fruit-bearing lateral structural branches emerging from the single stem beginning at a height about 60 centimeters (2 feet) above ground level, rather than having these laterals emerging at ground level, as usually is the case in an untrained tree. As the trees become older and better able to support the scaffold branches, the main trunk can be extended upwards by cutting off the lower interfering scaffold branches. Training to establish this single stem can be further advanced into the nursery propagation stage by pinching off laterals on the young stem to permit a single upright development. In getting this system of growth to develop properly, it may be necessary to hold the trees upright by staking in the early stages of training, especially on a tree propagated as a cutting. A single-stem tree is desirable whether harvesting is done by hand or with mechanical tree shakers. In the latter method of harvesting, depending on the machine used, the trunk height may need to be extended to accommodate the equipment. All trees should be trained to make operational movement at the base of each tree comfortable and easy.

Lateral structural branches should be pruned and trained to radiate outwards from the central axis of the tree. Any branch that does not fit into such a pattern should be gradually removed. A lateral branch that begins to extend beyond the confines of a symmetrical tree should be cut and eliminated at the point of its junction with another more confined branch. With this manipulation, the remaining side branch becomes the branch terminal to support the tree in fruit production until it, in turn, may be eliminated because of overextension. On trees that are harvested by hand, vertical branches that extend skyward beyond the reach of the hand harvesters should also be cut at the point of junction with another more confined branch. The remaining limb, if necessary, should then be bent into a horizontal or, at least, a nonvertical position.

Essentially, then, guava trees are pruned to increase yield and to reduce the total cost of field operations by eliminating obstacles and branch hazards, allowing easier movement around the trees. Except for tree training to a single trunk and canopy development, pruning thereafter is done only in conjunction with crop cycling. The messy, distracting small twigs within the crown of the tree need not be eliminated since these branches can bear fruit to add to the total tonnage produced. In time, these branches will dry out and save the grower some unnecessary trimming cost.

Crop Cycling

The principle of crop cycling was developed by Shigeura and co-workers (*60, 61*) to harness the natural flowering and fruiting tendencies of the guava and contribute to increased yield and profitability. The concept is based on the fact that the guava flowers are borne only on new, succulent, vigorously emerging vegetative growths. These new growth flushes can be either new emergences of lateral buds on older stems within the crown, or extensions of already established terminals of various size and vigor.

The seasonal harvest pattern of wild guava in Hawaii is a response to growing conditions naturally occurring here. Being situated in the northern hemisphere, Hawaii's cool winters begin about the first of December and extend to the end of March, and its hot and drier summers extend from the first of June to the end of August. At the same time, except in leeward Kona on the Island of Hawaii, where the high mountains contribute to a rainfall pattern reversal, rainfall throughout the chain of islands is heavier during the winter months and lighter during the summer months. As far as guava is concerned, there are two short periods during the year when the temperature and available water from rainfall following a period of drought are conducive to the natural triggering of massive vegetative growth with its development of flowers and subsequent fruit-ripening approximately 5 months later. The first of these periods begins about the first of February and the second about the first of August. More often than not, the total rainfall in February is somewhat less than either January or March, contributing to a drier and warmer period in February. When this warmer period is sustained, and with timely rainfall, a massive flush of vegetative growth with its flower buds takes place, resulting in a heavy harvestable crop of fruits in about 5 months. The second period when vegetative growth is again triggered begins about the first of August, after the dry summer months. The consequence of these reactions to water and temperature at the critical periods is two distinct guava harvest seasons, the February and March flowers producing fruits to mature in August through December, and the August flowers producing fruits in January through April (Fig. 18). This natural fruiting tendency of guavas growing unkempt in the wild is increased, reduced, delayed, advanced, or shortened depending on the yearly weather change. The resulting dilemma in the factory operating sporadically only a few months out of the year is obvious, necessitating part-time employment or a drastic shifting of full-time employees in the total work force. With the advent of commercial cultivation of guava and the attendant care given to the orchards, the delivery of fruits at the factory has now extended

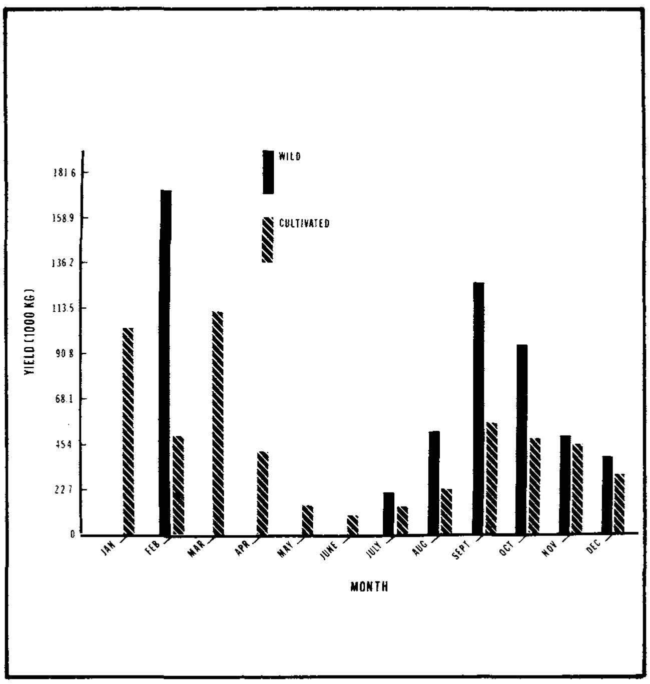

Fig. 18. Bar graph showing the yield pattern of guavas growing unattended in the wild (solid bars) compared with the yield pattern of cultivated guavas (striped bars). Note a definite spread in the season with cultivated guavas throughout the year, while the wild guavas have two distinct seasons of crop harvest. With improvement in management, the hope is to have commercial guavas ripening evenly and systematically throughout the year.

over a longer period for a more continuous operation, even though it is, as yet, very low in some months. With complete use of the crop cycling technique, operations at the factory should become constant throughout the year (Fig. 19). Production on a large plantation on the Island of Kauai is now being completely cycled to permit year-round operation with continued production of fruits in the field contributing to efficiency in the output of purees in the factory to be marketed in an orderly manner. Increased efficiency and cost reduction in factory operation can become an important item in the cash flow ledger. In addition, a systematization of field operations enables the formation of separate field work crews for pruning, herbiciding, fertilizing, and harvesting, to increase efficiency, resulting in large cost savings.

The production of guava fruits can be cycled by systematic cultural manipulations, i.e., pruning of trees, fertilization, irrigation, or defoliation. All of these methods singly or in combination are effective in influencing flower bud formation by forcing the trees into vegetative growth. Urea at 2 lb/gal with added surfactant has been found very effective in defoliation. However, since urea at that rate induces excessive vegetation, the recommended defoliant mixture per 100 gallons (378 liters) of final spray solution is 2½ pt (1200 ml) ethrel, 50 lb (12 kg) urea, and 1 qt (900 ml) surfactant. Its use on guava has been cleared by the Environmental Protection Agency (EPA) and the State government, under the Hawaii Pesticide Law 24C registration, SLN No. HI800012. The recommended method in crop cycling procedure should be instituted immediately after a crop is harvested or when the next cycled crop is desired. A crop harvest will begin approximately 7 months after cycling treatment. The cycle period is somewhat shortened to 6½ months if the fruit formation and enlargement period straddles the summer months, and lengthened to 7½ months if it straddles the winter months.

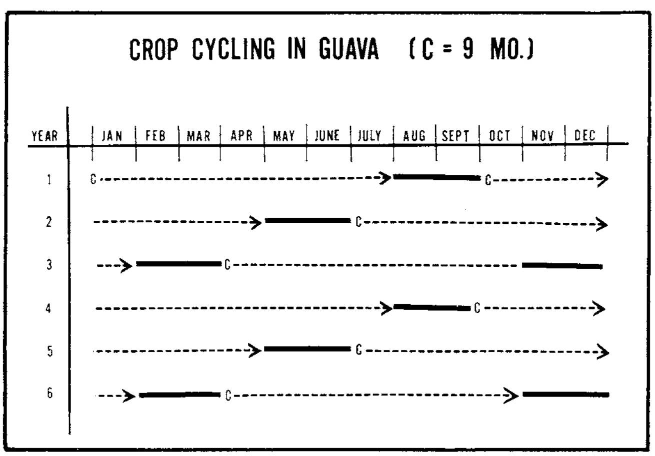

Fig. 19. A schematic cycling procedure indicating that when cultural treatment is applied at "C," fruit harvest can be expected 7 months later and extending over a 2-month period. Cycling again at "C" in October can be done to induce the next crop. Such a procedure can be continuously carried out in separate fields, when desired, with "C" at different times of the year, to contribute to year-round production on a plantation.

Whatever the wishes of the farmer in deciding which cycling method to use on the timing of fruit season, the trees should initially be pruned as suggested in the section on pruning. On a very lush tree, about 25 to 30 percent of the undesirable limbs can be eliminated. On a less vigorous tree, only about 20 percent of the undesirable limbs need to be eliminated. After this severe pruning, fertilize at the rate of about ¾ pound per inch in diameter of tree trunk as indicated by leaf analyses. The amount of fertilizer to apply will vary with leaf analysis information, the area being farmed, the available climatic condition, and the farmer himself. Water, if available, should be applied at this time. Defoliation beyond these treatments further adds to the precision in fruit set. The guidelines offered here should and will change with experience and as the needs differ.

Recent unpublished information (*11, 18*) has shown that the use of defoliation can sometimes be lessened and reduced. Reduced use of ethrel can be very effective on a hot, dry, or sunny day. However, weather conditions, especially temperature and rainfall on the spraying days, can be very fickle, hour by hour, and considerable caution needs to be taken when dosage manipulations are to be attempted. Then, too, while defoliation is not harmful to a tree, when ethrel is used continually at high concentrations, there may be an accumulation of ethylene within the tree, which may cause overblooming and a resultant poor fruit set. With this in mind, the rates of ethrel and urea can be reduced. These additional treatments may be used under differing conditions, and are given below:

Treatments (100 gallons of spray mixture)
- (a) 1 qt (900 ml) ethrel
  24 lb (10.9 kg) urea
  1 qt (900 ml) surfactant
- (b) 1½ qt (600 ml) ethrel
  24 lb (10.9 kg) urea
  1 qt (900 ml) surfactant

A schematic standardized outline for cycling is presented in Fig. 19. The outline uses a total of 9 months to obtain one crop, with the harvest season commencing 7 months after cycling treatment at "C." The chart indicates that when cycling is started on the first of January the crop can be completely harvested by the first of October. The second cycling begins on the first of October and ends on the first of July. The procedure can be similarly followed through 6 years of production for 8 crops during this time. Or, if 8 separate fields were separately cycled during the months indicated by "C," it would be possible to have fruits delivered to the factory throughout the year in a reasonably constant supply.

The crop cycling procedure disrupts the normal production tendencies of guavas obtained under natural circumstances. In response to natural climatic conditions, the guava produces a light crop of fruits in the spring months and a heavier one in the fall. The total yield under these conditions is relatively low since it is a simple response to two growth factors, sunlight and water. To force the tree into increased production by satisfying its other needs—fertilizer, supplemental pruning, and defoliation—is good farming since the cycling procedure extends the production potential of guava beyond its natural tendency. There is no current indication that crop cycling or defoliation is detrimental to the health and welfare of the trees, nor are there grounds to expect such a consequence. Until data are gathered to support this negative thought, crop cycling should and can be employed in guava production. However, work with growth regulators should be continued.

As in other tree crops, flower bud and fruit abscission in guava is a continuing problem from the time the flower buds emerge to the time fruits are about 1 inch in diameter. Preliminary observation suggests that as many as 90 percent of the flowers initially set do not form harvestable fruits. Although exact causes are not known, drought and erratic rainfall appear to be definite factors in this loss. Considerable research with growth regulators is indicated (*1*).

Harvesting

Although harvesting needs to be mechanized as the industry expands, at the current time harvesting is done by hand, using pails for temporary storage of fruits. Filled pails are emptied into lug containers, which in turn are loaded onto trucks to be hauled to the factory. During the height of the season, harvest intervals cannot be more than 2 to 3 days. Otherwise, losses in overripe and insect- or disease-damaged fruits can become very severe. The fruit is soft and requires considerable care in picking and handling. Once picked, the fruit deteriorates rapidly if left standing in the hot sun in the fields. If feasible, fruits should be hauled to the factory twice a day, or as soon after picking as possible. While in the field, they should be stored in a cool location under the trees or in a centralized shed protected from the scorching sun. Storage overnight in tightly stacked boxes on the truckbed is undesirable since the temperature within the stack of boxes can be higher than the surrounding air temperature. However, when overnight storage is necessary the boxes should be placed in a well-aerated, covered area.

The best way to maintain quality is to process the fruits soon after harvest, and have the fruit puree immediately chilled, frozen, or aseptically packaged. If necessary, the factory should be run 24 hours a day. An alternate procedure that may be used is to have reefer chill vans in the field to receive the fruits as fast as they are picked. This alternative may be economically unsound at the moment, but efficiency approaching these requirements should be strived for to maintain quality.

Mechanical harvesting trials (Fig. 20) with a tree shaker are very positive, but there are problems that need to be resolved before mechanical harvesting can become a reality. The type of machine, shaking stroke, proper maintenance of harvested fruits, and ripening of green fruits harvested are some problems that need to be solved (*39*).

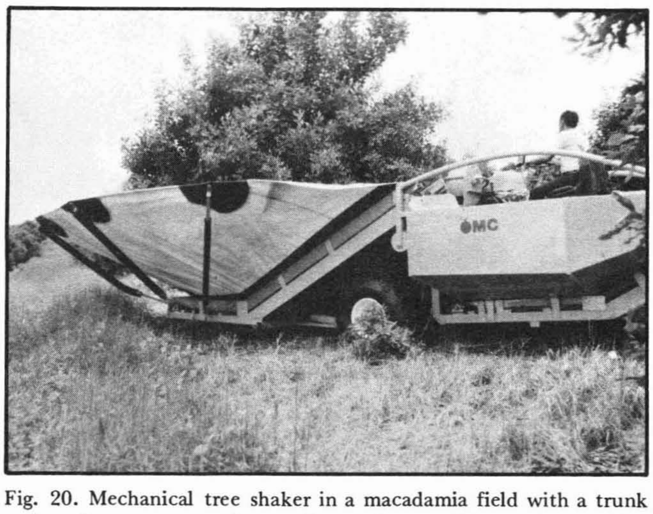

Fig. 20. Mechanical tree shaker in a macadamia field with a trunk grab and an apron catchment frame that possibly can be used for guava harvesting.

CULTIVARS

Cultivar selection in guava was initiated by Beaumont (*4*) in the early 1950's when he identified 'Kipapa', 'Halemano 1' and 'Halemano 2', 'Sacred Falls 1', etc. At about the same time, at the suggestion of Sherman (*56*), the senior author collected two clones, 'Lupi 1' and 'Lupi 2', from Haiku, Maui, which were exceedingly high in vitamin C, and planted these accessions in the Hilo and Ka'u areas. Ito and Nakasone (*26*) have identified several guava clones bred locally or introduced as being good for processing or eating out of hand. Nakasone, Hamilton, and Ito (*40*) report testing of cultivars including 'Beaumont', 'Ka Hua Kula', clone 'PR2' from Puerto Rico, and clones 'Patillo' and 'Pink Acid' from Florida.

'Beaumont', introduced in 1960 (*5*), and 'Ka Hua Kula', identified in 1972 (*26*) and introduced in 1978 (*41*), are the only processing guavas now recommended and grown commercially. Both of these cultivars have a high puree recovery percentage, are pink in color, have a pleasant aroma, and are delicate in flavor and high in total solids. They are somewhat low in acidity. These are also very high yielding and can be trained and pruned to whatever shape or system the farmer desires. In commercial field trials, 'Ka Hua Kula' appears to yield better than 'Beaumont' and seems to be a lower tree with less branch extension than 'Beaumont'.

Among the sweet guavas are the 'Hong Kong Pink', 'Lucknow 49', No. 7199, and No. 6363. Ito and Nakasone (*26*) have a few selections being tested for later introduction. Nakasone, Brekke, and Cavaletto (*43*) reported three selections—097 ('Ka Hua Kula'—authors' insertion), 107, and 093—as having sufficient merit to be retained for further observation.

INSECT CONTROL

Since many insects affecting guava growth and production have been dealt with in the reports by Zimmerman (*71*), Mitchell (*37*), and Fullaway and Krauss (*19*), only the major insects and their control will be considered in this text.

Oriental Fruit Fly, *Dacus dorsalis* (Hendel)

The oriental fruit fly is the single most destructive insect in the production of guavas. When the fly is uncontrolled, the amount of marketable fruit is drastically reduced. Damage occurs as the larvae hatch from the eggs oviposited beneath the skin of a ripening fruit and begin to feed on the flesh. Fruits turn progressively soft and mushy as the larvae begin feeding, until the fruits become "waterlogged" and the juice begins to drip on handling.

In a well-managed orchard with a dense canopy of foliage, which tends to obscure the ripening fruits, some farmers feel the damage is lessened. Fruit fly control in an orchard can be obtained with malathion and yeast hydrolysate bait sprayings. One or two bait sprays at weekly to 10-day intervals should be made throughout the field just before the fruits begin to ripen. During the harvest period this mixture can be used as spot sprays in the field and at the edges of the field on shrubs, grasses, or windbreak trees to attract and destroy the flies before they enter the field to oviposit in the fruits. Fruits that are infested with fruit flies in the field, in spite of this control measure, should not be left on the ground to rot. Infested fruits should be gathered and soaked in a container of water with an oil film on the surface, which suffocates any emerging larvae, or the fruits can be enclosed in a polyethylene bag from which emerging larvae cannot escape and thus are destroyed. These precautions can be of much benefit when adhered to rigidly.

Mediterranean Fruit Fly, *Ceratitis capitata* (Wiedemann)

Since the establishment of the oriental fruit fly in the lower elevations where guavas are found growing, fruit damage by the Mediterranean fruit fly has been minimal. The Mediterranean fly can be controlled with the same methods suggested for the control of the oriental fruit fly.

Green Scale, *Coccus viridis* (Green)

The green scale has been in Hawaii since the turn of the century and is presumed to have come from Brazil. It is a common scale insect found on many plants including guava, coffee, orange, and lime. The appearance of black sooty mold on the tree may be the first recognizable symptom to appear. In a badly infested orchard, the trees can be completely covered with scales, and the accompanying sooty mold that develops and grows on the honeydew secreted by the scales becomes very evident. In severe infestations, defoliation and flower abortion can occur and reduce yield drastically. The trees become black instead of the usual lush green. In working a badly infested orchard, the farmer can be completely smeared with honeydew and sooty mold by the end of the day. Such orchards should be sprayed immediately with malathion, petroleum summer oil, or a combination of these materials, with repeat applications at 10-day intervals. Since ants are nearly always associated with scales, ants should also be controlled.

Red-banded Thrips, *Selenothrips rubrocinctus* (Giard)

This species is another common insect in Hawaii, first recorded in 1910. It has a very large host list including guava, mango, litchi, and many ornamentals. Its presence can be characteristically identified by the silvery appearance of leaves and fruits. The affected areas may be excessively spotted with the dried excrement of the insect, which dries to form dark brown blotches. The larvae are generally yellow with a bright red band across the two basal segments of the abdomen.

Although the infestation of red-banded thrips can become unsightly, it generally is localized in the early stages, and control efforts should be instituted immediately in affected areas. Past experiences indicate that red-banded thrips infestation comes and goes, a hot and dry condition favoring a population increase, and a cold and wet condition a decrease.

Coconut Mealybug, *Nipaecoccus nipae* (Maskell), and Striped Mealybug, *Ferrisia virgata* (Cockerell)

Although the two species of mealybug are occasionally found on guava, they are seldom of economic importance. Several parasites and predators specifically introduced to combat mealybugs have been very effective.

Red and Black Flat Mite, *Brevipalpus phoenicis* (Geijskes)

The red and black flat mite feeds on the tissues of stems and fruits. The damaged surface becomes tan and appears corky. Damage and the effect on production are relatively small, and chemical control does not seem economically justified. However, when necessary, only localized sprayings with wettable sulfur should be made.

Chinese Rose Beetle, *Adoretus sinicus* (Burmeister)

The Chinese rose beetle is a very common insect that feeds at night on very young foliage. It consumes only the interveinal tissues, leaving a lacework of midrib and veins. The damage on guava from this insect is especially pronounced during a period of drought or when other host plants in a guava field are reduced by mowing or herbicide use. The adults hide during the day beneath loose soil or debris on the ground and emerge at night to feed. Chemical control appears unnecessary since the adult beetles are eaten by bufo toads.

Fuller's Rose Beetle, *Pantomorus cervinus* (Boheman)

This species forages generally in a similar manner to the Chinese rose beetle. Fortunately, chemical control is not necessary since the beetles are not too numerous. Parasites and predators reduce the larvae and pupae population, and the adult beetles are eaten by bufo toads.

Transparent-winged Plant Bug, *Hyalopeplus pellucidus* (Stal)

The importance of this insect to guava production has been somewhat confused because authorities disagree on whether this insect is predacious or a plant feeder. Zimmerman (*71*) reported that it is predacious while Fullaway and Krauss (*19*) considered it a plant feeder after finding a large number of this insect breeding on guavas. Gagne (*20*) more specifically considers it a flower feeder. In July 1975, Matayoshi (*33*) observed *H. pellucidus* in Isamu Maedo's guava farm in Hilo, where bud drop approached 100 percent. At that time, Maedo, at Matayoshi's suggestion, obtained control of this insect and bud drop with an application of malathion. Since then, whenever Maedo noticed bud drop and a buildup of the bug population, he obtained control with spot sprays of malathion. In 1981, Mau (*34*) determined through field experimentation that *H. pellucidus* nymphs and adults can cause flower bud abscission by feeding on the buds. Egg and nymphal stages are found in guava orchards primarily during the period between flower bud initiation and blossoming. Mau speculates that guava is not a preferred host.

Guava Moth, *Anua indiscriminata* (Hampson)

The larva of this moth feeds on young succulent leaves. However, reports on damage are very infrequent. The biology of *Anua* was worked on and reported by Fujii and Yoshida (*17*).

Spiraling Whitefly, *Aleurodicus dispersus* (Russell)

This whitefly was discovered in 1978, and a year later was found throughout the Island of Oahu, infesting many species of plants including guava. Although a spray program with malathion and petroleum oil may help, a major effort has been made by the state to introduce parasites and predators to combat this pest. The State Department of Agriculture reported in January 1981 that reasonably effective biological control had not yet been achieved in Honolulu.

The pesticides available for use on guava may change at any time due to changes in state and federal regulations. A grower should check the pesticide labels and secure the latest information from his county extension office before using a pesticide.

DISEASE CONTROL

Mucor Rot

Mucor hiemalis infection is initially noticeable on mature green fruits as a water-soaked lesion that develops very rapidly to involve the entire fruit. A fuzzy yellow mass of fungal bodies and mycelium as well as a yeasty odor are characteristics of later stages of disease (*29*). Small puncture wounds, probably made by insects, are consistently present in the infected fruits. Healthy fruits are not affected by the disease even when they are in direct contact with diseased fruits (Fig. 21). In laboratory trials, Ko (*28*) was not able to infect fruits with this disease without prior wounding of the fruit, so he considered *Mucor* to be a wound parasite.

Fig. 21. Two unaffected fruits in direct contact with a fruit badly affected by *Mucor*. Photo courtesy of W. H. Ko.

Mucor rot may be controlled by removing diseased fruits from the orchard and destroying them so that fruit flies and other insects cannot land on the fungal mass to pick up spores for reinfestation. The fruit fly population should also be controlled by insecticidal spraying to reduce wounding of fruits and the number of vectors. Ito et al. (*27*) identified several guava cultivars that are tolerant to mucor fruit rot.

Rhizopus Rot

Rhizopus stolonifer causes a fruit rot of guava in the field very similar to that caused by *Mucor hiemalis*. The lesion is initially oily and water soaked in appearance with a slightly sunken margin. It expands rapidly to involve most of the fruit. Mycelial development is sparse on the lesion surface, and the fungal fruiting structures (sporangia) are dark gray to black. Sporangia develop mostly at the infection site, which is always a wound. Spores are dislodged easily from the mature sporangia to become airborne (*47*).

Control of this disease is effected by field sanitation for reduction of inoculum, fruit fly control to reduce wounding of fruit, field management (e.g.. pruning of trees), and windbreaks to curtail prolonged periods of very high humidity and persistent dew.

Firm Rot

Firm rot is a disease identified only by its water-soaked appearance on the fruit. The lesions of such affected fruits are firmer than *Mucor* or *Rhizopus* rot lesions. Since no pathogenic microorganism has been isolated from fruits with this symptom, and bumping fruit against a hard object can initiate firm rot, it probably is not a parasitic disease (*28*). However, as the disease progresses, *Guignardia musae* may set in as a secondary problem.

Blossom-end Rot

Shigeura (*62*) reduced the incidence of blossom-end rot by applying calcium from many sources (Fig. 22). Penetrometer pressure readings on mature fruits were also higher after calcium application, indicating a firmer fruit. Although these indications have not been experimentally demonstrated, the farmers in a previously badly affected area noticed calcium application reduced the number of affected fruits in the field. The processors

Fig. 22. Blossom-end rot in guava. These symptoms on fruits have been reduced in preliminary trials with calcium fertilization.

also concur on this development. Further trials in this area are needed to substantiate these observations.

Fruit Spots

Fruit spots are commonly observed as a greyish-black, circular mass on ripening fruits. These spots are about 1.0 to 2.0 millimeters in diameter. *Guignardia musae* is also isolated from these spots but its cause–effect relationship has not been established. It is not usually a major problem in a well-managed orchard with a dense canopy of foliage covering the fruit. Preliminary field data seem to indicate fruits developing in direct sunlight are more affected by fruit spots.

Mummified Fruits

After a severe drought, dark black and undeveloped fruits will sometimes be observed on trees. While mummified fruits create some anxiety, an irrigation system to control just this condition is not justified. Occasionally, mummified fruits are found as small undeveloped fruits on pruned branches that have been left in the semishade for disposal.

Sooty Mold

Sooty mold is not a disease condition, as such, but a superficial growth of the molds *Asterina psidii* and *Meliola psidii* covering the trees (*31*). These molds grow on the honeydew excretion of insects such as scales, aphids, and mealybugs. In severe infestations the whole tree can be covered with this black mold, greatly reducing plant vigor and production. Working in an infested field can become quite messy since the sticky mold can be easily rubbed off the tree on contact. Sooty mold control is accomplished by ridding the orchard of honeydew-producing insects.

Parasitic Alga

Cephaleuros virescens on guava is common. It appears in a low cavity as brownish-black, slightly raised colonies on the leaf and fruit surfaces (*31*). The alga does not appear to be harmful, but further study of its development and importance is indicated.

WEED CONTROL

Guava is hardy, aggressive, and a perennial that has only recently become a cultivated crop. It is capable of growing and fruiting under severe competition from other plants; consequently, weed control efforts in a guava orchard may be only minimal to begin with, since control expenditure can become too high. There are several ways weeds can be controlled, however.

Minimal Control

Eliminate only tall weeds, by hand, that grow into the crown of the tree or in the space between trees. Eventually, however, such minimal management will result in an unproductive orchard, unless further effort in weed control is expended as cash flow develops.

Surface Mulching

Mulching at the base of trees can be done very inexpensively using black polyethylene sheets, cinder materials, or organic materials such as wood shavings. The latter two materials should be applied thickly enough to prevent weed growth yet permit rainwater penetration to the root area. Black polyethylene sheets prevent soil surface evaporation, and tend to produce water under the sheets through condensation, supporting tree growth besides affording weed control.

Mowing

Mowing throughout the orchard with an off-set tow mower is a good method by which tall, woody plants or grasses are eliminated. However, this method can become expensive since the weeds at the base of the trees will consume a large portion of the applied fertilizer depending on the application technique and available water. In such situations, the total amount of applied fertilizer needs to be increased.

Herbicide and Mowing

Herbicide around the base of trees with only occasional mowing in the areas between trees is a good method. The herbicide area can be gradually expanded into the mowing area as the trees become larger and older. This method is probably the most economical to use.

Complete Weed Control with Herbicides

Presently, only aromatic oil and paraquat are registered for use in guava fields (*45*). Roundup (glyphosate) and Aatrex (atrazine) have been tested by the College of Tropical Agriculture and Human Resources and petitions for registration have been submitted (*46*). The use of chemical weed control may initially appear expensive, but when properly applied, it can become a good economical method to achieve the gradual elimination of weed seeds and vegetative propagules.

PROCESSING

Depending on the length of time between harvesting and delivery of fruits at the factory, the quality of fruits as received will vary greatly. Consequently, the fruits are again immediately examined at the factory for further defects, malformations, and spoilage caused by insects, diseases, or mishandling. The defective fruits are discarded to ensure that only firm and clean fruits are processed. Clean, green fruits may be set aside at this time to ripen. Preliminary trials indicate these green fruits can be ripened using ethephon (*39*).

The fruits are then washed, either immersed in agitating water or placed on a washing table or a conveyor belt with a water spray system to wash off foreign debris clinging to the fruits. Further inspection and culling of undesirable fruits are again done at this point. The clean fruits are then macerated in a pulper fitted with a 0.033- or 0.045-inch perforated screen. In this pulping process the seeds and fibrous material are removed (*6, 55*).

The pulp is then paddled through a smaller-sized 0.020-inch screen, to eliminate the larger stone cells. The pulp can either be packaged in consumer containers or it can be sent through a mustard mill to further reduce the size of the stone cells. However, a mustard mill may increase the undesirable grittiness of the puree and will make the puree color whitish-pink, contributing to a less desirable product.

In the pulping procedure extreme care should be exercised so that the flow of materials through the system will be steady and even, permitting no pileup or backup of materials to be paddled excessively. When this happens, color quality is again reduced. To permit uniform flow, it may be desirable to chop the fruit prior to pulping.

The puree thus formed is a convenient, intermediary form of the guava fruit that can be immediately used in various ways, e.g., for beverage base, jam, jelly, and marmalade production, bakery goods, candy making, and sundry other concoctions as the gourmets wish. If not used immediately, the puree must be frozen, heat processed, or aseptically packaged.

Stored canned guava puree subjected to heat in processing deteriorates in flavor, color, and nutritional value upon storage (*6*). In another study, guava puree concentrate containing 1000 ppm potassium sorbate and stored at 45° F showed no signs of spoilage during 5 months storage. Flavor and aroma quality did not deteriorate appreciably until the 4th month. However, color breakdown to brown from pink was apparent in 2 months. Virtually all of the ascorbic acid was lost during the 1st month, but carotenoid values remained the same during the 5-month storage period (*9*). Obviously, this method is not ideal.

The primary commercial preservation method now in use is freezing (*6*). Although very expensive, this method brings about the least change in total quality of the puree. This technique requires that the puree be rapidly frozen at about -18°C (0° F) and kept frozen until the product is used. However, the cost of freezing and the holding of puree in a frozen condition until marketed and used is very high, and is a major deficiency of this method. A simpler and cheaper method needs to be used to make guava competitive with other fruit products.

Aseptic packaging has been studied by Cavaletto and Chan (*12*), with financial support of the state government. This method involves rapid sterilization of the puree in a heat exchanger for 20 seconds at 93°C (200° F) prior to filling presterilized plastic bags under sterile conditions. The product may then be stored without refrigeration. However, after 6 months of storage at ambient (room) temperature, aseptically packaged guava puree lost 70 percent of its ascorbic acid and a slight color change occurred. At the moment this procedure appears satisfactory for short-period storage, but remains somewhat questionable for a longer time if color is a prime concern to the end user. Quality reduction with time and temperature in aseptic packaging is quite serious; but to encourage its use, code dating and recommendation that the product be stored in as cool an area as possible, or even in the chill room, to prolong the shelf life is a possibility. The fact that aseptic packaging will result in lower processing, storage, and transportation costs is a substantial item in the total cash flow. Unreliability of sales can increase storage time and cost of frozen puree. The industry can probably be better developed if it changes the total industrial philosophy by considering the sale of puree as the primary objective of the total industry, and gearing every aspect of production to that sale. The ultimate, of course, is to use the puree in some consumer product as fast as possible. Aseptic packaging, with its lower storage cost, should fit into this scheme better than freezing. Operational management can fit the other production aspects into this system. With this new direction, the industry has a better chance of survival.

The chemical and physical nature of the fruit and the resultant puree have been investigated (*8, 9, 10, 13, 14, 38, 66*) to add to the total knowledge of the guava.

PROFITABILITY

The production of cultivated guava has increased considerably since 1974, as indicated in Table 4. This increase in acreage is the result of small farmers getting into guava on a part-time enterprise basis. The somewhat sudden increase in acreage in 1977 was the additional planting on the Island of Kauai by C. Brewer and Company, Ltd., a Hawaiian sugar and macadamia agency. The continued growth in acreage from 1978 through 1980 resulted in a large-volume increase in fruit production. Essentially, the total output in puree is predominantly used now in the production of guava juice or nectars, jams, jellies, pastry goods, and other sundry products.

Table 4. Cultivated guava production in Hawaii

Year	Number of farms	Acres of crop	Production (1000 lbs.)	Farm's value of sales ($1000)
1971	20	65	405	30
1972	25	80	437	34
1973	50	50	170	37
1974	61	299	775	60
1975	67	356	987	79
1976	84	459	1951	164
1977	96	660	2143	186
1978	97	795	3790	337
1979	105	905	4500	425
1980	108	975	7520	865

Source: Statistics of Hawaiian Agriculture, 1980.

Since the guava industry is still in a very early stage of development, cultivation and production methods have not as yet been standardized and accepted by all growers. Hence, any single or specific cost study (*52, 53, 65*) for a single situation, whether production or marketing, can be severely criticized as inadequate and hypothetical. In this line of thought Scott (*54*) and Marutani (*32*) independently reported cost studies on macadamia production under several different assumptions. Since such a procedure can become voluminously involved, the authors cite a study the senior author made (*64*) on a 100-acre farm. The study indicated, aside from the cost of land, taxes, or depreciation, that a grower can have a positive cash flow in the 4th year and amortization or pay-back on the 5th or 6th year. Net to the grower can be $1000 to $2000 an acre depending on the input-output assumptions. If cost of land is included, positive cash flow is again in the 4th year, but amortization is in the 10th year. These figures are gross indications of profitability. If any grower wishes to have a more exact cost study to fit his own tax, finance, and profitability needs he should hire a qualified agricultural economist using his own data and the current year's cost figures.

OUTLOOK–PRESENT AND FUTURE

Guava is a delicious and delectable tropical fruit crop becoming increasingly better accepted on the U.S. Mainland and in Japan. With the aid of the state government, promotional efforts in Southern California in 1978 and 1979 increased sales considerably over the previous years. Promotion in Japan by Takasago and Kirin Beer in 1978 indicated the strong position guava has taken in the vending machines. Both of these firms increased efforts in 1979 with added promotions over TV and radio. However, in 1981, there was a downturn in the market demand, and the outlook for guava in the juice and nectar markets in both the U.S. Mainland and in Japan now appears dimmer. However, it is hoped that with continued stronger promotion and market development the demand for guava should increase.

The opportunities to increase the economic base in Hawaii are a matter of conjecture. There are many concerns that need to be recognized and resolved so that guava can become a sizable industry in Hawaii. One of the largest of these is foreign competition from several Central and South American countries, the Caribbean islands, and possibly the Philippines, where the Philippine Packing Corporation (Del Monte) is now growing the Beaumont-type guava. Australia is also now becoming strongly interested; but technology, yield, cost of production, and shipping apparently are major deterrents.

However, a Hawaiian industry may yet be possible since all but two aspects of guava production in Hawaii have been positive. The negative points are the availability of investment capital and cost of promotion. In any event, when land, production, money, and promotion are drawn together in a reasonable pattern and logic, it is hoped that guava can be developed into a substantial industry. Guava is well adapted to Hawaiian conditions, where new technologies in growing, processing, and marketing are now adequately available, more so than in the competing countries, where technologies are weak or unavailable.

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NOTE: As part of a structural reorganization, the Hawaii Agricultural Experiment Station and the Hawaii Cooperative Extension Service have been merged administratively under the name HAWAII INSTITUTE OF TROPICAL AGRICULTURE AND HUMAN RESOURCES, College of Tropical Agriculture and Human Resources, University of Hawaii.

Hawaii Institute of Tropical Agriculture and Human Resources
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