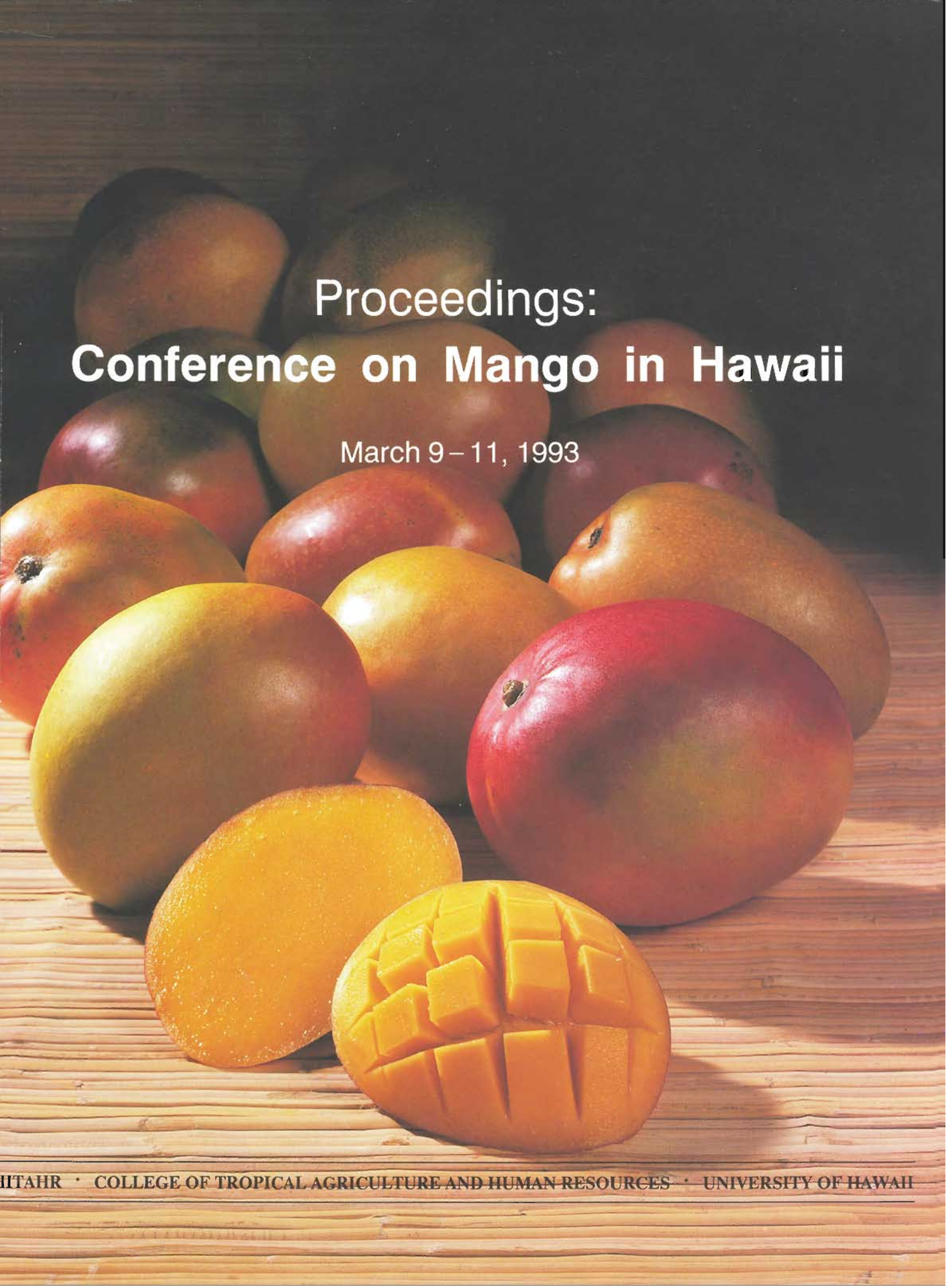
Proceedings:

Conference on Mango in Hawaii

March 9 – 11, 1993



HITAHR · COLLEGE OF TROPICAL AGRICULTURE AND HUMAN RESOURCES · UNIVERSITY OF HAWAII

Proceedings:

Conference on Mango in Hawaii

March 9-11, 1993
Campus Center, University of Hawaii at Manoa

PREFACE

The Conference on Mango in Hawaii was sponsored by the College of Tropical Agriculture and Human Resources (CTAHR), University of Hawaii at Manoa, with partial support from the Cooperative State Research Service.

Although the 1991 farm value for mango sales reported by the Hawaii Agricultural Statistics Service was only $46,000, mango is one of the most widely grown fruit trees in home gardens. Quarantine regulations prevent the export of mango fruit to the U.S. mainland. However, the fact is little known that mangos are being exported from Hawaii to Canada and Europe, and that Mexican mangos are imported to the Honolulu market via California. Because of the mango's popularity and potential, it is regarded as an important component of Hawaii's specialty fruits industry and merits attention for further development. This conference was organized to discuss a wide and comprehensive range of subjects related to mango. The only other meeting of this nature in Hawaii, the First Territorial Mango Forum, was held on Maui on July 1-2, 1955.

The speakers were chosen from CTAHR, state and federal agencies, and the industry itself for their specialized knowledge in the various areas revelant to mangos in Hawaii. We were fortunate to have the resources to invite Dr. Tom Davenport from the University of Florida's Tropical Research and Education Center at Homestead. His willingness to share his expertise, especially in the area of mango flowering manipulation, was very helpful. We were also fortunate to have several CTAHR retirees, Dr. Richard A. Hamilton, Dr. Wallace C. Mitchell, and Mr. Warren Yee, who agreed to share their knowledge.

Editors: C. L. Chia — Extension Specialist in Horticulture
D. O. Evans — Research Associate
Department of Horticulture
College of Tropical Agriculture and Human Resources
University of Hawaii at Manoa

Cover photo courtesy of the Hawaii Department of Agriculture, Market Development Branch; Kyle Rothenborg, photographer.

CONFERENCE ON MANGO IN HAWAII

Sponsored by the
College of Tropical Agriculture and Human Resources
University of Hawaii at Manoa

Venue: Campus Center (Rooms 306-307)
University of Hawaii at Manoa

PROGRAM

Tuesday, March 9

8:15 – 8:55	Registration at door
9:00 – 9:15	**Welcoming Remarks** Dr. N. P. Kefford, Dean, CTAHR
9:15 – 9:45	**Highlights of the 4th International Mango Symposium (Florida)** Dr. Tom Davenport, Univ. of Florida
9:45 – 10:15	Coffee break
	PEST CONTROL
10:15 – 10:45	**Fruit Flies and Mango Seed Weevil in Relation to Quarantine** Dr. Wallace Mitchell, Dept. of Entomology, CTAHR
10:45 – 11:15	**Research on Disinfestation Procedures for Mango Insects** Dr. John Armstrong, USDA – ARS, Hilo
11:15 – 11:45	**Irradiating Mangos?** Dr. James Moy, Dept. of Food Science & Human Nutrition, CTAHR
11:45 – 1:15	Lunch break
1:15 – 1:45	**Mango Blossom Midge** Larry Nakahara, Plant Quarantine Branch, Hawaii Dept. of Agriculture
1:45 – 2:15	**Mango Diseases and their Control** Dr. Wayne Nishijima, Dept. of Plant Pathology, CTAHR
2:15 – 2:45	**Pesticides Registered for Mango** Dr. Mike Kawate, Dept. of Environmental Biochemistry, CTAHR
2:45 – 3:15	Coffee break
	CULTIVARS & PROPAGATION
3:15 – 3:45	**Mango Cultivars** Dr. Richard Hamilton, Dept. of Horticulture, CTAHR
3:45 – 4:15	**Propagation Practices for a Commercial Nursery** Frank Sekiya, Frankie's Nursery, Waimanalo

Wednesday, March 10

	POSTHARVEST
8:30 – 9:00	**Postharvest Physiology of Mango Fruit** Dr. Robert Paull, Dept. of Plant Molecular Physiology, CTAHR
9:00 – 9:30	**Determining Internal Quality of Mango Fruits** Dr. W. K. Nip, Dept. of Food Science & Human Nutrition, CTAHR
9:30 – 10:00	Coffee break
10:00 – 10:30	**Sensory Quality of Mango Fruits** Cathy Cavaletto, Dept. of Horticulture, CTAHR
10:30 – 11:00	**Mango Processing** Dr. Harvey Chan, USDA – ARS, Hilo
	PLANT PHYSIOLOGY
11:00 – 11:30	**Floral Manipulation in Mangos** Dr. Tom Davenport, Univ. of Florida
11:30 – 1:00	Lunch break
1:00 – 1:30	**Use of Potassium Nitrate on Mango Flowering** Dr. Mike Nagao, HITAHR – Hawaii County
1:30 – 2:00	**Growing Mangos Under Hydroponic Conditions** Dr. Tung Liang, Dept. of Agricultural Engineering, CTAHR
2:00 – 2:30	**Determination of Leaf Age** Dr. Samuel Sun, Dept. of Plant Molecular Physiology, CTAHR
2:30 – 3:00	Coffee break
	COMMERCIAL PRODUCTION
3:00 – 3:30	**A Small Grower's Perspective** Warren Yee, Waianae
3:30 – 4:00	**A New Corporate Grower's Perspective** Steve Kai, Kau Agribusiness, Pahala

Thursday, March 11

TRADE, ECONOMICS & MARKETING

8:30 – 9:00	**Mango Industry in the Americas** Dr. Tom Davenport, Univ. of Florida
9:00 – 9:30	**Mango Market Statistics** Dr. Stuart Nakamoto, Dept. of Agric. & Resource Economics, CTAHR
9:30 – 10:00	Coffee break
10:00 – 10:30	**Hawaii Grading Standards for Mangos** Sam Camp and Isabelo Palalay, Commodities Branch, Hawaii Dept. of Agriculture
10:30 – 12:30	**Marketing Panel** Moderator: Dr. John Halloran, Dept. of Agricultural & Resource Economics, CTAHR Panelists: **Marketing Mangos in Hawaii** Ronald Yamauchi, Yamauchi Produce, Honolulu **Promoting Hawaii Mangos** Janet Leister, Market Development Branch, Hawaii Dept. of Agriculture **Exporting Mangos to Canada** Sam Hugh, Ham Produce & Seafood, Honolulu **Exporting Mangos to Europe** Michael Kohn, Equipment Team Hawaii, Kaneohe **Market Niches for Mango Products** Dr. Aurora Hodgson, Dept. of Food Science & Human Nutrition, CTAHR

Lunches on your own. Campus Center Cafeteria rooms 203 D & E are reserved for our group.

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HIGHLIGHTS OF THE 4TH INTERNATIONAL MANGO SYMPOSIUM

Tom Davenport
Department of Horticulture
University of Florida

I want to thank Dr. Chia for his kind invitation and helpful support so that I could participate in this conference. He asked me to summarize the events at the 4th International Mango Symposium that was held at Miami Beach in July, 1992. Planning for that meeting began with an invitation at the close of the 3rd International Mango Symposium in Darwin, Australia, three years ago. The Mango Symposia are sponsored by the Mango Working Group of the International Society for Horticultural Science. The symposium was organized by Dr. Jonathan Crane (Extension Specialist in tropical fruits) at the Tropical Research and Education Center at Homestead. Dr. Bruce Schaffer organized the program.

Overall, there were around 500 participants at the symposium representing around 40 different countries. The symposium included a pre-conference field tour of mango production in Sinaloa, on the west coast of Mexico. It is one of the major exporting areas of mangos to the United States. They primarily export 'Tommy Atkins', 'Haden', and 'Keitt'. Import from Mexico is one of our biggest problems, as far as our small mango-producing area in Homestead is concerned, because of the large volume of fruit that comes into the country.

Seventy-five oral presentations and a number of posters were presented. The subject areas covered world production, plant pathology, physiology, growth and development, taxonomy, breeding and genetics, horticultural practices, postharvest physiology, handling and marketing, entomology, and pesticide regulations. Following are highlights of the conference presentations.

World Production

Asia is the largest producer of mangos in the world, claiming around 62 percent of the world's production. They have a million hectares in production, producing 15.7 million metric tons of fruit per year. These figures include all of India, Pakistan, Southeast Asia, and the Philippines, but by and large, India is the largest major producer. Except for the Philippines, most of these producing areas do not export much fruit. Most is grown for local consumption. In India, for example, transportation and packing-house systems are crude, and they do not have the infrastructure required to move fruit over large distances. Their primary cultivars are 'Alphonso' and 'Dashahiri'.

The South African mango industry is growing rapidly. They currently produce around 42,000 metric tons of fruit. About 60 percent of that is processed to mango pickle, called atchar. Small fruits are harvested prior to seed coat hardening. Pickers also harvest fruit from the ground, taking them to processing plants where they are chopped, and spices are added to make atchar. The Indian population is quite large in South Africa, so there is a demand for mango pickle. Of the remaining 40 percent of the crop, most (about 30 percent) is distributed within the country and the rest (10 percent) is exported, primarily to Europe. This alternative use of what would otherwise be useless "drops" is quite interesting. I feel it has a tremendous market potential in the U.S. and other countries with ethnic consumers who are used to such spicy condiments.

A general talk by R. L. Brown focused on mango production and trade (Abstracts, IV Intl. Mango Symp., Miami Beach, Florida, July 5-10, 1992, Univ. Florida, IFAS, Trop. Res. & Edu. Cntr., and Intl. Soc. Hort. Sci., p. 4). He was optimistic about expansion of the mango market. The success of commercial mango production depends upon the people involved in mango distribution and the strategies they use to develop markets. In addition, another key element is to provide fruit the year around, as mentioned today by Dr. Kefford. If consumers saw mangos in the store every day – different cultivars, perhaps, and likely from different sources – they would better appreciate what a mango is and could begin to enjoy them as a regular part of their diet.

Plant Pathology

Some of the talks presented information on specific and newly discovered pathogens of mango trees and fruit. One new pathogen discussed by J. Darvas (ibid. p. 11) was *Dothiorella dominicana*, which he feels is an important pathogen currently spreading in South Africa.

Mango malformation is another disease that is rapidly spreading around the world. Caused by the fungus *Fusarium subglutinans*, one effective control measure is simply to prune infected branch tips and burn them. The disease organism attacks small, tender buds, especially those infested with mites or other insects. Growers have successfully limited its initial spread in Homestead in this manner. Similarly, successful control has been achieved in South Africa.

Commonly found in the southern hemisphere, *Xanthomonas compestris* pv. *mangiferaeindicae* (*Xcm*) causes bacterial black spot of mango. This was a particularly hot topic during the 3rd International Mango Symposium. It is especially prevalent in South Africa and has great potential for continued spread. The talk by O. Pruvost (ibid. p. 24) brought that message home. Any time we ship cuttings that are not sanitized we risk the possibility of spreading disease.

The rest of the pathology session focused primarily on anthracnose problems in mango-growing areas of the world.

Stress Physiology; Growth and Development

K. D. Larson (ibid. p. 40) presented a talk on root flooding and its influence on formation of hypertrophied lenticels in bark above the flooded zone. The authors speculated that these lenticels may be a means of facilitating oxygen diffusion down to oxygen-starved roots in chronically flooded soils. Flooding is a problem in some low-elevation areas of South Florida where urban encroachment is forcing growers to find cheaper land in the Everglades. Although trees are planted in mounded rows, the area is flooded sometimes five or six months of the year. Thus, the roots of these trees may be under water for extended periods. Many are not aware that trees in South Florida are grown in porous limestone rock. In higher areas (about 10 ft above sea level), this rock is ground into a course gravel in a grid of trenches with a special scarifying dozier blade similar to some I have seen used on Hawaii to break up lava rock. Trees are planted at the intersections of the trenches. They are planted on raised gravel beds in lower areas (about 4 to 5 ft above sea level) which are prone to flooding as the fresh water lens in the porous rock rises above the surface of the rock during the rainy season. It may flood up to the top of the raised bed itself, so there is an interest in South Florida to better understand flooding and its effects on the physiology of orchard trees.

A. W. Whiley (ibid. p. 54) stressed the importance of low temperature on mango flowering and emphasized the need to consider the genetic background of selections derived from various environmental conditions and its relation to flowering during minimal temperatures. For example, 'Tommy Atkins' was selected in a subtropical environment providing extended periods of chilling temperature to reliably stimulate flowering each year. It, however, does not flower reliably in lower latitudes which do not receive such cool temperatures. 'Carabao' and many other successful cultivars which were selected in the deep tropics may be triggered to flower at higher temperatures than those developed further north.

Water stress has been considered for many years to be a major induction factor of mango flowering. Flowering occurs during the dry season in many areas of tropics; however, results of controlled experiments conducted in Whiley's lab in Australia and concurrently in our lab have demonstrated no direct affect of water stress on flowering. There may, however, be an indirect affect which will be discussed in detail in my other presentation on mango flowering.

E. K. Chacko (ibid. p. 32) presented a talk on the role of immature leaves in mango shoot growth, stressing the importance of certain gibberellins involved in shoot elongation. There are over 80 known gibberellins. Some gibberellins may also inhibit induction (commitment) and/or initiation (commencement) of flowering. Aging of leaves reduces their capacity to produce gibberellins over time. We find that branches with young leaves do not flower even under inductive conditions, and as these leaves age they lose this inhibitory effect. Therefore, one or more of these gibberellins may be involved in inhibition of flowering.

This theme was continued in a talk by R. Nuñez-Elisea (ibid. p. 43), who discussed the influence of gibberellin-synthesis inhibitors on flowering. Soil applications of paclobutrazol can stimulate early and more efficient flowering of mango in tropical areas. This particular report demonstrated that it was not paclobutrazol per se that induced the flowering. Chilling temperatures, in which the trees were residing at the time, were necessary to actually induce flowering. It appears that the paclobutrazol simply reduced the level of a putative inhibitor (a gibberellin?). Thus, by reducing the level of inhibitor we are able to stimulate flowering under marginally inductive conditions, i.e., conditions where the temperatures are not as low as is normally required to induce flowering.

Factors responsible for seasonal changes and successful pollination rate of mango flowers in Israel was presented by S. Gazit (ibid. p. 36). He showed that even though optimum temperatures for normal flowering may be present at the time flowers are opening, it is the temperatures present during early development of panicles which determines their success. Chilling temperatures during floral development may inhibit pollen germination or survival. A talk by M. Issarakraisila (ibid. p. 64) in the Taxonomy, Genetics, and Breeding session presented information on this subject in more detail. It was reported that sporogenisis (pollen development) is greatly affected by low temperatures, so that even though you might have optimum temperatures at the time that flowering is actually occurring, those flowers which were previously exposed to low temperatures lack viable pollen.

There were more talks on paclobutrazol and its use, especially in relation to stimulation of early flowering. Another two talks concerned chemical and manual thinning of panicles to force a second, delayed flowering flush. Freezing temperatures in subtropical areas can have an important impact on the success of flowering. In such cases there is a desire to delay flowering to avoid early loss of the crop. The strategy is to deblossom or pinch inflorescences, which delays production of flowering panicles by a month or even a month and a half. Abscission of panicles has been successfully achieved using ethephon or hydrogen cyanamid.

Workshops

Several workshops on various topics were held during the evenings. One was "Mango Tree Size Control and Training," in which were discussed approaches to control tree size in orchards. There was a "Mango Genetic Resource Conservation" workshop which discussed the various germplasm reservoirs throughout the world, what is available, and how well they are doing. We have a collection of about 50 trees at the experiment station in Homestead. There is also a collection at the USDA center in Miami. Trees at both locations were severely damaged in Hurricane Andrew. Their survival is uncertain.

There was also an evening workshop on "Diseases of Mango" which mainly focussed on anthracnose, malformation, and postharvest diseases. I was surprised that bacterial black spot was not discussed in more detail, considering its emphasis in the previous symposium. The main reason may be that fewer Australians, Indians, and South Africans participated this year. These are areas where it is a major problem. It apparently does not occur in the Northern Hemisphere (except perhaps India?), but it seems to me that this is something which we should be aware of and understand before it migrates here.

Field Tour of a Mango Production Area

A field tour conducted during the Symposium showed participants the mango growing area in South Florida, all the way from our high-elevation mangos at ten feet above sea level to our low-elevation mangos at four feet above sea level. Participants were amazed to see mango trees sitting in water and people having at times to harvest some of those with a boat. That turned out to be quite a joke, when in fact they have done just that to avoid getting their feet wet.

Taxonomy, Genetics, and Breeding

Talks were presented on various breeding and genetic studies going on in Brazil, Australia, and Florida. An interesting paper by J. M. Bompard (ibid. p. 60) discussed other mango species with potential commercial importance for breeding into the commercially important *Mangifera indica*.

In more basic areas of study, H. Mathews (ibid. p. 66) demonstrated the use of *Agrobacterium tumefaciens* strains to obtain genetic transformations in mango, which opens the opportunity for genetic engineering. A talk on frequency and characteristics of zygotic seedlings from polyembryonic mango cultivars using isozymes as genetic markers was presented by C. Degani (ibid. p. 61). R. J. Schnell (ibid. p. 68) described use of RAPD^{tm} markers for doing something quite similar at the gene level. He is also trying to map genetic interrelationships among various cultivars and their sources to aid their breeding program.

Horticultural Practices

S. C. Mandhar (ibid. p. 83) reported on development of a mango harvester which snaps off the fruit about two centimeters above the pedicel, therefore reducing the amount of latex sap bleeding on the fruit. It was developed in India where they do not have sophisticated machinery available. The affect of soil temperatures on rooting of cuttings was presented by O. Reuveni (ibid. p. 88). Four polyembryonic cultivars were studied with variable results. Twenty to thirty degrees was optimum. Temperatures higher than this range inhibited rooting, as did lower temperatures.

A new approach to an old problem was discussed by R. Holmes (ibid. p. 79), who described formation of grower groups in Australia to increase efficiency of their extension programs. He described their success in extending research information to the growers.

Postharvest Physiology and Handling, Food Science, and Marketing

M. C. Lizada (ibid. p. 104) demonstrated that lowered oxygen tension such as one might get in controlled atmosphere storage facilities contributes to internal breakdown of mango fruit.

The basis for differential ripening was described by H. Lazan (ibid. p. 102). He described activities of enzymes actively involved in fruit ripening.

Handling systems to reduce mango sap burn were described by R. Holmes (ibid. p. 98). 'Kensington Pride' is the primary production cultivar in Australia. Sap burn is a particular problem with that cultivar. I have never seen that in any other cultivar. It is, however, an important problem for them.

Entomology

Most talks described various entomological pests that are common in their particular areas. The session began with a description, by J. Sharp (ibid. p. 126), of approved quarantine treatments available for fruit flies, such as hot water dip, steam vapor, quick freeze, radiation, and low temperature. Some of you are actively involved in this already and are familiar with all of these strategies.

Talks by speakers from the West Indies, Israel, Pakistan, Florida, and Costa Rica described various insect pests. J. D. Hansen (ibid. p. 120) reported on control of the mango seed weevil. It was a rather general presentation. The pest is not present in the Americas but it is a problem in many places around the world.

The main meeting ended with evening workshops. One entitled "What is Needed to Improve Research in Practical Aspects of IPM for Mango" focused on integrated pest management as a tool to reduce pesticide use while improving control of pests.

The workshop on flowering physiology of mango discussed environmental influences on flowering such as low temperature, water relations, nutrition, and day length. Indogenous factors influencing flowering, such as a florigenic promoter and inhibitor, were also covered. Discussion of flowering management strategies in tropical and subtropical environments included growth synchronization and use of triazole plant growth retardants such as paclobutrazol.

The last workshop focused on postharvest handling of mangos. The symposium closed with talks on quarantine treatments and pesticide regulations. A major problem, of which many of you are already aware, is the re-registration program currently being conducted by EPA on virtually all pesticides. It is going to be tougher and tougher for minor crops, such as mango, to get clearance for use of certain pesticides. There are people here who are a lot smarter than me that can discuss this issue, but it is a problem which needs to be addressed.

The meeting closed with the decision that the 5th International Mango Symposium be held in 1995 in Israel. I would encourage all of you who are interested in mangos to make plans to attend that meeting.

FRUIT FLIES AND MANGO SEED WEEVIL IN RELATION TO QUARANTINE

Wallace C. Mitchell
Emeritus Professor, Department of Entomology
College of Tropical Agriculture and Human Resources
University of Hawaii at Manoa

I am surprised so many came to this meeting, because the commercial value of mangos is not very large. In fact, I have always considered it to be nil as far as Hawaii is concerned. Looking at the group here, I will bet that the total value of your efforts, salaries, etc. for these three days added together is greater than the annual value of commercial production of mangos in Hawaii. In the Hawaii Department of Agriculture's statistics for 1991, mangos were included under the tropical specialty fruit sales, with a farm value of $46,600. The farm price was 73 cents a pound. There were 40 farms totaling 65 acres with 2,750 trees of which 810 were bearing. So, you see, we have a long way to go.

There are a number of factors that have limited the commercial expansion of this crop. Other speakers in the conference will cover cultivars, propagation, physiology, commercial production, economics, trade, marketing, and so forth. In the time allotted to me I will attempt to provide information on one of the limiting factors responsible for plant quarantine regulations.

Hawaii's mangos are hosts for plant pathogens, insects, mites, and other pests that are not present on the U.S. mainland. Tom Davenport mentioned that the mango seed weevil is not present in the Americas; neither are fruit flies, except every once in while they get into California and Florida and create havoc.

Plant quarantine regulations deter the accidental introduction and dissemination of mango pests into Hawaii. Tom Davenport also mentioned a number of insect pests from various parts of the world that were discussed at an international conference a few months ago. We have enough difficult problems and do not need any more. The plant quarantine regulations deter the possibility of these pests entering into Hawaii and also the dissemination of mango pests to the mainland. I wholeheartedly support Hawaii's state quarantine regulations and the U.S. Department of Agriculture's federal regulations. The quarantine regulations should be maintained and followed to prevent the movement of these serious pests to the mainland.

I shall briefly discuss the mango insect pests in Hawaii. Special emphasis will be given to tephritid fruit flies and the mango weevil, *Cryptorhynchus mangiferae* (Fabricius). We have 13 insect and mite pests that attack mangos in Hawaii. Some of these and their commodity treatments will be discussed by other speakers. The mango shoot caterpillar is a noctuid moth that is a minor problem. There are a number of scales (Homoptera). The mango soft scale, *Protopulvinaria mangiferae* (Green), the green scale, *Coccus viridus* (Green), the red wax scale, *Ceroplastes rubens* Maskell, and the Cockerell scale (white scale), *Pseudaulacaspis cockererelli* (Cooley), all attack growing mangos. The green scale has a quarantine regulation against it because it is not present on the mainland. We also have the red banded thrips (Thysanoptera), *Selenothrips rubrocinctus* (Giard), attacking the foliage. Two species of mites (Acari), the mango bud mite, *Eriophyes mangiferae* (Sayed), and the mango spider mite, *Oligonychus mangiferus* (Rahman & Sapra), occasionally cause problems and are difficult to control for the lack of a properly registered pesticide.

In the Diptera (true flies) we have a mango blossom midge, *Dasineura mangiferae* Felt, that is quite prevalent at this time of year in the blooms you see on the trees. In addition to the blossom midge, there are two tephritid species of fruit flies that attack ripe mangos.

Fruit Flies

There are four species of tephritid fruit flies (Diptera, family Tephritidae) in Hawaii. Two species, the Oriental fruit fly, *Bactrocera dorsalis* (Hendel), and the Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann), are pests of mango. The egg, larva, and adult stages of development of these fruit flies are greatly influenced by air temperature. Pupal development is greatly influenced by soil temperature.

Eggs. Eggs are deposited by the female beneath the skin of the host fruit and develop within two to three days.

Larvae. The eggs hatch and the larvae begin to tunnel out the fruit. Larvae are negatively phototrophic and tend to put their heads down into the pulp of the fruit and their small spiracles near the surface to obtain air and survive. Larva development takes place in about six to ten days depending on the temperature. The larvae molt twice. There are three stages in the development. From the egg comes the first instar, then the larva molts twice, producing the second and the third instars. The third instar develops into the pupa.

Pupae. The pupa is a stage in which the larva changes from a maggot to an adult insect. Pupae are found in the soil, usually in the top 2 in. They can be found in the top 2-6 in. of the soil. It takes nine to 10 days for the pupal development to take place and adults to emerge.

Adults. Adults of newly emerged flies must find a source of protein and carbohydrate for maturation of the ovaries and the testes. This preovipositional period may take one to two weeks for wild flies. The length of time for the preovipositional period depends upon the species of fruit fly and the ambient temperature.

Under natural conditions the flies will obtain this source of protein and carbohydrate from plant exudations, animal excrement, fruit fly regurgitant, honey dew, bacteria, yeasts, and fruit juices. Adult fruit flies in nature may live from two to six weeks or longer, again depending upon the temperature, humidity, and activity.

We have a number of things that we can do to reduce populations of fruit flies in mango orchards.

Preharvest control. *Biological control* is the use of fruit fly parasites, predators, and pathogens. A number of these beneficial organisms have been purposely introduced into Hawaii to reduce the populations of fruit flies.

Sanitation. Removing unusable fruit in the orchard is important. All infested fruit should be destroyed. The fruit can be buried, cooked, and fed to poultry or swine. Cultivating the soil beneath the trees to expose larva and pupa to ants, poultry, lizards, and song birds is also a worthwhile idea.

Fruit picking or stripping. Picking all the fruit from a tree has been used primarily in eradication programs. This was used a great deal in California. They picked all the fruit from the tree to remove any ovipositional sites that would be available for the continued development of the fruit fly population.

Wild host destruction. Elimination of noneconomic or noncultivated hosts that fruit fly populations need to survive is effective, especially in eradication programs. Fruit of these wild hosts provide a source for survival when the cultivated hosts are absent or not fruiting.

Paper bagging of fruit. Bagging of fruit to prevent fruit fly ovipostion has been used by many backyard growers and small farmers in Hawaii. The bag is removed 24-48 hours prior to harvest to allow the natural color of the fruit to develop. I do not recommend it for commercial farmers. Small holes must be made in the paper bag in order for transpiration to take place. Plastic bags are not used.

Chemical control. Bait sprays are the most common method of fruit fly control. The bait spray is mixture of a protein hydrolysate and the insecticide malathion applied to the mango foliage as a spray. Large droplet size is more important than a fine spray or complete coverage. Male and female fruit flies are attracted to the protein, feed on it, and the toxicant kills them before they are sexually mature or deposit their full complement of eggs.

We are gradually losing many of the insecticides, miticides, and fungicides, used as tools in the past. What is going to happen when we lose the presently registered compounds? We have nothing in the developmental stage for fruit fly control in the field. You can recall that when Rachael Carson published her book, "Silent Spring," we lost DDT, and others have followed.

Postharvest treatments. Commodity treatments are needed in order to be able to transport mangos and other host fruits from areas infested with fruit flies through quarantine barriers into areas that are free of the pests. The commodity treatments have been developed by researchers in the U.S. Department of Agriculture Fruit Fly Laboratory. Dr. Armstrong is going to speak after me and will discuss some of the later developments in commodity treatments. Some of the commodity treatments mentioned here are effective for fruit fly control but have not been approved for fruit flies in mangos.

Fumigants. These are chemicals which produce a gas or vapor that is toxic to insects, bacteria, or rodents. Methyl bromide (MB) and ethylene dibromide (EDB) have been used in the past. As many of you know, the use of EDB was canceled in 1984. The use of MB is presently on the ropes and we will likely lose it as an effective fumigant. Research on new fumigants is scarce.

Lethal temperatures. The use of heat and cold to kill insects is an old remedy. It is based upon the thermal tolerance of the insect and the commodity. Mortality is a function of temperature and time. We have a number of treatments that are concerned with lethal temperatures.

Vapor-heat treatment. Heated air which is saturated with water vapor is used to raise and hold the commodity to a specific temperature for a prescribed period of time. This has been effective for papayas and has also been tried and is utilized in other countries for fruit flies in mangos.

Heat and cold treatments. Hot and cold baths have been used with papayas which were immersed in hot water (120°F, 49°C) for 20 minutes for disease control and then held at 46-48°F (5-6°C) for 10 days cold storage (the time it takes for a ship the reach the U.S. mainland).

Two-stage hot-water treatment. A modified hot-water and cold-storage treatment to kill fruit fly eggs is promising. Papaya fruits are submerged in 105-109°F (41-43°C) water for 30 minutes and then transferred to a bath at 118-122°F (48-50°C) for 20 minutes. The fruit are then hydrocooled and placed in cold storage at 50°F (10°C)

Hot-water treatment. Mangos held in a hot water bath at 114.6 – 116.8°F (45.9-47.1°C) for 67.5 minutes will kill fly eggs and larvae. Mangos had to be mature green and fully developed to withstand the treatment. Immature mangos did not ripen and shriveled up after treatment.

High-temperature forced-air treatment. Hot air is circulated with fans over papayas for about 7 hours until the final (fourth) stage and air temperature of 120°F (49°C) is reached or fruit center temperatures reach 117°F (47.2°C) but do not exceed 118°F (47.8°C). You will be hearing more about this treatment for mangos from Dr. Armstrong.

Cold treatment. USDA regulations require a cold treatment, to kill eggs and larvae of the medfly, for 10 days at 32°F (0°C) or below; 11 days at 32.9°F (0.5°C) or below; 12 days at 33.9°F (1.11°C) or below; 14 days at 35°F (1.66°C) or below, or 16 days at 36°F (2.22°C) or below. Notice that as the temperature increases slightly the length of time for exposure of the commodity to that temperature is lengthened. Quick freezing is also an effective disinfestation treatment for fruits that can be used after freezing.

Gamma irradiation. Irradiation will kill all stages of the fruit flies. The dosages that kill fruit flies range in the neighborhood of 150-500 Gray (GY) (15-50 Krad) and will also injure some commodities. There are still questions about consumer acceptance of irradiated food. Irradiation is used to sterilize the fruit flies released in eradication programs. Dr. Moy is going to speak on irradiation later this morning and he will give you the latest information. In my opinion, irradiation has great chances of being approved as a quarantine treatment for fruit fly disinfestation of mangos and other tropical fruits.

Shrink-wrap plastic. This is the enclosing of individual fruits with a semipermeable plastic shrink-wrap film. The shrink-wrap film has extended the shelf life of papayas, has retarded ripening, (depending upon the atmosphere within the fruit), and has reduced water loss. Jang (1990) reported that shrink wrap reduced Med fly egg hatch by 80 percent after 72 hours and 120 hours. Shrink wrap is a new idea that is being investigated as a possibile quarantine treatment.

Insect growth regulators (IGR). These are chemicals that interfere with the action of insect hormones controlling molting, maturity, and other growth functions from the pupae to the adult stage. Saul and Mau et al. (1985, 1987) tested methoprene applied as a dip to papayas and peaches. It allowed larvae to pupate but prevented adult insects from emerging. Another problem we have in plant quarantine is that you cannot have anything survive. Just because the larvae pupated and no adults emerged, that particular method of treatment would not be accepted. IGRs are experimental compounds.

Methods for fruit fly disinfestation of mangos and other tropical fruits and vegetables have been developed by researchers in the USDA Tropical Fruit and Vegetable Research Laboratory. Their research program continues to be the lead agency in Hawaii for future development of commodity treatments.

Mango Weevil

Mango weevil *Cryptorhynchus mangiferae* (Fab.) (Coleoptera, family Curculionidae) was first reported in Hawaii in 1905 (Pope 1929). We also have a scolytid beetle, the mango bark beetle, *Hypoglossum pyrrhostictum* (Butler), and the scarabaeid mango flower beetle, *Protaetia fusca* (Herbst). The latter two may become serious problems.

The mango weevil is more difficult to kill than fruit flies. Immature and adult stages of the weevil are found in a protected position within the seed in the center of the fruit and not near the surface. Less than 1 percent of the mangos examined have shown beetle damage to the flesh. Damage is confined almost entirely to destruction of the seed, which is of prime importance to propagators of rootstock.

Weevil life cycle information in Hawaii was developed by Balock and Kozuma (1964). Adult beetles are about 1/3 in. long, and they may live for a long time (437 days in the laboratory). Warren Yee tells me he read a paper describing how a weevil was starved but lived for several months without food or water. Adult mango weevils have elbowed antennae and a very short beak, unlike the sweet potato weevil. They have a habit of feigning dead. They are active at night, feign death and hide in crevices in the bark of the tree during the day. The pre-ovipositional period is variable.

Eggs. Eggs are fastened singly on the surface of the skin of young mangos with a brownish exudate which completely covers the egg. The female also uses her short beak to make a crescent-shaped cut in the skin of the mango near the egg. Exudate from the cut flows out and solidifies; this also covers and protects the egg. Eggs hatch within five to seven days, depending on the temperature. A female may deposit as many as 15 eggs per day, and in the laboratory we have seen as many as 300 eggs within a three-month period.

Larvae. The larvae are legless grubs with a light brown head that bore directly into the fruit by cutting a hole in the chorion (egg shell) where its surface was in contact with the fruit. Larvae quickly penetrate the flesh and bore into the seed. As the fruit matures the tunnel is obliterated. The exact number of instars in not known but is believed to be from five to seven. Larval development takes from 15 to 22 days. As many as six larvae have been observed in a seed.

Pupae. Pupal development occurs within the seed and takes from seven to 10 days, depending on the temperature. When first formed, the pupae are white, and they then change to a reddish color near completion of development. Within seven to 10 hours after the reddish color change occurs, the pupa changes to an adult weevil. Egg to adult development may take as long as six to seven weeks.

Adults. Adults remain in the seed for a long time, perhaps months. Under natural conditions, the infested fruit falls to the ground, the flesh disintegrates, the seed becomes wet with rain, disease organisms soften the seed, and the adults chew their way out. Rodents may feed on the seed. Ants may enter the seed and devour the pupae, larvae, or adults. Pope (1929) reported that adults appear in May in Hawaii and begin laying their eggs on the very small mangos.

Preharvest control. *Sanitation.* Since there are no known alternate hosts for this weevil, the biggest source of infestation is dropped fruit and mango seeds lying on the ground. Field sanitation, regular removal and destruction of fruit and/or seed, is recommended, but it is not a sure cure. Even undersized fruits remaining on trees after the harvest season should be destroyed.

Chemicals. Sprays applied to the boles of the trees to contact adults hiding in the crevices of the bark have not been very successful in Hawaii. An effective chemical spray for mango seed weevil has not been found.

Commodity Treatments. No quarantine treatments for mango weevil have been approved by the USDA, to my knowledge.

Fumigants. EDB was used experimentally, but its use was canceled in 1984. Methyl bromide at 3 lb/1,000 ft^3 for 8 hr at 70°F (21°C) killed all stages of the weevil but damaged the fruit. Research for new fumigants is not receiving the attention it should. Alternative methods of commodity treatments for the mango weevil are needed if the mango industry is to expand in Hawaii.

Lethal temperatures. Hot water immersion treatments for mangos in Mexico and the Caribbean Basin have been effective. Both vapor heat and forced air are under consideration as quarantine measures for the mango weevil. Subfreezing temperatures were investigated by McBride and Mason (1934) many years ago.

Gamma irradiation holds promise as an effective commodity treatment for the mango weevil. Seo et al (1974) found adults were more resistant to gamma irradiation than were eggs, larvae, and pupae. Researchers have reported larvae development is inhibited and pupation prevented at 20,000 rads. Pupae failed to develop into adults with dosages of 10,000 rads or higher. No adult mortality occurred at 80,000 rads. Researchers in South Africa report that mango fruit is very sensitive and phytotoxicity occurred to mangos at 100 krad or higher.

Microwave (dielectric heating). Studies utilizing microwaves to control mango weevil were initiated by Seo et al. (1970). Mangos were irradiated continuously for 25-60 sec or irradiated in four to 10 increments of 10-15 sec each. The interval between increments was 3-4 sec. The fruit undergoing treatment was rotated 360°. Results indicated that continuous treatment with microwaves of stationary fruit for 45 sec or longer cooked the rind and pulp of 90 percent of the fruits. Rotating the fruit in 10-15 sec intervals cooked the pulp, but only in small areas next to the seed. The internal seed temperatures varied from 123 to 165°F (50.56-73.89°C). Mortality of adult weevils ranged from 50 to 99 percent. Further work is needed to secure approval of this method as a quarantine treatment.

Radiographic (x-ray). Radiographic detection (Hansen 1981) has been used to detect insects in plant tissue. Preliminary tests utilizing an x-ray machine to determine if mango weevils could be detected in the seed was done by a group of us including Cathy Cavaletto and Leng Chia. This technology is used to inspect luggage in the airports. Fruit were examined with a Hewlett-Packard 43804 Faxitron x-ray system. Tube voltages of 40-50 KV for 2.5-5 minutes exposure, depending upon fruit size, were used. Fruit size varied from 180 to 850 g. Kodak Industrex Instant 600 photographic paper produced the final images by which the fruits were judged to be infested or clean. We were able to see larvae within the seeds. Fruits were then cut open and the seeds examined for weevils. Of 163 fruits examined, 31.3 percent were infested. The researchers had an 89 percent accuracy in determining the presence or absence of the weevil. With the improvements in baggage inspection x-ray machines and computerized methods for examination, further work is justified in the development of this as a possible quarantine treatment.

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RESEARCH ON QUARANTINE DISINFESTATION OF MANGOS

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Mangos cannot be transported from Hawaii to markets on the U.S. mainland or in other countries that prohibit the entry of fruit fly hosts without quarantine treatment. Mangos in Hawaii presently have no available quarantine treatments to disinfest the fruit of tephritid fruit flies, including Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann); melon fly, *Bactrocera cucurbitae* Coquillett; and oriental fruit fly, *B. dorsalis* Hendel; or the mango (seed) weevil, *Cryptorhynchus mangiferae* (F). Whether mangos can be a host for the so-called Malaysian fruit fly, *B. latifrons* (Hendel), is questionable.

Japan imports mangos from Australia, Philippines, Taiwan, and Thailand after the fruits receive a vapor heat disinfestation treatment that raises the fruit pulp temperature to a specified temperature and holds that temperature for 10 – 20 minutes before hydrocooling.

The ARS Hilo laboratory recently completed construction of a vapor heat research facility that will be used to provide data to determine the required parameters for an efficacious quarantine treatment using this technology. Meanwhile, we have been developing a high-temperature forced-air treatment that, to date, shows promise in disinfesting Mediterranean and oriental fruit flies from mangos. The treatment consists of heating mangos with forced hot air at 85 – 95 percent relative humidity. The fruit surfaces remain dry during treatment because the dewpoint of the air is maintained below the fruit surface temperature to preclude condensation onto the fruit. The mango pulp is heated to 47.2°C, measured at the outer seed surface during treatment, followed by hydrocooling until the pulp is 30°C.

The data required to demonstrate a probit 9 quarantine security to USDA – APHIS is a treated population of 100,000 target insects of the most heat-tolerant life stages with no more than three survivors. Mediterranean and oriental fruit flies are the most heat-tolerant species, and the late-aged eggs and first instar larvae are the most heat-tolerant life stages.

Our accumulated data for the forced hot-air treatment are:

370,805 Mediterranean fruit fly eggs treated, with four survivors.

25,318 Mediterranean fruit fly first instar larvae treated, with zero survivors (74,682 more needed to complete data).

443,789 oriental fruit fly eggs treated, with zero survivors.

114,676 oriental fruit fly first instar larvae treated, with zero survivors.

About 30,000 of the less heat-tolerant life stages are needed to show that the forced hot-air treatment provides quarantine security. We hope to complete these data for the forced hot-air treatment this year during mango harvest season.

Vapor-heat treatment is identical to a forced hot-air treatment except that water condenses on the fruit surfaces during all or some part of the treatment process. When the forced hot-air treatment data is complete, we will test a vapor-heat treatment to show corresponding pulp temperature profiles and insect mortality using Mediterranean and oriental fruit fly eggs and larvae. One to two years will be required to complete this work to provide a second quarantine treatment.

Mango weevil remains a major problem. No available treatment technology, other than irradiation, has shown promise as a quarantine treatment, and the temperatures and times required to kill mango weevil with heat also damage the fruit. Microwave treatment, ultrasound detection, and field sanitation were found ineffective. So long as there is no available quarantine treatment against mango weevil, USDA – APHIS may not allow the entry of mangos from Hawaii into the U.S. mainland regardless of applicable fruit fly disinfestation treatments. Japan imports mangos from countries where mango weevil occurs and, although there is a zero tolerance for mango weevil, evidently does not inspect for this insect *at this time*. With applicable quarantine treatments against fruit flies, some countries may accept mangos from Hawaii without disinfestation treatment against mango weevil. The inherent danger is that quarantine regulations may change.

Q: What is the distribution of the mango weevil?

A: The survey that Jim Hansen and I did during the 1986 mango season found mango weevil on every island and in almost every orchard where we looked; the only differences were the percentages of infested mangos in any particular orchard. We did orchard sanitation studies where we removed the fruits and seeds from the ground, but after two years of tests we found more weevils in the treated orchard plots than in the controls. Apparently there were enough non-cultivated mango trees growing wild near the test orchards to provide more mango weevils, and therefore the orchard sanitation did not work. We forced adult weevils to fly in the laboratory by placing them on the ends of dowels with a sticky barrier around the sides that the insect could not pass; the weevils eventually took flight from the dowels and flew around the laboratory for several minutes. This demonstrated that, contrary to reports in the literature, this insect is capable of sustained flight. This may explain in part how the mango weevil becomes distributed, and why our orchard sanitation tests failed to control this insect.

Cathy Cavaletto: I should add that when we did our studies using X rays to detect mango weevil, we compared varieties from one location and observed what seemed to be large differences in infestation among varieties.

A: We also noted that during our survey, but we did not develop sufficient data to analyze for major differences. The problem is that regulatory agencies generally regard a fruit as a host or a non-host, and it is difficult to prove that an individual cultivar is not a host when many other cultivars of that fruit are hosts. A seedless mango would, of course alleviate this problem.

Q: Have you done irradiation research?

A: We are not equipped to do irradiation work at our laboratory. However, one of my counterparts in Australia informed me that dosages required to kill mango weevil caused damage to the fruit. Because of this damage and the question of consumer acceptance, Australia dropped that approach, and now they use vapor-heat treatment against fruit flies. When I asked him what they did about mango weevil in regard to exporting mango to Japan, he told me that although Japan has a zero tolerance for mango weevil, Japan does not inspect for mango weevil because mangos are not grown in Japan. Of course, regulatory agencies can change such policies at any time.

Q: How did the ultrasound technique work?

A: We used ultrasound detection systems to listen to mango weevil and fruit fly larvae. We could actually hear the insects moving about inside the fruit, especially when they were feeding. This approach was dropped because there were too many false positive or false negative readings caused by other factors in the fruit, such as gas movement in ripening fruits, or because the larvae occasionally became quiescent and made no sounds we could detect.

Q: Why wasn't microwave effective?

A: We found that the types of equipment we were using caused uneven heating of the fruit, which tended to cook parts of the fruit. Also, air in the seed cavity expanded when heated, causing the mango to explode. We need to use microwave equipment that will permit differential heating, i.e., heating the insects without heating the fruit. Contacts I have made with microwave researchers in the military-industrial sector indicated to me that such technology was available and that it may be possible to target the insect without heating the fruit. New Zealand's HortResearch group in Auckland is conducting research in microwave technology as a disinfestation treatment for a number of insects, and a colleague in Thailand recently told me that Japan is planning to begin testing a microwave treatment facility in Bangkok for quarantine treatment purposes. This is an exciting area of technology with potential use in quarantine treatments.

Q: Does the mango weevil attack other fruits?

A: No, it is host-specific to the mango. There are two species of the mango weevil. The one we have attacks the seed and is rarely found in the flesh. The other species tends to attack the flesh and is found in India and elsewhere.

Q: Would ultrasound technology, such as is used to break up kidney stones, possibly be effective against the weevils in the seed?

A: We did some work with that, briefly and without success. You'll note that kidney-stone patients are placed in a water bath, because water is the best way of transmitting ultrasounds. The ultrasound heats up the water, and we thought that was a rather expensive way to get hot-water immersion. It also tends to affect the fruit surface; there is not a lot of penetration.

Q: When does the adult weevil leave the seed?

A: It has been our experience that the adult leaves the seed after the flesh has rotted away and the seed is naked on the ground. The seed then splits with age, or openings occur from deterioration. During our survey, we found it difficult to find adults outside of the seeds. Several of us spent three days collecting only about a dozen adult weevils. They tend to hide in the bark of the trees, and they may hide in the lava rock in mango orchards on the Big Island; we call this cryptic activity "overseasoning" from one mango season to the next, since we do not have a real winter here. They hide very well, for a very long time.

Q: Why is mango weevil quarantined from the U.S. mainland?

A: Regulatory statute prohibits the transport of any live insects from Hawaii to the U.S. mainland, Furthermore, mangos are cultivated in Florida, where mango weevil does not yet occur. Even if mango weevil did occur in Florida, the prohibition against the transport of live insects would still be in effect.

Dr. Michael Williamson: I have worked with Dr. Armstrong on the commercial application of dry heat. I had a request from Taiwan to test a vapor-heat chamber there for mangos to certify it for treating against fruit flies. Taiwan is going to be shipping a small amount of mangos in June into California. Taiwan has had this facility for several years, but it has never been certified, so they have never been able to ship their fruit to the U.S. Apparently they don't have the mango weevil. There is a good possibility that vapor-heat treatment could be commercially certified by APHIS for killing fruit flies in mangos, but that doesn't help you with the weevil. The fruit fly problem can definitely be overcome with Dr. Armstrong's dry heat technology.

IRRADIATING MANGO ?

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Mango can be marketed as fresh fruit or as processed products. The latter includes juice and puree, dehydrated slices and juice powder, canned, and frozen products. My discussion today will be on fresh mango, and on the question of whether or not we should consider irradiating mango.

As we know, mangos grown in Hawaii are prone to infestation by two groups of pests: fruit flies, of which there are three commercially important species in the islands, and mango seed weevils. Because mangos grown here are likely infested by these pests, USDA-APHIS has not allowed Hawaii-grown mangos to be exported to the U.S. mainland. For many years, this has persisted as a "catch-22" situation. Without an approved quarantine treatment procedure by USDA, growers are not considering large-scale cultivation of mangos in the islands. On the other hand, without adequate commercial planting, a market for fresh mangos from Hawaii cannot be developed.

As we also know, quarantine treatment of papayas grown in Hawaii for the export markets has shifted since September 1984 from chemical fumigation to thermal methods. While the thermal methods (vapor heat and dry heat) meet USDA approval, some aspects of these treatments have created some quality problems due to the effect of heat on the biochemistry and physiology of the fruit. Assuming the mango seed weevils can be inactivated by thermal means, the quality problem of the fruit will probably be similar to that of papaya and needs to be considered as a marketing problem.

The irradiation process is an alternative for treating mangos. The process can be described as simple, versatile, efficacious, and controversial. Foods can be placed next to a radiation source, either a gamma source such as Cobalt-60, or electron beams, for irradiation, exactly the same as treating a food or a medical product with x-rays. Therefore, it is a very simple process. Studies around the world have shown that different foods can be irradiated for various purposes: fruits and vegetables for disinfestation and shelf-life extension; grains and beans for disinfestation; potatoes and onions for sprout inhibition, a form of shelf-life extension; and meats and seafoods for decontamination by killing harmful bacteria. The process is therefore very versatile, much more so than any existing process in use today. Also, it is efficacious, meaning it is both efficient and effective. Consider the treatment of papaya, for example. If papayas are to be irradiated as a quarantine treatment, which has been approved, the dose required is 0.15 kiloGrays (kGy), which will take 10-15 minutes on the conveyor belt for cartons of papayas to travel from the entrance to the exit of the irradiator, and every papaya in the carton will be thoroughly irradiated. Therefore, the disinfestation process is both efficient and effective.

The controversial aspect of the irradiation process is due to two factors: first, the negative publicity we have heard for the past 50 years about nuclear bombs, nuclear reactor leaks, and radioactive fallout. Some people mistakenly relate food irradiation with these happenings, which is completely not true. And secondly, the misinformation spread by anti-food-irradiation activists about the safety of food irradiation. The facts are that irradiated foods, when handled and treated properly, are completely safe for human consumption and contain no radioactivity or toxic substances. As of 1992, irradiation has been approved in 37 countries for treating more than 45 foods or food groups for purposes indicated above. UN agencies such as the FAO, WHO, IAEA, and the American Medical Association are some of the organizations endorsing food irradiation, and urging countries to develop and use this process commercially. Currently, 22 countries are irradiating some 20 food items commercially or semi-commercially.

For mangos, irradiation can disinfest the two groups of pests as a quarantine treatment, and could also extend the shelf-life of the fruit. A study by Cornwell (1966) showed the non-emergence dose for mango seed weevils (*Cryptorhynchus mangiferae*) to be 0.33 kGy. Brodrick and Thomas (1978) reported the required dose to be 0.50 kGy. For sterilization of three species of fruit flies, the minimum dose is 0.15 kGy. Therefore, the disinfestation dose needed for mangos falls in the range of 0.33 to 0.50 kGy.

What about extending the shelf-life of mangos by irradiation? There certainly is incentive to do so if research results support this expectation. From the mid-60s to the early 70s, studies of irradiation of mangos for shelf-life extension by researchers from Thailand, the Philippines, India, Puerto Rico, Florida, and Hawaii have shown that shelf-life of mangos can be extended from 5 to 16 days when treated with doses of 0.25 – 0.75 kGy, depending on the variety of the mangos tested. The sum of all these data would suggest that a minimum dose of 0.50 kGy and a maximum dose of 0.75 kGy would give the 'Haden' variety a shelf-life extension of seven days or more, and, at the same time, would take care of all the fruit fly eggs that might be oviposited in the mango.

Quality retention of irradiated products must also be considered. Data from the irradiation project at the University of Hawaii at Manoa from 1965 to 1972 showed the 'Haden' variety could tolerate radiation dose up to 1.0 kGy, its sensory qualities are retained up to 1.5 kGy, and its nutrient qualities (Vitamins A and C) are retained up to 2.0 kGy. These figures are encouraging, because as long as the tolerance dose is higher than the disinfestation dose and the shelf-life extension dose, the process is useful. It was also found that irradiated mangos would ripen normally, even though the ripening might be delayed.

A market test of irradiated mangos was conducted in a supermarket in Miami in October, 1986. In less than three weeks, 4,000 kg (almost 9,000 lb) of irradiated Puerto Rican mangos were sold out, a good indication of consumer acceptance. In early 1992, Vindicator, Inc. in Florida, the only dedicated food irradiator in the United States, irradiated strawberries and citrus and marketed them in Central and South Florida, and in the suburbs of Chicago. All the irradiated fruits received very high consumer acceptance.

In the United States, government rules and regulations are in place to allow irradiation of Hawaii-grown papayas. In April 1986 the FDA approved irradiation of fresh foods for disinfestation and delaying maturation at doses up to 1.0 kGy. In January 1989 the USDA – APHIS approved irradiation of Hawaii-grown papayas as a quarantine treatment procedure at a minimum dose of 0.15 kGy. For mangos, the FDA rule will apply. A request to USDA – APHIS to modify the dose requirement for Hawaii-grown mangos will be needed.

Economic studies of irradiating various fruits indicate that the cost is not high, and is competitive with the cost of thermal treatment of fruits, especially if the irradiator can be used for several products at different seasons.

In conclusion, results of various studies mentioned above indicated a number of advantages and benefits in irradiating mangos for export markets. Therefore, if the question is raised as to why we want to irradiate mangos, the answer is that irradiation will efficiently and effectively serve as a quarantine treatment method as well as bringing the benefit of shelf-life extension of the fruit.

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Q: How is the radiation produced; what elements are involved?

A: There are three types of sources. The first are gamma sources, which include two radioactive elements, either cobalt-60 or cesium-137. Cobalt-60 has a half-life of 5.3 years, meaning after that time you lose half of its strength, so you have to replenish the source often, possibly every two years, in order to keep the dose rate up and have an efficient operation. Cobalt is a solid metal, insoluble in water, so it will not contaminate a pool. Even if it leaks out of the capsule, it can be recovered from the bottom of the pool. Cesium-137 is not available commercially; cobalt-60 is. The biggest supplier of cobalt-60 is in Canada, and they sell it for about $1.60 per curie. When we built our research irradiator in 1965 we began with 30,000 curies. A commercial irradiator would have about a million curies, and a pilot-plant sized irradiator should have about half a million curies. A problem with cesium-137 is that it is a byproduct of refining uranium and is in the form of a chloride. It has to be double-encapsulated in stainless steel tubes because it is highly soluble in water, as all chloride salts are. It is somewhat corrosive, and it generates a lot of heat. Standing at room temperature, a capsule of cesium-137 could reach 400°F. When used for food irradiation, it has to be raised up out of the pool to be in proximity to the food as the cartons of food move by; when the source is returned to the pool, the water sizzles. Cesium-137 has a half-life of 30 years, so it can be used for a long time without replenishment.

The second source is high-energy electrons. These are generated in a machine and shot out at almost the speed of light. The electrons are shot at the food as it passes on a conveyor belt. The problem with this source is that the penetration of electrons is very shallow. For every million electron-volts (Mev) of the machine, the penetration is only half a centimeter. The maximum we can use is a 10-Mev machine, due to the worry about radioactivity getting into the food. Beyond 10 Mev, there is a chance of causing some nuclear changes in the food by knocking some electron off the food's atoms. A 10-Mev machine would give a maximum penetration of 5 cm. There is also a problem of uniformity, or how to ensure that every part of foods on a conveyor belt gets the same amount of electrons. The advantage is that the machine is very compact and can be turned on and off, and people are much more comfortable about this kind of technology. The Department of Energy funded two electron machines, to Florida and Iowa, as part of a demonstration irradiator program mandated by Congress to help industries learn how food irradiation is done. This was supposed to have been established in six states, including Hawaii, but it was funded for only three years, and each state was to have submitted a proposal to get the funds. Our people did not move fast enough. Florida and Iowa obtained the funds and acquired the machinery, which was made in France. I saw the one in Gainesville. Two years after being received, it is still not working yet; it is very complex, and the French engineers are still working on it.

The third source is converted x-ray. If you take a strong metal, like tungsten or vanadium, and bombard it with electrons, they will emerge from the other side as x-rays. Like gamma irradiation, x-rays are very penetrating, and can be used to irradiate foods. The conversion efficiency, however, is very low: 5 – 8 percent; the rest is heat.

Q: What dosage would be useful for postharvest disease control.

A: Bacteria are easier to kill with irradiation; fungi are somewhat resistant. Pathologists find about seven different fungi invading papayas, and studies revealed that 1.5 – 5 kGy would be needed to kill these fungi, which is beyond the tolerance dose of most fruits. Irradiation is not a good way to treat postharvest diseases.

Q: If you use the sterilization dose on a fruit to sexually sterilize the fruit fly eggs, there will still be a live organism in there. How do you know that it is really sterile.

A: A task force of the International Atomic Energy Agency concluded that the generic dose necessary for sexually sterilizing the fruit fly at any of its stages is 0.15 kGy. They believe that even though the eggs might survive and grow, the next stage would not be normal. Therefore, USDA – APHIS accepted that dose and promulgated the regulation in January 1989. However, as a practical matter, if you have a fruit that contains a wiggling larvae, whether or not to accept that fruit is a difficult question for quarantine authorities to ponder.

There is a move to develop means to determine whether or not a food item has been irradiated. This is partly for the consumer, so that they can have informed choice in purchasing irradiated foods. However, it is most difficult to detect changes in foods given dosages under 1 kGy, particularly foods with high water content. Dry foods and bony foods can be detected if they have been irradiated, using techniques involving thermal luminescence or electron spin resonance. Really, there is no good way for a quarantine official at the arriving port to tell whether or not a papaya or mango has been irradiated.

Q: What could be the effect of over-irradiation?

A: Most likely this would result in undesirable chemical changes in the food. In fruits, it could cause depolymerization of the pectin, meaning that it would get soft. Higher doses could oxidize the food, turning it dark. There would not be any toxicity, no residual radioactivity whatsoever.

Q: Could you use dosimeters in the boxes to verify that the box had been irradiated.

A: Yes. That would be the way to do it. And based on that indicator, you could accept the results of research that at the dosage received by the box, the fruits within it would have been adequately disinfested.

MANGO BLOSSOM MIDGE

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Damage by the mango blossom midge was first noticed in late 1980 by a Hilo resident who anticipated a good mango crop because of drought conditions on the Big Island. In previous years, wet winter conditions had resulted in poor mango yields in rainy Hilo. When poor fruit set continued, the blossoms were examined by the resident and tiny "worms" were found in the buds.

The resident reported the find to Department of Agriculture Entomologist Ernest Yoshioka, who collected the first sample on January 4, 1981. Adult midges were reared from the sample and subsequently identified as the mango blossom midge, *Dasineura mangiferae* Felt, by Dr. Raymond Gagne of the Systematic Entomology Laboratory, USDA, Beltsville, Maryland. This was the first record of this midge in Hawaii.

Dasyneura mangiferae Felt was originally described from southern India in 1927, later renamed to *Procystiphora mangiferae* (Felt) and then to *Dasineura mangiferae* Felt. *D. mangiferae* belongs to the family Cecidomyiidae in the order Diptera.

Distribution

The mango blossom midge is only recorded from India but is believed to occur elsewhere in Asia. Because there are four species of midges that attack mango inflorescences in India, there is some confusion in earlier accounts as to the economic significance of this pest. Three species attack the blossoms while one attacks the axis of inflorescences. Of the three that attack the blossoms, two pupate in the soil and only *D. mangiferae* pupates in the bud. Mango is the only known host.

Life Cycle

Eggs. Eggs are deposited in the fold of the sepal and petal of small unopened mango flower buds. The tiny translucent eggs are elongated and cylindrical and are deposited during the daytime.

Larvae. Like other midges, *D. mangiferae* has four larval instars. The first is transparent, the second is whitish, while the third and fourth larval instars are yellowish-orange. The larva migrates from its place of hatching to the interior of the bud and begins to feed on the plant juices and internal organs of the bud. The larva feeds on the reproductive parts of both perfect and staminate flower buds, arresting the normal growth of the bud. This causes the buds of perfect flowers to abort, preventing normal fruit set. The fourth instar larva attains a length of 2.6 mm and a diameter of 0.7 mm.

Surveys showed that infested mango buds developed a reddish color before turning black while uninfested buds were light green to yellow in color.

Pupae. Before it pupates, the fourth instar larva orients its head towards the surface of the bud and cuts an exit hole. The larva then spins a cocoon of silken fibers and pupates within the bud. The pupal stage lasts 4–6 days.

Adults. Normally, the life cycle is completed within two weeks. Adults are minute and orange colored, the male slightly smaller than the female. Soon after emergence, the adults mate and the females look for oviposition sites. A female may deposit 2–3 eggs in one sitting.

1981 Surveys

Statewide distribution. Surveys showed that the mango blossom midge was well established on Oahu, Maui, and Kauai by February 1981. Infestations were reported from Molokai in May. Because of its widespread distribution, it was believed that the midge may have remained undetected in the state for several years. Damage by the midge may have been overlooked because of mango's variable fruit set.

Infestation rate. To determine the rate of infestation, mango panicles were collected in February from Manoa, Punahou, Pawaa, Waialae, and Waianae. Buds from each panicle were examined for midge larvae or pupae. Each sample consisted of 25 buds from one or more panicles per location.

Of three varieties, including 'Haden' and 'Pirie', 72–100 percent of the buds were infested with larvae or pupae. On the average, 91 percent of the buds were infested. The number of larvae or pupae ranged from one to 12 per bud, averaging 3.6 individuals per bud.

Fruit set. To determine possible effects on fruit set, 25 panicles with small fruits (1 – 3 cm diameter) were randomly selected from trees in Manoa, Punahou, Pawaa, and Waialae. The numbers of fruits per panicle were recorded from each tree. Fruit set for the 'Haden' variety ranged from zero to 13 fruits per panicle. The average was 1.9 fruits per panicle for the 'Haden' and 2.3 fruits per panicle for all varieties sampled.

1982 Surveys

Surveys conducted from February 1981 to February 1982 showed that flowering mango trees could be seen throughout the year on Oahu eliminating the need for diapause or alternative hosts for the midge's survival between seasons.

Infestation rate. In February, eight 'Haden' and 'Pirie' mango trees were sampled at Punahou and Kaimuki. Twenty-five buds from each of five panicles per tree were examined for the midge.

No differences were observed between varieties, and 68 – 100 percent of the buds were infested with larvae or pupae. On the average, 90 percent of the buds were infested. A range of one to 16 larvae or pupae were found in each bud, averaging 3.5 individuals per bud.

Although infestation rates were very high, 4.4 percent of 800 infested buds examined showed signs of normal fruit set, which may account for the presence of some fruits later in the season.

Fruit Set. In late April, the numbers of large fruits (7 – 10 cm lengths) were counted on 50 panicles at Punahou and Kaimuki. Fruits were found on 60 percent of the panicles. The number of fruits ranged from zero to five fruits per panicle, averaging 0.8 fruits per panicle. Surveys in June showed mango yields on backyard Oahu trees to be erratic and generally poor.

Economic Significance

Before the arrival of the midge, Yee (1976) noted that several individuals with mango orchards reported having as many as 10 fruits to a flower cluster from 'Haden' trees that were girdled to encourage annual bearing. In 1981, it was estimated that three to five fruits per panicle was considered acceptable for growers of the 'Haden' variety. The 1981 and 1982 surveys showed average yields of 2.3 and 0.8 fruits per panicle, respectively, indicating that the midge had a significant affect on mango yields. During the surveys, it was noted that several days of heavy rains during the flowering period helped increase fruit set, perhaps by killing the adult midges or affecting its egg-laying behavior. Wind, diseases, cultural practices, and varietal differences also affect fruit set. Because of these factors, it was not known to what degree the mango blossom midge affected fruit set and yield. To some degree, the midge helps stabilize the erratic bearing habits of most varieties. In 1983, a new powdery mildew fungus was discovered on mango blossoms in Hawaii. This new disease also affected fruit set.

Recommendations

Recommendations made after the 1981 surveys were not encouraging. Eradication or containment were not feasible because of the midge's widespread distribution. Flowering occurred during periods of high rainfall and gusty, variable winds, when conditions for chemical applications to tall trees were not ideal. The prospects for biological control were also dim, since the midge was a pest in its native country. Also, the public did not complain about the lower mango yields, perhaps remembering the "bumper-crop" years when it was difficult to even give mangos away.

However, recent amendments to 7 CFR part 318 by the United States Department of Agriculture, Animal and Plant Health Inspection Service may change that situation. The final rule, which took affect on February 5, 1993, allows previously prohibited fruits and vegetables from Hawaii to transit certain states in the northern corridor of the continental U.S. for shipping to foreign destinations if certain safeguards are met. This rule change will allow the transiting of untreated mango and other fruits to Canadian and European markets on sea vessels and flights from Hawaii through certain U.S. ports and airports. The new rule also allows for the off- and onloading of shipping boxes from one carrier to another.

More information on the economic significance and control of the mango blossom midge will be needed if Hawaii is to take full advantage of exporting mangos to those markets that have now become available because of the new shipping routes through the continental U.S.

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Q: Has this pest never been considered a serious enough problem to do something about it?

A: In 1981 there were a few of us that thought it was a significant problem. It turned out not to be significant simply because nobody complained. Nothing has been done on this midge since 1982. The pest is there every year. We noticed that clear weather at flowering favors the midge, whereas if there is rain at that time we see it less. We found the most severe incidence of this pest in dry areas.

Q: How did this pest get here?

A: We do not know. It is unlikely that anyone brought in a mango blossom carrying it. More likely it hitch-hiked on a plane somehow.

Q: Is there any biological control for it in India?

A: Some predators are mentioned, and we have seen some locally, like spiders and ladybug beetles, feeding on the midge. These are general predators, and from the standpoint of providing control of this particular pest, they are not effective.

Q: Have you evaluated any insecticides for controling this midge?

A: No.

Table 1. Mango blossom midge 1981 surveys: Infestation rate of mango flower buds on Oahu in February.

Location	Variety	Infested buds (%)	Number of larvae or pupae per infested bud: Average	Range
Manoa	Haden	100	4.3	1–9
Mango	Pirie	96	5.2	2–12
Punahou	Haden	100	3.8	2–10
Pawaa	Haden	72	3.3	1–5
Waialae	Haden	96	2.8	1–6
Waianae	unknown	84	2.5	1–4
	Average	91	3.6	

Table 2. Mango blossom midge 1981 surveys: Fruit set of mango panicles on Oahu in February.

Location	Variety	Number of fruits per panicle: Average	Range
Manoa	Haden	4.5	0–13
Manoa	Pirie	2.9	0–12
Punahou	Haden	0.4	0–2
Pawaa	Haden	0.8	0–2
Pawaa	Haden	2.7	0–5
Waialae	Haden	0.9	0–0
Waialae	Haden	2.8	1–6
Waialae	common	4.4	1–12
	Average (Haden)	1.9	

Table 3. Mango blossom midge 1982 surveys: Infestation rate of mango flower buds on Oahu.

Sampling date	Location	Infested buds (%)	Number of larvae or pupae per infested bud Average	Range
February 3	Punahou	92	2.8	1-9
	Kaimuki	68	2.1	1-5
February 9	Punahou	100	5.0	1-16
	Kaimuki	100	4.1	1-13
	Average	90	3.5	

Table 4. Mango blossom midge 1982 surveys: Fruit set of mango panicles on Oahu.

Sampling date	Location	Panicles with fruits (%)	Number of fruits per panicle Average	Range
April 27	Punahou	60	0.9	0-5
	Kaimuki	59	0.8	0-4
	Average	60	0.8	

MANGO DISEASES AND THEIR CONTROL

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Published accounts of mango disease research in Hawaii are very limited. The most recent published work on a mango disease in Hawaii was in 1971, when Dr. A. Cook, while on sabbatical leave here, published an abstract on the scaly bark/woody gall problem on mango trunks (5). Prior to that, Aragaki published two papers on the chemical control of mango anthracnose in 1958 (2) and 1960 (3).

Table 1 lists the major mango fruit, flower and leaf, stem, and root diseases described in the literature. Those reported from Hawaii are identified with an asterisk.

The two major diseases of mango in Hawaii are anthracnose and powdery mildew.

Anthracnose

Anthracnose, *Colletotrichum gloeosporioides* (perfect stage *Glomerella cingulata*), is probably the most important disease of mango wherever it is grown. It is the limiting factor for mango production in areas that are wet. The fungus is ubiquitous and responsible for many fruit diseases of other tropical fruits such as papaya, banana, avocado, coffee, and many others. Although isolates from one host have been inoculated successfully to other hosts, the pathogen is basically host specific. On mango, the fungus affects the inflorescence, young leaves and branches, and fruit.

Symptoms. *Inflorescence*. All parts of the inflorescence are susceptible. The disease first appears as small dark spots that enlarge, coalesce, and eventually affect the entire panicle under rainy conditions. Infected flower parts and young fruits fall off the inflorescence.

Leaves and stems. Infections of young leaves start as small dark flecks that enlarge to irregular dark lesions, often with a distinct yellow halo. Under wet conditions, lesions may coalesce into large infected areas, especially along the leaf margins. Symptoms on young succulent branch tips are similar. Infections begin as small dark flecks that expand and coalesce on branches that are usually no bigger than 1 cm diameter. Older leaves are also susceptible, but the fungus remains latent until the leaves senesce.

Fruit. Infection on young fruits (less than 4 – 5 cm) appears as dark, irregular, sunken lesions and causes the fruit to abscise from the panicles. Infection of larger fruits usually remains latent (dormant) until the fruit ripens. Lesions are black, expand rapidly in size, and produce pinkish-orange spore masses under wet conditions.

Disease cycle. The fungus survives between seasons primarily on infected and defoliated branch terminals and mature leaves. Conidia are produced in fruiting bodies, referred to as acervuli, over a wide range of temperatures and especially under rainy or humid conditions. Conidia are spread by splashing rain or irrigation water. The ascospores do not appear to serve an important role in the spread of the disease. Conidia are readily produced on all infected tissues and serve as secondary inoculum to spread the disease.

Control. *Site selection.* The best way of controlling anthracnose is to avoid planting mangos where conditions are favorable for disease development. Mango production is best suited for hot and dry areas. In Hawaii, this generally refers to the low elevations on the leeward sides of the islands where rainfall is less than 38 cm (15 inches) a year.

Resistant varieties. Select varieties that are resistant to anthracnose. There are wide differences in anthracnose resistance among mango cultivars. Very few if any replicated studies have been made to evaluate anthracnose resistance of mango cultivars in Hawaii. The literature, however, does contain some information on anthracnose resistance (Table 2). Note that some varieties (eg. 'Tommy Atkins' and 'Zill') have different reported resistance levels when evaluated in different countries. It is not known whether this is due to different strains of the fungus, environmental differences, or evaluation methodology.

Sanitation. Because the fungus survives from season to season on diseased branch terminals,

Table 1. Major diseases of mango (those marked with an asterisk have been reported in Hawaii).

Disease	Pathogen	Remarks
Fruit Diseases		
Anthracnose*	*Colletotrichum gloeosporioides*	Most important
Stem-end decay	*Lasiodiplodia theobromae* *Phomopsis mangiferae* *Dothiorella dominicana*	Postharvest/storage
Bacterial black spot	*Xanthomonas campestris* pv. *mangiferae indica*	Very serious; S. Africa India, Brazil, Aust.
Rhizopus soft rot	*Rhizopus stolonifer* *R. arrhizus*	Postharvest/storage
Soft brown rot	*Hendersonia creberrima*	S. Africa, cold storage
Jelly seed*	Physiologic	Certain cultivars prone
Flower And Leaf Diseases		
Anthracnose*	*C. gleosporioides*	Common
Powdery mildew*	*Oidium mangiferae*	Recent introduction
Mango malformation	*Fusarium moniliforme* var. *subglutinans*	Mites often vectors
Bacterial black spot	*X. campestris* pv. *mangiferae indica*	
Scab	*Elsinoe indica*	Fla., Americas, Phil.
Blossom blight*	*Botrytis cinerea*	Not serious
Many leafspots	Many	Not serious
Stem Diseases		
Anthracnose*	*C. gloeosporioides*	Mainly branch tips
Bacterial black spot	*X. campestris* pv. *mangiferae indica*	Can be moved on scion wood; serious threat
Mango malformation	*F. moniliforme* var. *subglutans*	Can be moved on scion wood; serious threat
Verticillium wilt	*Verticillium albo-atrum*	Old vegetable fields
Scaly bark/woody gall*	Unknown	Colombia/Hawaii
Dieback*	*L. theobromae* (Botryosphaeria)	Not severe
Recife sickness ?	*Diplodia recifensis* ?	Assoc. w/ambrosia beetles
Root Diseases		
<u>Nematode</u>	<u>Name</u>	
Sting	*Hoplolaimus* sp.	
Dagger*	*Xiphinema* sp.	
Lesion*	*Pratylenchus* sp.	
Reniform	*Rotylenchulus reniformis*	
Rootknot	*Meloidogyne* spp.	
Ring*	*Criconemoides* sp.	

leaves, and old flower panicles, sanitizing orchards by pruning and removing debris from under trees should reduce inoculum and, therefore, disease levels.

Field fungicide sprays. Commercial orchards in all but the driest environments need to be sprayed with a fungicide on a regular basis. Spray intervals vary from weekly to monthly, depending on rain. Spraying weekly during flowering and up to when fruits are about 4–5 cm long, and once every two weeks during fruit development, appears to be a standard recommendation. Fungicides reported to be effective against anthracnose in field trials are benomyl, thiophanate methyl, captafol, mancozeb, and vinclozolin (9). Fungicides effective against anthracnose that are registered for use in Hawaii are benomyl, captan, basic copper sulfate, and sulfur plus basic copper sulfate.

Mancozeb is currently recommended on a weekly basis in Australia (13), and maneb and mancozeb is recommended on a 5 – 10 day interval in the Philippines (1). Ferbam and chlorothalonil were being used under a Section 18 Emergency Use Exemption in Florida (10), but most growers currently use copper-based fungicides for anthracnose control.

Postharvest treatments. Postharvest hotwater treatments (15 minutes at 51°C (124 – 125°F)) have been shown to reduce anthracnose development in ripe fruits of the cultivar 'Larravi' in Puerto Rico (12) and with the cultivars 'Zill', 'Haden', 'Sensation', 'Kent', and 'Keitt' for 5 minutes at about 55°C (131°F), and 15 minutes at 49°C (120°F) in Florida (17). Hot water dips also reduced stem end decay caused by several fungi (21). Because of varietal differences in heat tolerance, tests must be conducted to determine the optimum time and temperature for each cultivar.

Vapor heat (4) and forced-air dry heat used to meet quarantine regulation against fruit flies have shown some efficacy against postharvest diseases on the cultivars 'Tommy Atkins', 'Keitt', and 'Palmer' (8). The major disadvantage of these methods is the long treatment time required, typically 3 – 6 hours.

Refrigeration at 10°C (50°F) will significantly slow the development of anthracnose. However, since chilling injury might occur, fruit should be ripened before refrigerating.

Benomyl and thiabendazole at 500 – 1000 ppm heated to 52°C (126°F), in which mango fruits were dipped for 1 – 3 minutes, were effective in controlling postharvest decay on 'Tommy Atkins' and 'Keitt' (7, 19, 20). Unheated benomyl was ineffective. However, within a short time the fungus developed resistance to benomyl and had cross resistance to the related fungicides thiabendazole and thiophanate methyl (18).

Heated iprodione (14), unheated prochloraz (7), and unheated imazalil (21) have also shown efficacy in controlling anthracnose. Gamma radiation has shown some efficacy in reducing anthracnose, but the doses required are higher than the dose required for fruit fly quarantine treatments. Radiation does not appear to be feasible for postharvest mango disease control at this time.

Anthracnose is best controlled by a combination of preventive measures, field fungicide sprays, and postharvest treatments.

Powdery Mildew

Powdery mildew (*Oidium mangiferae*) is the only other significant disease of mango in Hawaii. It is a relatively new introduction to Hawaii, having been first reported in 1983. It is most severe in the drier areas of the state when rain occurs during the flowering season. Worldwide, it is found in most mango growing areas. It is often sporadic in severity but has been reported to cause up to a 20 percent loss in production (6). Mango is the only known host.

Symptoms. Powdery mildew is primarily a disease of flowers, young shoots, and young fruits. From a distance, the infected parts of the mango tree have a grayish haze resulting from the masses of conidia and fungal growth on the infected surface. Closer inspection will show a velvety, white growth. The fungus grows primarily on the plant surface but obtains its nutrients from living plant cells through a system of haustoria that grows within the infected plant cells.

Young leaves are mostly infected on the underside, especially along the veins, but more susceptible varieties are also infected on the upper surface. Infection causes flowers and small fruits to abort and fall off, usually when the developing fruits are about pea size (11). Early infection of shoots causes panicles and young leaves to become curled, distorted, and reduced in size. Infected areas eventually may turn brownish and necrotic. Fruits that become infected after they have set have purple-brown blotchy lesions that crack and form corky tissue as the fruitlet enlarges.

Disease cycle. The fungus survives in old leaves and branch tips when young succulent growth is not present on the tree. Spores are spread short distances by wind and long distances by infected scion wood. Unlike most fungi, spores of the fungus do not require free water or high humidity for germination. Spores are capable of 70 percent germination at 20 percent RH and 33 percent germination at 100 percent RH. However, germ tubes and hyphae from spores that germinate at low relative humidities are less aggressive than those that germinate at higher humidities. The disease is most severe in dry areas that receive intermittent rains during the flowering season. Ideal temperature for disease development is 20 – 25°C (68 – 77°F) (11).

Control. As with any disease, the use of resistant varieties is the ideal control measure. Varieties vary considerably in their susceptibility to powdery mildew. Table 3 is a compilation of published evaluations of resistance by mango cultivars to powdery mildew.

Avoiding the disease through site selection is difficult because the disease is relatively independent of moisture. Hot, dry areas are still best overall for mangos. If possible, avoid areas that consistently have rain during the flowering season.

Powdery mildew can be controlled by sprays applied during flowering at 10–14 day intervals. Sulfur dusts and sprays have been demonstrated to be very effective and are exempt from tolerance. However, sulfur must be used with caution because of the potential for scorching if used during too-hot periods or if used in conjunction with oils. In Israel, wettable sulfur provided better control than benomyl and piparazin (11).

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Table 2. Resistance or susceptibility of mango cultivars to anthracnose (*Colletotrichum gloeosporioides*).

Country	Resistant	Moderate	Susceptible	Very susceptible
Australia[14]	Carrie Caraboa Florigon Tommy Atkins Saigon	Kensington Pride		Willard Neelum Manaranijan
Phillipines[15]	Palmer Siam Velei Columban Joe Welch	Fernandin Arumanis Edward Gedong Tjenkir	Carrie Peter Passand	Ah Ping Julie Cherakurasa Hingurakgoda Kensington Otts Pope Willard Zill
Hawaii[22]	Paris Fairchild Rapoza	Haden	Exel	Pirie
Florida	Zill	Haden	Irwin Sensation Kent Keitt Tommy Atkins	

Table 3. Resistance or susceptibility of mango cultivars to powdery mildew (*Oidium mangiferae*).

Country	Slightly susceptible	Moderately susceptible		Very susceptible
Australia[14]	Carrie Sensation Tommy Atkins			Zill Kent
Israel[11]	Carrie Gondo	Haden Mabroka		Bullock's Heart Zill Mistakawi Pairee Faizanson Alphonso
Venezuela[16]	Carrie Sensation Tommy Atkins Banana	Haden Lippens Smith Keitt Glenn Pico deLoro Martinique Springfels Rosa	Graham Divine Peter Hilacha Bocado Edward Mango criolla Fresca	Amini Kent Labich Apple Zill Blackman

PESTICIDES REGISTERED FOR MANGO

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The following is a list of pesticides currently registered for use in mango. **However, this list is not a substitute for pesticide labels.** Users should determine whether the particular pesticide that they want to use, can legally be used on mango **before** they purchase the pesticide. Read labels completely and carefully because restrictions may apply (*e.g.*, Fusilade 2000 and Touchdown labels specify for crop establishment, nonbearing use, only; also, various copper hydroxide products are registered for use on mango in Florida only).

Requests for pesticide registration research should be directed to the Chairman of GACC's Pesticide Subcommittee, currently Mr. Ray Nishiyama. Pest problem(s) should be identified and losses due to those pest(s) documented.

NOTE:

Mention of a trademark or a proprietary product does not constitute a guarantee or warranty of the product by the University of Hawaii and does not imply its approval to the exlusion of other products that also may be suitable or that may have been inadvertently not listed. **All materials should be used in accordance with label instructions.**

FUNGICIDES[a]

Common name	Trade name	Registrant	Pests on label
benomyl	Benlate (EPA Reg. No. 352-354)	Du Pont	Anthracnose[b]
copper sulfate	Tennessee Brand Tri-Basic Copper Sulfate (EPA Reg. No. 1109-13)	Tennessee	Anthracnose
sulfur	Microthiol Special (EPA Reg. No. 4581-373)	Elf Atochem	Powdery mildew
	Thiolux Dry Flowable Micronized Sulfur (EPA Reg. No. 55947-48)	Sandoz	Powdery mildew
thiabendazole	Decco Salt No. 19 (EPA Reg. No. 2792-50)	Atochem NA	Anthracnose (postharvest)

[a] Although a tolerance exists for Captan in mango, no pesticides are currently registered for this use.
[b] Frequent use of Benlate will result in development of resistant strains. Use judiciously and alternate with other registered fungicides.

INSECTICIDES

Common name	Trade name	Registrant	Pests on label
methidathion	Supracide 2E (EPA Reg. No. 100-501)	Ciba-Geigy	False oleander scale
malathion (+ protein bait)	Malathion 8 Aquamul (EPA Reg. No. 34704-474)	Platte	Fruit flies
	*Malathion 50 Plus Insect Spray (EPA Reg. No. 239-739)	Chevron	Various insect pests
	*Malathion 50 Insect Spray (EPA Reg. No. 239-739)	Chevron	Various insect pests
petroleum distillate (+ Malathion 50 Insect Spray)	*Volck Oil Spray (EPA Reg. No. 239-16)	Chevron	Various insect pests
Bacillus thurengiensis var. *kurstaki*	Dipel 2X (EPA Reg. No. 275-37)	Abbott	Lepidoptera (caterpillars)
pyrethrins + rotenone	Pyrellin E.C. (EPA Reg. No. 30573-2)	CCT Corp.	Various insect pests
pyrethrins + piperonyl butoxide	Pyrenone Crop Spray (EPA Reg. No. 4816-490)	Fairfield	Various insect pests
potassium salts of fatty acids	Attack Soap Concentrate (EPA Reg. No. 36488-45)	Ringer	Various insect pests

*Chevron's Ortho products are probably available in small containers only (i.e., quart bottles).
Ortho products are packaged for backyard, not commercial, growers.

Note: Chevron's Ortho Volck Oil Spray (EPA Reg. No. 239-16) is **not** the same product as Volck Supreme Spray (EPA Reg. No. 59639-20) that is manufactured by Valent. Chevron's Ortho Volck Oil Spray is less refined than Valent's Volck Supreme Spray, and therefore may be phytotoxic to sensitive varieties. Treat a small section of a tree and watch for phytotoxicity before spraying the entire orchard. Also, Valent's Volck Supreme Spray is **not** registered for use in mango.

HERBICIDES

Common name	Trade name	Registrant	Pests on label
fluazifop-p-butyl	Fusilade 2000 (EPA Reg. No. 10182-104) (crop establishment/nonbearing use only)	ICI	Grassy weed control
glyphosate	Roundup (EPA Reg. No. 524-445)	Monsanto	General weed control
sulfosate	Touchdown (EPA Reg. No.10182-324) (crop establishment/nonbearing use only)	ICI	General weed control

FLORIDA USE ONLY

Common name	Trade name	Registrant	Pests on label
copper hydroxide (fungicide)	Champ Flowable (EPA Reg. No. 55146-41)	Agtrol	Anthracnose
	Champion WP (EPA Reg. No. 55146-1)	Agtrol	Anthracnose
	Kocide 101 WP (EPA Reg. No. 1812-288)	Griffin	Anthracnose
	Kocide 606 Flowable (EPA Reg. No. 1812-303)	Griffin	Anthracnose
	Kocide DF (EPA Reg. No. 1812-334)	Griffin	Anthracnose

PESTICIDE REGISTRATION ACTIVITIES

Common name	Trade name	Registrant	Pests on label
FLORIDA (IR-4) *chlorothalonil*	Bravo	ISK Biotech	Powdery mildew Anthracnose (?)
NATIONAL (MILES) *imidacloprid*	Merit	Miles	Piercing/sucking insects
HAWAII *refined petroleum distillate + Na-bicarbonate*	SunSpray Ultra-Fine Spray Oil	Safer	Powdery mildew

ORIGIN AND CLASSIFICATION OF MANGO VARIETIES IN HAWAII

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Mangos (*Mangifera indica*) are widely grown as a home garden fruit in the warmer, drier areas of all major islands of Hawaii. The fruit is mostly consumed fresh as a breakfast or dessert fruit. Small quantities are also processed into mango seed preserves, pickles, chutney, and sauce.

Production

Most mangos in Hawaii are grown in dooryards and home gardens. Although commercial production has been attempted, acreages remain small. Production from year to year tends to be erratic, which has resulted in limited commercial success. Shipment to the U.S. mainland is presently prohibited due to the presence in Hawaii of tephritid fruit flies and the mango weevil, *Cryptorhynchus mangiferae*, which is not found in other mango-growing areas of the United States. Opening of the U.S. market through development of an effective treatment to disinfest mangos of the mango weevil and fruit flies would improve the potential for commercial production. It is not known when or if this will occur.

Cultivar Types

Mango cultivars in Hawaii are classified by embryo type: polyembryonic and monoembryonic. *Polyembryonic* varieties develop multiple embryos, of which all except one arise from nucellar (i.e., maternal) tissue in the developing seed. Because of this, most seedlings from polyembryonic seeds are genetically identical to the mother tree. The single gametic embryo of such seeds, originating from the sexual process of pollination, is often so underdeveloped and weak that it fails to germinate. *Monoembryonic* varieties produce seeds with a single gametic embryo developed as a result of the sexual process. Among seedling trees of monoembryonic varieties, fruits vary widely in quality and appearance.

In addition to type of embryo produced, mango cultivars can also be classified according to origin (see Table 1). Some mangos in Hawaii derived from early polyembryonic introductions are known as "Hawaiian" mangos. Another type of polyembronic mango that became popular in Hawaii was the "Chinese" mango ('No. 9'), originally from the West Indies, but so called because it was frequently grown by persons of Chinese ancestry. Indian mangos are mostly monoembryonic types originating on the Indian subcontinent, a center of mango diversity. Many monoembryonic mango cultivars have been introduced to Hawaii as a result of their introduction and selection in Florida, an important center of mango growing in the Americas. Finally, several cultivars, mostly seedlings of monoembryonic cultivars, have been selected and named in Hawaii (Tables 1 and 2).

Cultivar Introduction and Selection

The exact date of the first introduction of mangos into Hawaii is not known. In attempting to trace the date of introduction, a number of different lines of evidence and interpretations are encountered. The first documented date of introduction appears to be 1824, when Captain Meek of the brig *Kamehameha* brought several small mango plants from Manila. These plants were divided between Don Marin, a Spanish horticulturist in Honolulu, and Reverend Joseph Goodrich, a missionary in Wailuku, Maui.

According to the published diary of Andrew Bloxam, a midshipman aboard the *H.M.S. Blonde*, a British Navy frigate, three small mango trees were brought to Honolulu from Valparaiso, Chile, on this ship in 1825. These trees were planted and presumably survived. Bloxam's diary also provides a list of some of the economic plants already growing in Hawaii prior to 1825, which did not include mango. Although both the 1824 and 1825 dates seem well documented, some authorities have stated that mangos were introduced to Hawaii before 1824. Dr. Willis T. Pope stated that mangos were probably imported from Mexico by Don Marin sometime between 1800 and 1824. It has not been possible to provide more definite information or a specific date relating to this presumed earlier introduction. Subsequently, however, in an unpublished manuscript, Pope mentioned 1824 as the probable date of the first

Table 1. Classification of mango varieties in Hawaii.

Recommendation status for Hawaii	Origin			
	Hawaii	India	Florida	Other countries and states
Suggested for commercial use	Harders Rapoza	none	Keitt	Manzanillo (Mexico)
Suggested for home gardens	Ah Ping Exel Gouveia Harders Kurashige* Momi K Paris Selection No. 1* Pope Rapoza White Pirie	Basti No. 3 Fernandin Himsagar Itamaraca Pirie	Brooks Late Edwards Keitt Haden Zill	Harumanis* (Indonesia) Fairchild (Panama) Julie (Trinidad) Kensington* (Australia) Manzanillo (Mexico) Otts (California) Tete Nene (Puerto Rico)
Undergoing testing	Adams Buchanan Fukuda Milda Waianae Beauty Wong	Alphan Amin Ibrahimpur Amin Sahai Chowsa Dasheri Fazli Zafrani Husnara Janardin Pasand Langra Padiri Pulihora Taimuria Zardalu	Carrie Eldon Fascel Jacquelin Ruby Simmonds Smith-Haden Sunset Van Dyke Zill Late	Apple* (Kenya) Ataulfo (Mexico) Borbon (Paraguay) Carabao* (syn. Manila)(Philippines) Extrema (Paraguay) Fall (China) Fire Red (China) Francis (Haiti) Graham (Panama) Keowsavoy* (Thailand) Mandeler (China) Milk (China) Mun (Thailand) Nangsangwon* (Thailand) Oakrong* (Thailand) Wa Great (China)

*Polyembryonic cultivar.

introduction of mango plants into Hawaii.

Another report of an early introduction is found in an undated publication by John Cook. In this account of historical events of the times, Cook stated that the first mango tree planted in the territory was growing in Kalihi on the property of Captain Alexander Adams. Captain Adams is said to have grown this tree from seed he obtained on a trading vessel from South China which he visited in Honolulu harbor.

From these accounts, it appears that mangos were introduced into Hawaii sometime before 1825, probably from several different sources.

Before 1899, when S. W. Damon of Honolulu introduced several grafted trees of Indian varieties, most mango trees in Hawaii were seedlings of the polyembryonic type commonly referred to as "Hawaiian" mangos. These were also called 'Manini' mangos, after the name given to the horticulturist Don Marin by Hawaiians. Because these seedlings apparently came from several different sources, individual trees of the

Table 2. Characteristics of some of the best mango cultivars recommended for growing in Hawaii.

Cultivar	Origin	Bearing season	Fruit size (oz)	Fruit quality	Bearing character
Ah Ping	Hawaii	June – July	16 – 32	Good	Moderate yield, regular
Fairchild	Panama	June – July	8 – 12	Good	Moderate yield
Gouveia	Hawaii	July – August	12 – 16	Excellent	Moderate yield
Harders	Hawaii	June – August	10 – 12	Good	Regular
Keitt	Florida	August – October	15 – 30	Excellent	High yield, regular
Manzanillo	Mexico	June – July	20 – 30	Good	Moderate yield, regular
Momi K	Hawaii	June – July	10 – 12	Good	Moderate yield, regular
Pope	Hawaii	July – September	10 – 16	Good	High yield, regular
Rapoza	Hawaii	August – October	25 – 35	Excellent	Heavy yield, regular

"Hawaiian" mangos often differ in tree characteristics as well as fruit form, shape, and flavor.

Although polyembryonic seedlings of the "Hawaiian" type mangos have been widely distributed on all six major inhabited islands, they have never been grown on a commercial scale. More than 40 polyembryonic seedling selections have been described and given names (Tables 1 and 3). Some of the better "Hawaiian" varieties are still being grown as dooryard fruit trees, but none of them have become important varieties. Seedlings of the general "Hawaiian" type are found growing along roadsides and in pastures and marginal lands throughout the state. The fruit of these "Hawaiian" seedling mangos is usually somewhat fibrous, with a turpentine odor, and not much sought after except by children. Although not marketable as dessert fruit, "Hawaiian" mangos are often processed into mango seed preserves, pickled mango, and chutney.

In 1903 the Hawaii Agricultural Experiment Station was established, and testing of mango varieties for adaptation, quality, and productivity began. Up to the present time, nearly 200 varieties have been evaluated. Many of these have been discarded for various reasons including unsatisfasctory production, inferior quality, unattractive color, and susceptibility to anthracnose caused by the fungus *Colletotrichum gloeosporioides*. Anthracnose resistance, or at least some degree of tolerance, is necessary in mangos grown in Hawaii. This is because rainy weather and high humidity frequently occur during the flowering season. Under these conditions susceptible varieties usually set few or no fruits.

Many of the older varieties grown before 1940 have become obsolete or extinct. Table 3 lists mango cultivars tested to date but not presently recommended. Some of these cultivars are superior in other regions but do not perform well or produce acceptable fruit when grown in Hawaii.

Individuals may prefer varieties that cannot be generally recommended. Many cultivars listed in Table 3 may have value for certain persons and purposes.

Cultivars Grown in Hawaii

'Haden' originated from a 'Mulgoba' seedling grown in Florida in 1902. It has been the most widely planted mango in Hawaii. The fruits are medium-large, weighing 16 to 24 oz. The attractive skin color of 'Haden' fruit, crimson over a deep yellow undercolor, has helped to support this cultivar's popularity. Although 'Haden' was undoubtedly superior to most local cultivars at the time of introduction in Hawaii, it has since been ranked considerably below several other cultivars in taste panel studies (Table 4). The fruit flesh is somewhat fibrous and tends to separate from and deteriorate around the seed, resulting in marginal quality and poor shelf life. 'Haden' seeds are relatively large, and the trees usually develop an undesirable alternate-year bearing habit. All the cultivars recommended here for commercial or home garden planting are superior to 'Haden' in fruit quality and bearing habit.

'Gouveia' was named in 1964 for Mrs. Ruth Gouveia of Palolo Valley, Oahu, who planted the seed from which the original seedling tree grew. 'Gouveia' is probably a seedling of the 'Pirie' cultivar. The trees produce excellent quality, medium-sized fruits that are distinctively aromatic and highly flavored. 'Gouveia' is best adapted to "ideal" mango-growing areas, which are warm, sunny, and relatively dry. The quality and bearing do not develop well in marginal areas which are cool and humid during flowering and fruit setting.

'Harders' is an excellent variety for both commercial and home garden plantings. It originated from a tree of unknown parentage grown in Manoa, Oahu, recognized by Robert M. Warner, a University of Hawaii horticulturist in the mid-1970s. 'Harders' produces attractive, highly colored, medium-sized fruits of very good quality. The trees bear regularly and frequently produce off-season fruit in late fall and winter.

'Ah Ping' originated as a seedling planted by Mrs. Chun Ah Ping of Mapulehu, Molokai. The fruits are medium-large, ranging from 16 to 32 oz, and have a very attractive skin color similar to that of 'Haden'. Fruit appearance is excellent and quality is good. The fruits generally ripen in June and July.

'Pope' is a consistently high-yielding, regular-bearing cultivar selected by R. A. Hamilton and named in 1960 in honor of Willis T. Pope, horticulturist at the Hawaii Agricultural Experiment Station from 1920 to 1937. 'Pope' originated in Hawaii from a seedling of the variety 'Irwin', from Florida. 'Pope' mangos mature in July and August. Fruits are medium in size (12 to 18 oz). The undercolor of ripe fruit is greenish yellow, which in the popular conception is less desirable than yellow undercolor. Fruit quality is much better than 'Haden'.

'Keitt' originated in Florida as a seedling of 'Mulgoba'. 'Keitt' is presently the best export variety in the Americas. It bears well and late in Hawaii, usually maturing one to two months after midseason cultivars. The fruits weigh from 15 to 30 oz, and the flavor and quality are excellent.

'Momi K' originated from a seedling grown in Waipahu, Oahu, by Mrs. (Oliver) Ka Lei Momi Kinney. It was evaluated by University of Hawaii horticulturists in 1957. The trees bear regularly, producing moderate crops of very good quality, mild-flavored, medium-sized fruits, maturing in June and July.

'Fairchild' was introduced to Hawaii from Panama by Walter Lindsey in the 1920s. It produces small yellow fruits of very good quality weighing 8 to 12 oz. This cultivar is considered relatively tolerant of anthracnose and produces in areas considered marginal for mango production. It is recommended for home gardens in cool locations where wet, humid weather conditions usually result in poor production by other varieties.

'Rapoza' was selected about 1984 by R. A. Hamilton and J. H. Rapoza from a seedling of 'Irwin' grown at the University of Hawaii's Poamoho Research Station in the mid-1970s. It produces large, attractive, excellent quality fruits weighing 25 to 35 oz. It is generally late bearing, the fruits maturing over a long period from mid-July to October.

'Manzanillo', which originated in the state of Colima, Mexico, is probably a 'Haden' seedling. It was introduced to Hawaii in 1978. 'Manzanillo' produces large, attractive, mild-flavored fruits which are of good quality half-ripe as well as when fully ripe. The fruits usually mature in June and July.

Discussion and Summary

There is more interest developing in new fruit crops and new mango varieties than at any time in the past 50 years. Mangos have been grown in Hawaii for about 150 years but have not yet developed into a viable commercial industry. Climatic factors often adversely affect mango production in Hawaii and lead to poor quality and loss of crop from anthracnose and powdery mildew. Mangos nevertheless remain a favorite home garden fruit in Hawaii. Restrictions against exporting fresh mangos to the U.S. mainland remain in effect, but both Canada and Alaska accept mangos exported from Hawaii without restriction.

Insect and disease problems limit production, and some of these can be controlled. To date, however, very few control measures are applied to most of the mangos produced, which are grown mostly in small plots or as dooryard fruit trees. These problems are being addressed at this conference by other speakers.

Present plantings of mangos are mostly confined to a few old varieties such as 'Haden' and 'Pirie', which have serious shortcomings as commercial varieties. A number of new selected or imported varieties offer better possibilities. The older varieties 'Pirie' and 'Haden' are, however, so much better known and widely planted that no rapid change is likely to occur. New varieties bearing better crops of improved quality fruits with longer shelf life are only beginning to be planted experimentally.

It takes many years for new varieties to attain commercial status. In the case of macadamias, it has taken about 20 years for new varieties to become accepted and planted on a commercial scale.

In the case of mangos it may take even longer, because old dooryard mango trees are seldom replaced after they are in production. There are presently nine excellent, relatively new mango varieties recommended for planting in Hawaii: one each from Florida, Mexico, and Panama, and six local selections (Table 2). This list does not include 'Haden' and 'Pirie', which are considered obsolete, although there are thousands of trees of these two varieties bearing in dooryard plantings throughout the state.

Garden shops and nurseries continue to advertise and sell 'Pirie' and 'Haden', because they are not well informed about better alternatives and because 'Pirie' and 'Haden' are what their customers ask for. I doubt if this will change quickly, although 'Rapoza', 'Harders', and other excellent home garden varieties are beginning to be propagated and sold on Oahu.

Mangos continue to be a favorite fruit in Hawaii. The search continues for better adapted varieties with higher quality fruits and more reliable bearing behavior than 'Haden' and 'Pirie'. Superior new varieties have been developed and are already available for planting. These new varieties can eventually replace the two older but less desirable varieties which now predominate only because they were introduced first.

Table 3. Mango cultivars tested but not presently recommended.

(Note: The varieties listed in this table have been evaluated but are not considered satisfactory by present standards of color, flavor, firmness, uniformity, productivity, or disease tolerance. Most of these varieties are no longer cultivated. It is understandable that individuals may be partial to certain varieties on this list and therefore continue to grow them for home use.)

Alphonse	Ewa	Lotts	Sandershaw
Amini	Farrar	Ludwig	Schobank
Ameeri	Fiji Long	Manini	Sensation
Banganapalli	Fiji Short	Maya	Shibata
Batu Ferringhi	Freitas	McDougal	Smith
Bennet's Alphonse	French Wine	Mulgoa	Smith-Wooten
Bicknell	Georgiana	Mulgoba	Som Keo Won
Bishop	Hansen	Mundappa	Steward
Blackman	Harries	Murashige	Suvarnarekha
Borsha	Helens	Nam Doc Mai	Tamuriya
Bombay	Himayuddin	Neelum	Tenney
Bombay Yellow	Holt	Nimrod	Texeira
Brindabani	Irwin	Non Plus Ultra	Tolbert
Calidad	Jamshedi	Oahu	Tommy Atkins
Cambodiana	Joe Welch (syn. Mapulehu)	Ono	Totapari
Cherukurasam	Kalihi	Osteen	Van Raj
Chinese	Kent	Opureva	Victoria
Cigar	Kinney	Palmer	Waterhouse
Cogshall	Larnach	Paris	Whalen
Crescent	Lazarus	Parvin	Whitney
Cowasji Patel	Lemon Chutney	Prince	Wooten
D'or	Lewis	R2T2	
Earlygold	Lippens	Roberts	
Ehrhorn		S-T	

Table 4. Taste panel scores for some mango cultivars grown at Poamoho Research Station, Oahu (from UH Cooperative Extension Service Circular 435, 1969).

Cultivar	Flavor	Texture	Skin color	Flesh color	Size and shape	Proportion of seed to flesh	Total
Gouveia	29.0	21.0	12.5	4.3	4.5	4.8	76.1
Pope	26.5	24.1	12.6	3.8	4.1	4.5	75.6
Momi K	25.7	22.5	14.0	3.7	3.0	4.4	73.3
Pirie	29.1	22.3	9.2	3.3	3.0	3.0	69.9
Zill	23.6	18.8	11.9	3.4	3.1	4.2	65.0
Haden	17.7	17.6	15.3	3.4	3.7	2.9	60.6
Joe Welch	17.2	18.9	11.3	3.2	4.2	4.1	58.9
Highest possible score	35.0	30.0	20.0	5.0	5.0	5.0	100.0

MANGO PROPAGATION PRACTICES IN A COMMERCIAL NURSERY

Frank Sekiya
Frankie's Nursery, Waimanalo

Most of the mangos recommended in Hawaii originated as chance seedlings from monoembryonic varieties, which show wide variation in their offspring. I have heard that 'Rapoza' and 'Exel' were selected from a group of about 100 'Irwin' seedlings. That is about a 2 percent success rate for getting selections from seedling populations. We have customers who have planted seedlings that never produced for them. We also have customers who planted seedlings and ended up with a good tree. We sell only grafted mangos.

When growing seedling rootstocks, we plant the seeds flat in their husks in well-drained media. We find it too time-consuming to remove the seed from the husk. We prefer seeds of monoembryonic varieties to polyembryonic seeds, because monoembryonic seedlings can be grafted much sooner, about nine months after planting.

We select terminals with plump buds that are ready to burst with a new flush. If the buds have started to grow, beyond just being swollen and ready to grow, then it is too late. Sometimes terminals can be prepared for use as scion wood by removing the leaves at the base of the terminal 10 – 14 days before removing the terminal. By the time the petiole stumps of the trimmed leaves fall off, the buds are likely to have begun to swell. Girdling may also help to prepare scions. We store scion wood in plastic bags and protect them from heat. If they are to be stored for a while, some moist sphagnum moss can be put in the bag.

Most commonly we use cleft grafts in our nursery. For that graft you need scion wood and stock plants that are about the same diameter. After the union is taped firmly, we use some thinner plastic to wrap the whole union and scion. Usually it takes about three weeks for the buds to begin growing through the plastic.

We also use splice grafts and side veneer grafts. We always leave some leaves on the stock plant. Grafted materials go into a hot-house, which we find promotes their growth. We leave the grafting tape on until after the scion has hardened its new leaves. When we take the tape off, we also remove any side branches from the stock.

In topworking mangos we often use inarching, as well as bark grafting. Occasionally a homeowner will want a single tree topworked with more than one cultivar, and we have put up to six cultivars on one tree.

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Q: What potting media do you use?

A: It is basically peat moss, perlite, and cinders, but we add some manure and soil. There is one part peat to about six part perlite plus cinders.

Q: Sometimes I'm very careful and everything seems right and I get poor take; other times I'm kind of sloppy and I get 100 percent take. Do you think the phase of the moon can influence that?

A: We get the best results in the springtime, when the trees have had a period of dormancy. It is harder to get good scion wood in the fall; often the wood is too soft. Sometimes you can get better scions at that time of year if you girdle the branches to prevent flushing. I don't think the moon has anything to do with it.

Q: Do you have any new cultivars?

A: Some homeowners come to us with what they think are good mangos and ask us to graft them. We have sold some of one called 'Fukuda', which has exceptionally firm fruit with good storing qualities. I have kept them for up to six weeks in the refrigerator. The fruit is round and bright yellow, without much red coloring. We have a Thai cultivar, 'Brahm Kai Mea', a long, green mango with poor appearance but very good eating qualities, and it can be eaten half-ripe as well as ripe. It is sweet and fiberless. The tree seems to bear at different times of the year. We are trying a number of other cultivars at our farm in Waimanalo, where the weather tends to be wet, and we concentrate on Asian varieties because they come from wet areas, but we are finding that it is not necessarily true that mangos from such areas have anthracnose resistance. We have gotten consistent fruiting for several years from 'Rapoza' in Waimanalo, with good anthracnose resistance.

Q: Have you transplanted volunteer seedlings from old groves to pots to use as rootstock?

A: I haven't, but I think you can. One drawback we find in starting from seeds without removing them from the husk is that we used to have poor germination rates because of seed weevil. Now, we open up about ten seeds, and if they have low weevil infestation, maybe one in ten, we use them. Sometimes they can be 50 percent or more infested, and we don't bother planting those.

Q: Are there any rootstocks that tend to dwarf the trees, or keep them from getting very large?

A: In Thailand they have some polyembryonic types that do not get big, and we have some hope that they might produce a smaller tree when used as rootstock. We cannot bring in mango seeds because of quarantine, but we can bring in scion wood to grow to get seeds.

Dr. Hamilton: Henry Nakasone and others have done experiments on this, and the dwarfing effect of rootstocks has been zero. It depends on the vigor of the scion tree and has nothing to do with the rootstock. People have used small-tree rootstocks like 'Julie', and weak rootstocks from airlayers, and compared them with large-tree stocks like 'Haden', and all the trees grew the same size.

A: There might be some other desirable qualities with these polyembryonic mangos that the Thais prefer as rootstocks. We have made one observation comparing a grafted tree brought in from Thailand and scion wood from that tree grafted onto a second rootstock in our nursery. I noticed that the node length on the original plant was much shorter than that on the local rootstock, and I will be interested to see if this persists.

Dr. Hamilton: There is a disease, and we have it here in Hawaii, that was found to cause poor tree growth in a rootstock trial in Puerto Rico, but that wasn't a case of dwarfing rootstock, it was diseased rootstock.

POSTHARVEST PHYSIOLOGY OF MANGO FRUIT

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My experience with mangos is mostly through eating them, which I do whenever I can. There is one minor problem; I am allergic to the sap but can handle ripe fruit. Limited work has been done on the postharvest life of mangos in Hawaii. I am familiar with mango postharvest research in the US, the Caribbean, Australia, and Southeast Asia. Mango postharvest research in Hawaii has been limited, first, by the absence of an industry here, and second, by inability to obtain sufficient quantity of a selected variety. Varietal selection is needed because there is great varietal variation in susceptibility to postharvest disorders. The choice of one, two, or three varieties for commercial purposes is therefore crucial to industry development. In addition, insect quarantine procedures are variety specific, hence limiting the number of varieties that can be handled.

Postharvest Characteristics of Mango

The mango is a climacteric fruit that ripens from the seed outwards (Figure 1). It is chilling sensitive, being damaged by temperatures below 12°C (about 55°F). Relating to its climacteric nature, it is sensitive to ethylene, which means that we can use ethylene to ripen the fruit postharvest.

Calcium has a significant effect on fruit firmness and rate of ripening (Table 1). This response has been studied in Florida, Southeast Asia, and Australia. Fruit shelf life can be increased by dipping in 4–5 percent calcium chloride. There is, however, a varietal difference in response, and the response varies from season to season with the same variety. Calcium uptake by fruit is via the xylem and is very dependent upon environmental conditions.

Table 1. Response of 'Julie' mangos to calcium dip treatments (Mootoo, Tropical Science 31:243-248).

% Ca	Shelf life (days)
0	4.5
2	8.6
4	9.4
6	14.6
8	14.8

Ripening changes. As mangos ripen there is an increase in total soluble solids from 8.5 to 19 percent, mostly a result of starch conversion to sucrose. Titratable acidity declines dramatically from 3.8 percent to about 0.3 percent. Citric acid is the major titratable acid, followed by tartaric and malic acid in lower quantities. Vitamins C and A increase during ripening. Phenolics, which give the tart flavor, decline, reducing astringency.

Climacteric fruits like mangos, bananas, and apples go through a marked change as they ripen. Fruits harvested mature green with a touch of color have already begun the ripening process. The climacteric fruit is characterized by a dramatic rise in respiration as skin color develops (Figure 1), while fruit firmness declines. Citrus fruits and pineapple, on the other hand, are not climacteric and do not exhibit such dramatic changes. Mangos given an ethylene treatment ripen several days ahead of nontreated fruits

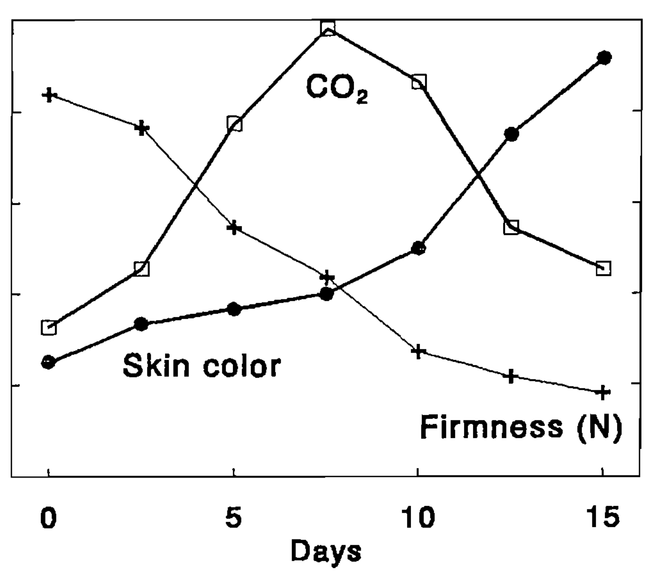

Figure 1. Changes in respiration, skin color, and mango fruit firmness after harvest.

(Figure 2). Ethylene is a major atmospheric contaminant, with cars being the main source. There is a dramatic loss of water during mango ripening (Figure 3), and we need to develop ways to reduce this shrinkage. Consumers object to buying fruit that is shriveled. In general, fruit that have lost 7 – 10 percent of initial weight show some shriveling. The example shown in Figure 3 is rather severe and represents a maximum.

Maturity indices. A number of indices have been tried to estimate when the fruit is at mature green stage and ready to harvest. Immature fruit do not ripen to full flavor and aroma. Proposed maturity indices include softness of cheeks, peel color (the most common), and shoulder development (roundness). Starch content is of use but is destructive and difficult to measure. These indices are all observed at an advanced stage, and each mango variety has its own criteria. You can also count the number of days from flowering, but variability is large. Specific gravity has been suggested as a means of dividing fruits into ripeness classes, but it does not work with all varieties.

Storage temperature. The recommended storage temperature for mangos is about 12.5°C (about 55°F). Even at 12°C you see softening with time (Figure 4); at 17°C, softening is more rapid, but you still get some delay in softening. At room temperature (22°C), fruit would be ripe in about six days.

Chilling injury is a major problem below 12.5°C, particularly below 10°C. Not only do you see skin scald and pitting, but the fruit is more susceptible to decay (Figure 5). After 20 days of refrigerated storage, then removal to ambient temperature, fruits stored at 0°C show a sharp rise in disease incidence, with fruits stored at 10°C showing a somewhat slower increase. In this particular case, those stored at 5°C had a slight delay in disease development, for unknown reason.

Chilling injury is the major postharvest disorder of tropical products, occurring at various steps in the shipping chain. The reason for this is a lack of appreciation of the recommended mango storage conditions by people at those various steps in the handling chain. The people who store the fruit under excessively cool conditions may not see any problem, but the next person will likely see deteriorated fruit. Chilling injury is a temperature and time function (Figure 6). You can store mangos at 0°C for a few days, but if you store the fruits for a longer period, a threshold is reached where they are unable to recover from the effects of the low temperature and are damaged. At 10°C, mangos can tolerate about 12 days, but after that there is injury, skin scald being one of the first symptoms.

Disorders

Sapburn injury is a major problem occurring at harvest, when you get sap running down the side of the fruit. This needs to be removed, particularly because it can cause damage, trap fungal spores, and act as a site for disease development. Sunburn can be a problem when fruits are exposed to direct sun. It is problem associated with fruit on the

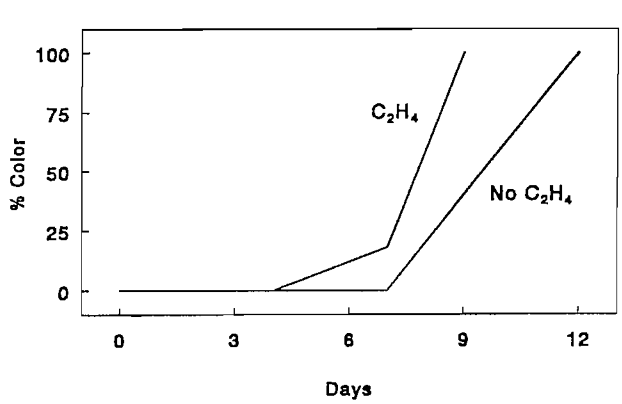

Figure 2. Mango cv. 'Haden' response to a 48-hr exposure to ethylene (100 ppm) (Fuchs et al., 1975, Tropical Science 17:211-216).

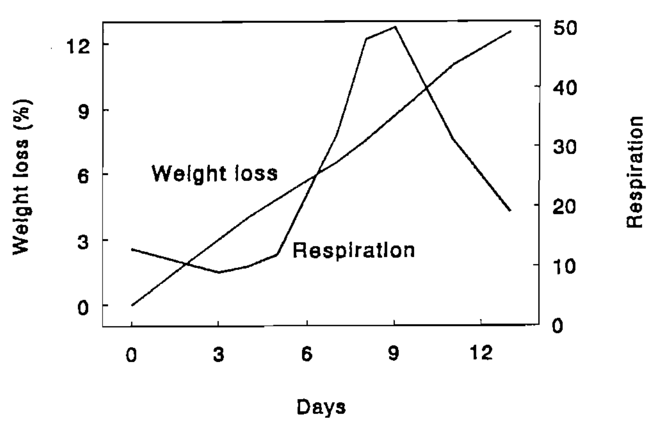

Figure 3. Weight loss from 'Pairi' mango held at 28°C shows a continuous increase, and the rate does not change during the climacteric. Weight loss, mainly water, occurs via stem scars, stomata, and lenticels (Krishnamurthy and Subramanyam, 1973, Tropical Science 15:167-193).

outer areas of the tree canopy and the poor handling of boxes of fruits left exposed to the sun. Hot-water scald is associated with disease control treatments. Bruising is a major problem wherever you go, and is associated with poor handling and improper equipment. Abnormal ripening due to various environmental conditions is not a common problem but occurs intermittently.

Internal disorders include stem-end cavity, a breakdown of the fruit flesh around the stem, the cause of which is unknown. Jelly seed, where the flesh around the seed becomes mushy and off-flavored, is common and variety specific; for example, 'Tommy Atkins' is very prone to this disorder. There are a number of possible causes for jelly seed, none of which has been accepted. Impact damage leading to internal breakdown without any surface disruption is a common problem in rough handling. Premature ripening is a major problem related to variety, environment, harvesting, and management conditions.

Postharvest Treatments

Waxing and wraps vary in their effectiveness in improving postharvest qualities of mangos. Wraps control oxygen transfer and water loss, and are much better than waxes in controlling water loss. Ethylene is used by some countries in a rather crude fashion; the Thais use acetylene generated from calcium carbide, which has the same effect as ethylene. Hot water treatments are usually used for disease control but also may be used for fruit fly control. Irradiation is another treatment that has been researched in great detail. Fungicides are also used to control postharvest diseases; the range of approved fungicides is now very limited in the U.S.

Table 2. Effect of irradiation on scald and internal breakdown development on two varieties of mangos (Spalding and von Windeguth, 1988, HortScience 23:187-189).

	Scald severity		Internal breakdown	
Grays	Tommy Atkins	Keitt	Tommy Atkins	Keitt
0	1	1.5	3	42
150	1.3	2.7	3	48
250	1.8	3.3	20	41
750	6.3	6.5	22	37

Fruit disorders resulting from irradiation treatments are varietally related (Table 2). Scald severity at 150 Grays is more dramatic on 'Keitt' than on 'Tommy Atkins'. Also, internal breakdown can be made more severe by irradiation, as was observed with 'Tommy Atkins'.

Postharvest Constraints

Varietal selection is a major factor influencing postharvest handling, and postharvest characteristics need to be considered when varieties are evaluated and selected. A maturity index needs to be developed for each commercial variety. Storage limitations must also be considered. My personal view is that anyone in the handling chain who has mangos for a day has them for 20 hours longer than needed. Fruit flies and the mango seed weevil

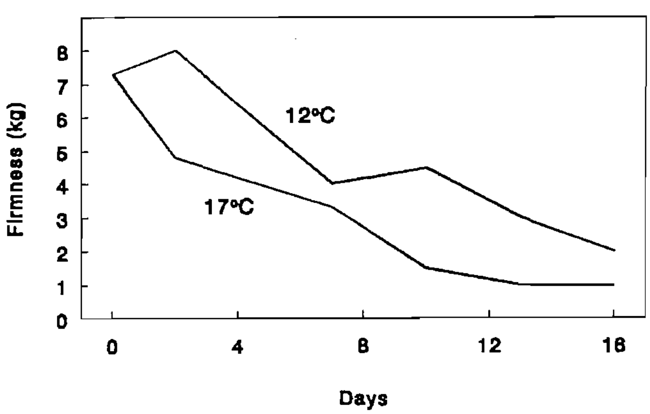

Figure 4. Effect of storage temperature on the rate of decline in mango cv. 'Tommy Atkins' softening (Medlicott et al., 1986, Jour. Sci. Food Agric. 37:469-474).

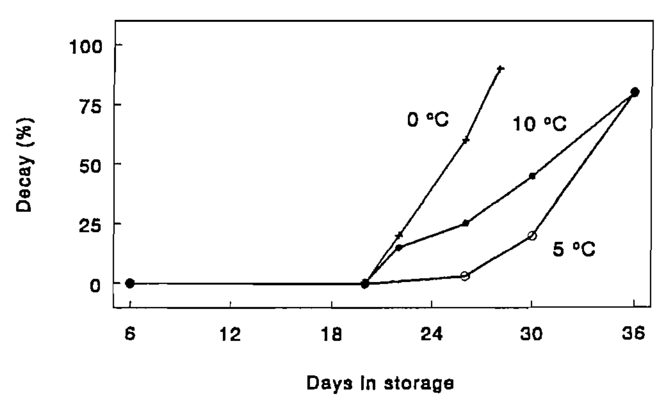

Figure 5. Effect of 20 days storage at various temperatures on 'Taimour' mango susceptibility to decay as a result of chilling injury (Abou Aziz et al., 1976, Scientia Horticulturae 5:65-72).

are two major problems, for which we need quarantine treatments. Before these treatments are developed, we need to have selected commerical varieties. Disease, particularly anthracnose, is also a major problem postharvest, though heat treatments do help to control disease.

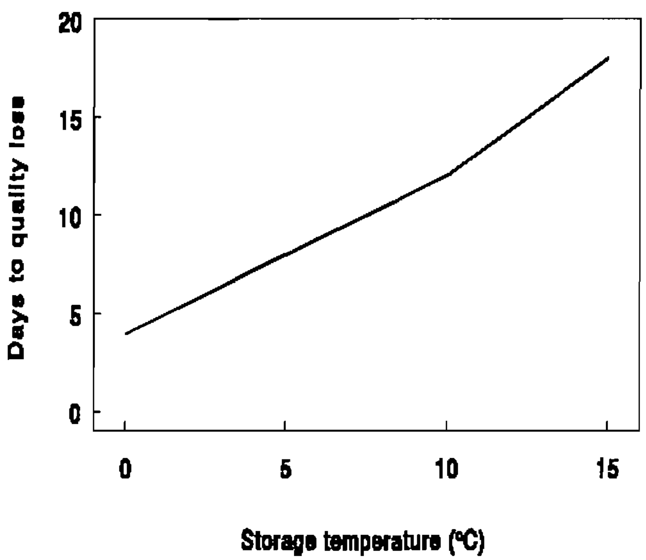

Figure 6. Relationship of storage temperature and days in storage to the development of the first symptoms of chilling injury: no symptoms below the line, increasing symptoms above the line (Abou Aziz et al., 1976, Scientia Horticulturae 5:65-72).

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Q: Can calcium be applied preharvest?

A: You can apply calcium, but you may not get much into the fruit. When dipping fruits postharvest, you can get good control of calcium intake. Calcium uptake into fruits is not fully understood. Movement into the fruit depends very much on water movement into the fruit. Under certain conditions, such as high humidity, you don't get much water moving into the fruit. In papaya, when the fruits are sprayed weekly, higher levels occur on the skin but not in the flesh, which is where we want it. In mangos we are able to get it into the flesh with postharvest dips. There are a number of possible pathways for calcium to enter the fruit during postharvest dipping. The lenticels may allow some uptake, along with movement through the cuticle and stomata; there may be some stem uptake.

Q: Does calcium treatment leave any residues?

A: You may get a white coloration, but it can be washed off.

Dr. Davenport: Calcium uptake, and water uptake, occurs readily through the lactifers in mango. These are latex channels all through the fruit that converge at the stem and go up into it. When you snap the stem, the latex squirts out of the fruit. If you have a fruit that is somewhat water deficient, the latex will exchange with water quite readily.

Q: Is there any way we can predict when to pick the fruit in relationship to the amount of sap that comes out?

A: I'll let Tom Davenport answer that. During ripening, the lactifers start to break down, and you start to get some weeping of latex from these openings.

Dr. Davenport: The viscosity of the latex is dependant upon the fruit maturity. Immature fruits squirt sap many feet when you snap the stem, but mature fruits will just weep slightly. Fruits maturing on the tree may leak sap when the fruits are moved about by winds. The sap that drips down the skin may serve as a sticker for *Colletotrichum* spores and result in anthracnose damage later on after harvest.

Q: So calcium dips are the answer for improving postharvest life?

A: Not with all varieties. We can't get much calcium into papaya, for example, but we seem to be able to get it into mangos. It varies with the variety, however. There are two ways: simple dipping, or applying a vacuum to the bath. It is easier to just put the fruits in a deep bath than to apply a vacuum, and you get the same effect. They have facilities to treat apples by the pallet load. Certain fruits or varieties of fruits can get too much calcium from dips, developing a browning flesh disorder.

Q: What form of calcium do you use?

A: Calcium chloride. A 3 – 5 percent solution is generally adequate. It is very soluble. It is also very deliquescent and difficult to keep dry in storage.

Q: Can there be a problem with bacterial contamination during calcium dipping?

A: Yes, this has been considered with apples, although calcium dips are usually associated with decreases in postharvest disease.

Dr. Davenport: I have had problems during experiments with avocado, where *Erwinia* was sucked in with the calcium, while the fruits dipped into just water were not contaminated. The calcium-treated fruits were delayed in ripening, but they were destroyed by the bacteria in the process.

A: You don't see the same problem in apples. I should point out that the calcium is not evenly distributed within the fruit, even if you dip under vacuum. Apples are in storage for as much as six months, and there is time for redistribution of calcium within the fruit, although we do not know how that occurs.

Q: Is there any sacrifice of flavor for longer postharvest ripening with calcium dips?

A: It hasn't been reported. You do get a firmer fruit which takes longer to ripen, which makes it difficult when you have undipped and dipped fruit in the postharvest chain, with different schedules for ripening. The dipped mangos tend to be firmer than undipped ones at a given stage of ripeness.

DETERMINING INTERNAL QUALITY OF MANGO FRUIT

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Why Determine Internal Quality of Mango Fruit?

Mango (*Manifera indica* L.) is a tropical fruit originating in the Indo-Burma region (Mukherjee 1972) and currently grown in many tropical countries and frost-free regions in the subtropics. It has been cultivated for more than 4,000 years and is said to be as important to the tropics as apples to temperate America and Europe. The fruit has a unique taste, pleasant aroma and flavor, and contains more vitamin A than most fruits. It is mostly consumed raw as a dessert fruit, and small quantities are also processed into mango juice, jams, jellies, nectars, and preserves. Eastern and Asian cultures use unripe mangos for pickles and in chutney, relishes, and sauces (Wanitprapha et al. 1991; Jain 1961).

Considered an exotic fruit, a good quality mango fruit is highly desired and fetches a good price in the world market. Thus, for Hawaii, which aims for the competitive but lucrative export markets and also its local/tourist market, it is of significant importance to develop a viable mango industry based on high quality fruit.

In Hawaii, the commercial production of mango is still rather limited due to production techniques and practices. Shipment to the U.S. mainland is presently prohibited due to the presence of the mango weevil (*Cryptorhynchus mangiferae*), which is not found in other mango-growing areas of the United States. This problem can be thwarted, either by controlled atmospheric (CA) storage, irradiation, or through development of an effective treatment to disinfest mangos of the mango weevil. Currently, mango fruits from Hawaii can be exported to Canada and some European countries without any difficulty.

The potential of the mango industry in Hawaii is good due to recent interest in commercial production. The large number of tourists makes it possible to develop a local market in Hawaii. The major potential is envisioned in the export of mango fruit. While the future opening of the U.S. market to mango fruit shipped from Hawaii would improve the viability for increased commercial production, the major potential is visualized in the Far East markets. In 1989, Hong Kong imported 14.6 million lb of fresh mangos at a value of $6.1 million, Singapore imported 24.3 million lb of fresh and dried mango, avocados, mangosteens, and guavas, Japan imported 11.6 million lb of fresh mangos (Wanitprapha et al. 1991). Japan, in particular, is considered a preferred target for future export of mangos from Hawaii because of the high prices, which exceed $15,000/t, obtained for high quality mango fruits and gift fruit packages even sell for $110 per package of four fruits. Since demand for fresh mango fruits is constantly increasing, and mango imports in Europe and North American markets have increased ten-fold since 1975 (Wanitprapha et al. 1991), a major potential exists for developing the mango industry in Hawaii based on high quality fruit destined for export.

An ensured supply of high quality fruit is the key to a successful export. This can be guaranteed only from productive commercial orchards with selected varieties, proper control of the harvesting of fruits with a proper degree of maturation, and selection of high quality postharvested fruits for packaging and export. With technology available to ensure high quality fruit, there will be sufficient incentive to solve the quarantine problems. In fact, ensuring high quality fruit may solve the quarantine problem. Quality of fruit consists of various attributes and is defined differently by various researchers. One of the major quality characteristics, however, which is directly related to consumer acceptance, is the fruit maturity at harvest. While in general usage, "mature" is a term that is synonymous with "ripe," most postharvest technologists consider "mature" to the stage at which a commodity has reached sufficient development that after harvesting and postharvest handling (including ripening, where required), its external and internal quality will be at least the minimal acceptable (Kader 1991). It is generally considered that the fruit ripens after it is physiologically mature.

Today, there are no known external or visible changes in mango fruit which could be used for the accurate determination of internal quality. External fruit maturity indices such as color, size, and shape provide only approximate information on the internal quality characteristics (Thangaraj and Irulappan 1989). If an immature mango fruit is harvested, it will not ripen at all, or will ripen improperly. On the other hand, an over-ripe mango fruit will decay rapidly after harvest. In addition, mangos on the same tree mature at different times, making harvesting at the right time a handicap for marketing. An optimal index of maturity for harvest is especially crucial for fruit destined for export because of the long shelf-life required. Consumers generally prefer to buy ripe fruits, and it is important to maintain a consistent quality of fruit on the shelves. Thus, preharvest detection of maturity indices will aid management of harvest, handling, and marketing of the fruits. Subsequent on-line postharvest sorting for maturity uniformity will assist in obtaining high quality fruit with long shelf-life, mandatory for the competitive export market.

Maturity of mango fruit is not defined explicitly in the literature; hence, different scientists have viewed it in different perspectives (Peacock 1984). Many studies have been reported on maturity measurement of mango, but with marginal success. Most of these studies applied destructive measurements of the internal quality. Only very limited work has been done on the relationship of the external and internal quality attributes to support the development of a reliable, objective, nondestructive technique to accurately estimate the internal fruit quality. It is well known that mango fruits become soft after they mature. Thus, emulating the manual judgement of maturity which involves pressing the fruit with fingers by measuring the fruit response to some loading, together with the odor and appearance of the fruit as related to the internal quality of mango fruit, may provide a reliable method closely related to the consumer practice of estimating the internal fruit quality.

What Do We Know about Determination of Internal Quality of Mango Fruit?

Mango fruit varies considerably in appearance (skin color, shape, size), texture (firmness of the whole fruit), texture of the pulp and amount of fiber, flavor (volatile profile), and taste. The shape varies from round to ovate-oblong and the skin color from green through yellow to red (Hulme 1971). Cultivated fruits weigh from about ¼ lb to 3 lb (Chia et al. 1988). However, not all varieties are cultivated on a commercial scale and most of them are found only in a particular area. The aroma of mango fruit is often spicy and alluring. The flesh is yellow to deep orange, juicy, and in the best varieties almost fiberless and melting in texture. The flavor is rich, luscious, and semi-spicy in the best varieties. The better types are comparable to the best quality peaches. The seed is relatively large and flattened. The tough woody outer coat contains a large kernel (Lynch and Mustard 1955).

Mango fruits are usually harvested at the physiological mature but unripe stage, 15 to 16 weeks after fruit setting (Lynch and Mustard 1955). They will be ripened and/or stored before marketing and consumption, to provide the optimal eating quality (Hulme 1971; Tripathi 1980; Kapse et al. 1988; Khurdiya and Roy 1988; Roe and Bruemmer 1981; Roe and Shrimath 1967; Roe et al. 1970; Satyan et al. 1984; Vazquez-Salinas and Lakshminarayana 1985; Bartley and Schwede 1987; Chaplin 1984; Ashraf et al. 1981). International trade in mangos is currently restricted because of unpredictable quality and often high market losses. Information on the postharvest physiology of mango fruit has been reported by various researchers (Brown et al. 1984; Chaplin et al. 1982, 1990; Medlicott and Thompson 1985; Mukerjee 1959; Medlicott et al. 1986; Pantastico et al. 1984; Popenoe and Leong 1957; Yoneya et al. 1990; Krishnamaurthy et al. 1960; Salunkhe and Desai 1984; Sharaf et al. 1989; Shashirekha and Patwardhan 1976; John et al. 1970; Chowdhury 1950; Lazan et al. 1986a, b, c; Pantastico et al. 1984; Kane et al. 1982; Peacock et al. 1986; Veloz et al. 1977; Medlicott et al. 1990a, b; Matto and Modi 1970; Mann and Singh 1975, 1976; Miller et al. 1991; Rolz et al. 1971; Yanko et al. 1984; Yuniarti 1982). These studies focused mainly on destructive evaluation of physico-chemical parameter of the flesh in the mango fruit. Parameters which have shown some usefulness for determining maturity in mango are the softening of the flesh; a decrease in acidity; an increase in sugars, soluble solids, and total solids; and an increase in carotenoid pigments.

Research on preharvest physiology of mango has also been reported (Anantnarayanan and Pillai 1968; Baker 1984; Harkness 1949; Hussein and Youssef 1972; Krishnamurthy and Subramanyan 1973; Kosiyachinada and Pankasemum 1990; Kosiyachinda et al. 1984; Medlicott et al. 1990a; Mukherjee 1959; Nip et al. 1992; Peacock et al. 1986; Popenoe et al. 1958; Suryaprakasa Rao et al. 1970 1972; Teaotia et al. 1968; Wang and Shieh 1990). Again, most of these studies are focused on the destructive measurements of the physico-chemical parameters of the fruit pulp. Chemical parameters which have demonstrated some usefulness for determining maturity of the fruit before harvest are the solid content, acidity, carbohydrate content, volatile compounds, and phenolic constituents. Physical parameters, such as shape and size, surface and flesh color, lenticels, shoulder growth, pit around the pedicel, specific gravity, heat units, etc., have been used. None of these parameters are foolproof methods for determining internal quality. The situation gets more complicated when different varieties are involved. Evaluating maturity requires a combination of parameters coupled with considerable experience. Therefore, variations in fruit maturity are bound to be inevitable in commercial harvest using these existing practices. This situation must be improved in order to compete in the lucrative export and local market of mango. Development of more reliable, nondestructive quality evaluations of mangos before harvest and at the packing site is critical to the success of a mango industry.

Nondestructive quality evaluation of horticultural crops to guarantee quality have been reported and reviewed by various researchers (Abbott et al. 1992; Armstrong et al. 1989; Ballinger et al. 1978; Bhambare 1991; Brecht et al. 1991; Bower and Rohrbach 1976; Marion et al. 1978; Finney 1970 1978; Finney and Norris 1973; Dull 1978, 1986; Chan and Forbus 1988; Dull et al. 1989; Forbus and Senter 1989; Forbus and Dull 1990; Forbus et al. 1985, 1991a, b; Garrett and Furry 1972; Lee and Rohrbach 1983; Lenker and Adrian 1971; Mahan and Delwiche 1989; Nip et al. 1992; Robertson et al. 1992; Sarig 1989; Sarig and Nahir 1973; Toivonen 1992). Crops investigated include blueberries, grapes, almonds, pecans, seeds, oranges, peaches, cherries, tomatoes, papayas, cantaloupe, persimmons, apples, watermelons, onions, lettuce, melons, etc., as well as mangos. The techniques include x-rays, ultraviolet, visible light, infrared, microwaves, nuclear magnetic resonance, ultrasonic, sonic, deformation/compression, acoustic impulse, dielectric properties, fluorescence, delayed light emission, reflected radiation, and transmitted radiation. Even though these researchers claimed the usefulness of these techniques in the laboratory, the techniques suffered from the drawbacks of using expensive indoor equipment, lack of flexibility of the equipment, reliability of the technique, inefficiency, and unsuitable application for preharvest or postharvest quality evaluation. Electronic and mechanical technology has advanced to the point where development of miniature low-power sensors is possible for properties such as firmness and reflectance.

In order to reduce the reliance on the experience of workers for picking and sorting products for high efficiency and quality uniformity, development and refinements of nondestructive quality evaluation of agricultural crops must be increased. In the case of mango, there is only limited work reported on nondestructive quality evaluation of mango before and after harvest that is applicable in the field and in the packing house (Nip et al. 1992, Peacock 1984). It is generally agreed that the mango fruit will soften when it ripens. Thus, emulating the manual judgement of maturity which involves pressing the fruit with fingers, by measuring the fruit response to some loading, may provide a reliable method closely related to consumer acceptance and that of the experienced worker in the field and in the packing house.

Will Nondestructive Methods Work for the Determination of Internal Quality of Mango Fruit?

As indicated earlier, it is generally accepted that mango fruits soften after they mature and continue to ripen. Consumers also use their judgement on the load response of their fingers when they pick up the fruits. Dull (1978, 1986) summarized published information on the use of deformation/compression as a nondestructive technique on the evaluation of pear, grape, peach, apple, tomato, onion, and melon. However, this approach has not yielded to automation in commercial practice. In the case of preharvested fruits, the same hypothesis will also be applicable since workers in the field rely on their judgement of the load response of their fingers when they pick the fruits.

For 'Haden' mangos, it has been reported that the fruits will show a color break. This is shown as a yellow spot usually toward the blossom end (Lynch and Mustard 1955). However, it is difficult for this sensory evaluation to be accurate. A more objective evaluation is highly desirable. It is also believed that there is a change of the volatile profile of the mango fruits when they mature and ripen. However, this index is also difficult to be practicable, especially in the field. It is our belief that pressure tests on the fruit before they are picked from the tree and before putting them in the box for shipment may be a reliable index, because this will simulate the response of touching or picking up the fruits. If this hypothesis is proven accurate, mechanized processes may be possible to pick the fruits in the field and also sort the fruits before packing. In consequence, quality of mango fruits can be predicted at the wholesale or retail level. Mango fruits of guaranteed quality will be possible. This will have significant impact on the development or expansion of the mango industry.

Preliminary Work at the University of Hawaii.

Research was conducted recently in Hawaii on three cultivars of mango ('Haden', 'Pope', and 'Fairchild') on the relationship of physico-chemical parameters of postharvest ripened mango fruits (Yoneya et al. 1990). Regression analyses of these mango fruits' firmness (as measured by the Instron Universal Texture Tester) and their physico-chemical parameters showed that there is a definite correlation between fruit firmness and some physiological indices such as total soluble solids/titratable acidity ratio, pulp firmness, and color (Nip et al. 1992). Physico-chemical and physiological changes of postharvest mango fruit and its quality control methods are also reviewed (Yoneya and Nip 1991). These research findings showed that there is an urgent need of methodology to predict the internal quality of preharvested and postharvested mangos in order to guarantee the quality of mango fruits most preferred by consumers. Fruit hardness seems to show promise as a reliable index to meet this need. However, considerable refinement on the methodology is needed to perfect this technique in order to be practical.

How Should We Develop the Methodology Needed for the Determination of Internal Quality of Mango Fruits in Hawaii?

The main objective of this conference is to gather all the information related to the development of a viable mango industry in Hawaii. With the information collected in this conference, we should be able to identify the problems and constraints related to the development of a mango industry in Hawaii. We should work together to develop a systematic approach to solve these problems and constraints in order to be successful in this endeavor.

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SENSORY QUALITY OF MANGO FRUIT

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This is actually the second mango meeting held in Hawaii. In developing my talk I came across the Proceedings of the First Territorial Mango Forum held in July 1955 on Maui. Looking through the titles and abstracts of that proceedings, it struck me that although we know a lot more about mango now, not a lot has changed in terms of the types of problems faced as we try to develop a mango industry. Problems still persist with seed weevils, fruit flies, cultivar selection, and uncertainties about taste preferences.

An important aspect of consumer acceptance for any food is its sensory quality. By sensory quality, we mean those characteristics that are perceived by our senses of sight, smell, taste, touch and hearing. Translated to food, these characteristics include color and appearance, aroma, flavor, texture, and sometimes sound. Only if all of these characteristics meet consumer expectations will the product be accepted.

The mango is a rather unique fruit in that there is such a wide variation in sensory characteristics, depending on cultivar. The growing regions for this fruit are widely distributed throughout the world and consumer tastes have developed over long periods of time. If you have ever discussed consumer preferences for mango varieties with people in various parts of the world, you will learn that every region has "the best mangos in the world." I used to attribute this conclusion to regional pride, but I have come to conclude that everyone is right! People like the mangos they have become accustomed to. The explanation is that we come to prefer those things we are familiar with. Let me give you an example to illustrate this point. Many people who grew up eating canned peas prefer them to frozen peas even though frozen peas taste more like fresh peas. This point is a very important one for anyone intending to produce and market mangos in a given market. It is especially important if the market is one which has already been exposed to mangos, where consumers may already have developed a preference. We know that it is very difficult to change consumers' preferences. Ethnic preferences for mangos have not been documented, but are generally accepted as being real. It appears that this may be an area for some research. Regarding marketing mangos in our local market, it makes a difference whether you are marketing to the hotel industry, the tourist industry, markets focused on immigrants, or the supermarket.

There are really two facets to sensory quality. The first is this issue of consumer preference. What are the basic qualities that consumers want in a mango? This information can only be obtained from the marketplace. We need to survey the intended market to determine its preference; this cannot be done in a laboratory. For example, if we want to know if varietal preference differs by ethnic group, then we need to survey those ethnic groups. It is not likely that we can predict consumer acceptance in Minnesota by asking consumers in Hawaii what they like. There is not much published work relating to consumer preferences. About twenty years ago, a study was conducted by Mattern and Pennock (1971) in supermarkets in Puerto Rico to determine the market potential for improved varieties. They concluded that Puerto Rican consumers showed a strong preference for semi-ripe mangos and that coloration and fruit size were very important determinants of acceptance. Color was more important than size. In that study they were measuring purchases; consumers had not yet tasted the mangos. Continued purchases by those consumers is an important matter that would require additional study. Knight (1985), in Florida, in describing criteria for evaluating fruit characters in mango, stated that the North American preference is for a bright, highly-colored fruit with a red or purple blush. This is apparently also the case here in Hawaii. The same is probably not the case for consumer preferences in Asia and Southeast Asia, where different varieties are grown.

Beyond the issue of preference, we also need to know how other factors affect quality. You have heard many speakers here discussing a variety of treatments that may be used for insect and disease control in mango. Invariably, you have heard about detrimental effects of these treatments on fruit quality. These effects are very important and are something we can measure in the laboratory in a more analytical way, either by chemical and physical methods or by a taste panel.

Appearance

Mangos vary in size and shape from round to oval, flat to full, symmetrical to asymmetrical, and beaked. Their skin color varies from green to yellow, to these colors with blushes of red or reddish purple. Flesh color ranges from a light yellow to vivid orange. Consumer preferences for color, size, and shape may vary from region to region. Appearance is the first impression the consumer gets from the fruit and can be a decisive factor in purchasing. Defects that may be present are thus important: bruising, scalding, scarring, and disease.

Aroma

Mangos are harvested at the physiologically mature, but unripe stage and require ripening to reach the optimum edible stage if eaten as a dessert fruit. Sometimes, however, green and unripened fruit are used for certain products. Full development of the aroma occurs during ripening. The compounds that contribute to the aroma and flavor of mango have been examined and many of them identified. However, none has been identified that has a typical mango aroma. Some of those considered important have coconut-like, peach-like and caramel aromas. However, the presence of many compounds seems to be necessary to achieve the mango aroma.

Lipid compounds appear to be linked with both color and aroma development during ripening. In a study by Gholap et al. (1971), oil extracted from mango pulp contained the following fatty acids: myristic, palmitic, palmitoleic, stearic, oleic, linoleic and linolenic acids. In later work, they found that the ratio between palmitic and palmitoleic acids was important in determining the intensity of mango aroma. If this ratio was >1, the aroma was mild, but if <1, the aroma was strong. The relationship appeared to hold for a number of varieties.

One of the aroma characters is a turpentine aroma found in certain varieties. Acceptance of this aroma is partly a matter of preference, but when it is excessive, it is usually considered undesirable. Certain varieties are more aromatic than others and some have a spicy character.

Taste / Flavor

The flavor characteristics of mango include the aroma components mentioned above. Much of what we attribute to "taste" is, in fact, aroma. To these characteristics are added the important taste components of acidity and sweetness which are perceived by the taste buds on the tongue.

Sweetness in mango is a function of the sugars present. The primary sugars are glucose, fructose, and sucrose, with sucrose predominating. The simple measure of sugars is percent total soluble solids (%TSS) in the flesh of the fruit. The %TSS increases during maturity and also after harvest, during ripening, when starch is converted to sugar in the fruit. However, if the fruit is allowed to ripen on the tree, the %TSS will actually decline. The %TSS of ripe mangos varies with variety, ranging from 14 to 24.

The other critical taste component is acidity which is imparted by organic acids, predominantly citric acid. Acidity is very high in young fruit and declines as the fruit approaches maturity. At maturity, the acidity can be as high as 3 percent titratable acidity or 0.5 to 1.0 percent in most of the Florida varieties. During the ripening process, the percent titratable acidity declines to as low as 0.1 to 0.2 percent.

It is the balance between the sugars and acids that provide the pleasant sweetness of mango. If this ratio between %TSS and percent titratable acidity is too low, the fruit will be too tart; if it is too high, the fruit will taste too sweet and bland.

Texture

Generally, smoothness, rather than fibrousness, is desirable in a mango. This characteristic is largely a function of the variety and can be a determining factor in acceptability. Knight discusses this characteristic in terms of the abundance of the fiber and its fineness or coarseness. He feels that the presence of abundant, but fine fiber is desirable to protect the fruit from damage during handling. A fiberless fruit may not be a good shipper. Juiciness is another sensory characteristic contributing to acceptability and is related to variety.

Factors Determining Sensory Characteristics

Any of these sensory characteristics may be a limiting factor in determining acceptability of a mango by the consumer. Variety is a major factor in determining these characteristics, but there are other factors as well.

The time of harvest, ripening conditions, treatments, and storage and handling conditions can play a significant role in modifying the appearance, aroma, taste, and texture of this fruit.

We should also consider the quality characteristics that may be required for a processed product for these may be different than for a fresh, dessert fruit. These characteristics may vary depending on the type of processing that will occur, whether it will be heated, frozen, dried, etc.

The bottom line is a successful mango industry will depend on determining the wants of the marketplace and the selection and handling of fruit to meet those requirements.

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Q: What about the local preference for 'Haden' mangos? I hear people at this conference saying it is not such a good fruit.

A: We need to examine those established preferences and consider factors such as color, size, and fibrousness in choosing what to grow. It does not have to be 'Haden', but could be something like it, or something better. If you try to predict what consumers might like based on your personal preferences, you are on dangerous ground. You can learn a lot from evaluating what consumers find acceptable now, what they are buying. Certainly, 'Haden' seems to be quite well accepted in the local market. Consumer preference do change, however.

Q: What are the major varieties grown in Florida?

Dr. Davenport: Our two major ones are 'Tommy Atkins' and 'Keitt'. Nobody argues the fact that 'Tommy Atkins' is an inferior tasting and somewhat fibrous mango, but the people who buy mangos in the U.S. generally do not know the difference, even in Florida. They think it tastes great; they do not know there is something that tastes better. They see a beautifully colored fruit, and so by and large they demand 'Tommy Atkins'. We focused on these because 'Tommy Atkins' is attractive and easy to sell, and 'Keitt' is a later variety that extends our season into August. The 'Van Dyke' is another colorful mango being planted recently because people thought it was a good producer, but they are discovering that it only produces 50-75 percent of the yield of 'Tommy Atkins'. Production rather than quality was the factor that led to planting 'Van Dyke', but production is not an unimportant consideration. There used to be a 'Haden' industry in Florida, but it died because 'Haden' does not ship well.

MANGO PROCESSING AND PRODUCTS

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Mangos are an important part of the diets in certain parts of the world. The edible portion of the fruit varies from 55 to 75 percent depending upon the variety. Most of the mangos can be characterized as having a high sugar content (15–20%) and a low acid content (0.2–0.5%), which would account for mangos' sweet, pleasant characteristics. Nutritionally, mangos are a good source of vitamins A, C, and fiber.

The variety of processed mango products is endless, and variations exist from country to country and region to region. We can peel, slice, chop, dice, and puree mangos, which we are able to preserve by dehydration, canning, bottling, freezing, and pickling. You would recognize these mango products as dried fruits in trail mixes, or as canned fruit slices in syrup, or as nectars, juices or blends in tropical fruit punches, or as jams and jellies, or as mango chutney. Chutney is derived from salted green mango slices and constitutes the largest commercial volume of processed mango products.

Mango products such as canned or dehydrated chunks or slices require considerable amounts of manual labor to peel, trim, and slice; hence most of these products are produced in developing or emerging countries where labor is inexpensive. For the developed countries where the cost of labor is prohibitive, highly mechanized processes are desirable. The manufacture of mango puree is a good example of a highly mechanized process which requires less labor and offers other advantages, such as that the process makes use of fruit not suitable for other products, and the product can be used in other products such as jams, beverages, and dairy products as a flavoring ingredient, or as a fruit filling in pastries. Such product diversity expands the market potential for mango puree.

Whether the final product is puree or slices, processed mangos undergo several common unit processes such as sorting, washing, and peeling. Peeling is generally done manually and is facilitated by steaming the fruit for 1–2 minutes to loosen the peel, which is slit with a knife, and the peel can be further removed manually.

Mango puree is produced by taking the steamed and slit fruits and passing the fruit through a Bertuzzi Mango Creamer pulper fitted with 0.060-inch screen and nylon bristles for paddles, which pulps the fruit and separates the pulp from the skins and seeds. The pulp is then passed through a finisher fitted with a 0.020-inch screen to further remove fibers to produce a smoother consistency. The puree is then acidified to pH less than 4.5 with the addition of citric acid to prevent botulism. The puree is then prepared for preservation by passing the puree through a heat exchanger. The heat treatment is necessary in the case of frozen storage to inactivate the fruits' enzymes, and, in the case of canning or aseptic processing, both enzymes and micro-organisms must be rendered inactive. The heat treatments can be accomplished using heat exchangers that heat and cool the puree. In the case of an aseptic or frozen product, the puree is acidified to pH 4.2–4.3 and then passed through a heat exchanger where the puree is heated to 204°F, held for two minutes in a holding tube, and then cooled to 85–90°F. The puree is then pumped, in the case of a frozen product, to a pre-chiller or a slush freezer, which chills the product to less than 40°F. The chilled product then is filled into 40-lb poly-lined cartons, which are then frozen in a blast freezer. In the case of an aseptic product, the puree is pumped after cooling to an aseptic filler where the puree is filled into a pre-sterilized polybag under aseptic conditions. The aseptic bags can vary from 1 to 300 gal. The most popular sizes are the 5-gal and 55-gal containers.

The puree appears commercially in nectars, juices, ice cream, yogurts, baby food, jam, jellies, and fruit syrups. Within the past few years the largest increase in consumption of mango products within the U.S. has been the consumption of mango juice and mango puree packaged in baby food jars. The large increase in consumption of mango juice is part of the world-wide increase in fruit beverages, and within the U.S. the increase in consumption reflects the changes in ethnic composition, which have prompted a large baby food manufacturer to promote tropical fruit ingredients in its food line.

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Appendix: Slide Presentation

The following comments provide a comparison of the differences in operation in terms of labor requirement between canned mango slices in Thailand and an aseptic mango puree operation in Guatemala.

Canned Mango Slices

This is a fruit canning operation in Ratchaburi, Thailand. I was accompanied on this visit by a group of food inspectors for the Thailand Export Standards Bureau. This is the fruit receiving station. Here the fruits are sorted out with the higher quality fruits being packed out for sale on the fresh market. The remaining fruits are allowed to ripen under a burlap cover.

Many workers are employed in hand peeling the fruit. The workers make 50 bhat per day, which is about $2.00. The workers are gowned, capped, gloved, and masked. It is a very clean operation; Thai export standards are very high.

The peeled fruits are placed in the tubs of brine solution to inhibit browning. The cheeks of the mango are sliced by hand from the sides of the mango seeds. The slices are packed into the cans by hand and checked for fill by weight. The fruit slices are then covered with a syrup. The cans with fruit and syrup are then placed in a steam box called an exhaust box to heat the fruit and syrup which expels air and oxygen from the product. The exhausted cans, while still hot, are covered with the cover lid and seamed. The canned mangos are then cooked in a pressure cooker called a retort to sterilize the product. As typical in many developing countries, the labeling is done manually; while this may appear to be inefficient, you must remember that these people are earning the equivalent of US$1.00-2.00 per day, and in this type of operation they are being paid piecemeal, or by the number of cans labeled.

Within the quality control lab was a display of the many products canned at this plant from asparagus to lychees, rambutans, bamboo shoots, mangos, and pineapples. All of these canned products require a considerable amount of hand labor.

The Mango Industry in Guatemala

I consulted for a fresh mango fruit packing and aseptic mango puree operation near Guatemala City. The mangos packed at this plant are of the 'Tommy Atkins' variety. This cultivar had been recommended by consultants from Florida; it is a good shipper but a poor processing fruit. About 500 hectares of 'Tommy Atkins' had been planted in Guatemala by the time EDB use was suspended. The plant also uses mangos collected from wild trees; these fruits are very stringy but make good juice.

The mangos are delivered in plastic lug boxes. The fruits are sorted by size and maturity and hand waxed. Each fruit is individually labeled. The mangos are then packed in cartons for delivery.

Within the same plant where the fresh fruits are packed is a mango puree plant. The mangos are allowed to ripen in their lug boxes. The fruits are dumped into an elevator/conveyor belt. On the conveyor belt the fruits are sorted and trimmed. For certain varieties of mangos, steaming the fruit for 1-2 minutes helps in removal of the skin during pulping. It also lowers numbers of microbes on the skin. Here the fruit are shown entering the steam tunnel. The fruit then traverse an inspection belt where the fruits are further trimmed and slit to help in the removal of the skin. The mangos are then passed trough a special piece of equipment called a destoner, which removes the skin, pulp, and seed. As shown from the waste discharge, the seed or pit is being discharged.

This shows the exposed inside of the destoner which consists of set of nylon bristles rotating against a set of large gapped screens. The pulp is then passed through a pulper to remove some of the fiber. The pulp is further screened through a second pulper fitted finer screen to produce a smooth consistency to the puree. Mango puree must be acidified if it is to be processed, in order to prevent botulism. Here the plant engineer is calibrating the citric acid metering pump. The acid is delivered during the finishing process were the acid solution is mixed into the puree to lower the pH to below 4.4. The acidified pulp is then pumped to a set of stainless steel vats where the pulp is further adjusted to for pH and the volume of puree is allowed to accumulate. The puree is pumped to a set of scraped surface heat exchangers where the puree is heated to 204°F and held for two minutes to inactivate enzymes and kill the microorganisms to render the puree aseptic or germ-free. The puree is pumped from the holding tube to a triple tube for pre-cooling and then further cooled in a scraped surface heat exchanger to 85°F. The puree is then pumped to an aseptic filler where the product is delivered aseptically or germ-free to a sterile, gamma-irradiated plastic bag, which can vary in size from 1 to 55 gal.

This plant has, as any aseptic processing plant should have, an alternate power supply. If there is any power outage during a processing run, then the whole batch is ruined.

Q: Is this processing equipment available in Hawaii? Are there companies here that do this kind of processing, and could they expand their product range to include mangos?

A: Most of this equipment is available in Hawaii, and there are fruit processing companies here that could adapt their processing facilities to accommodate mango. The main item of equipment they would need to add would be the mango destoner, which costs about $30,000. The problem would be with supply. You can't run these systems with a few lugs of fruit. The plant in Guatemala was processing 5,000 – 10,000 pounds per hour. They would run 24 hours a day, six days a week, clean up the system on the seventh day, and start again. Processors in Hawaii do not usually run all the time like that. But with most fruits the main share of production gets channeled to the fresh fruit market; you need a large enough industry to create culls before you can process culls. The farmer makes it on fresh fruit prices, not cull prices. Mango aseptic puree from Guatemala is selling for around 45¢/lb, and from that you can estimate how much the processor has to buy the fruit for to make his margin.

Q: Then labor for culling would be a limiting factor here?

A: I don't think so. You have to cull to get rid of the rotten fruits and keep the mold counts down, but the labor for aseptic puree processing is nothing compared to what is required for the canning operation I described.

Q: Sometimes we have a lot of green mangos blown off our trees. Can these be preserved with some combination of salt, sugar, shoyu, and MSG?

A: That's a local-style way of flavoring green mango, but it's usually consumed as quickly as it is made, or after being refrigerated for a short while. At the concentrations of ingredients added in those recipes, it is really for flavoring rather than preserving. Without refrigeration, mango prepared that way will rot. The rate of rot depends on temperature and microbial load, how clean your knife and cutting board was. MSG, by the way, is not in itself harmful; it is present naturally in many foods such as mushroom and tomato, and it is a building block of glutamic acid in our bodies.

Q: Sometimes in Zanzibar we have problems with fermentation in our pickled mangos. How can that be avoided?

A: That depends on the pickling process, acetic acid or salt brine. Usually sanitation is the main problem. Brine is a preservative, and the mango needs to be as clean as possible and get into the brine quickly. Heat processing will stop the fermentation, but there are a lot of variables that need to be considered when you develop thermal food processing methods.

Q: Dried mango as snack food seems to be an unexploited possibility; what would be involved in that?

A: A dried fruit operation would require hand peeling and hand slicing, which would be labor intensive for Hawaii. Much of the dried mango from Southeast Asia has been sugared. If it is at all moist and pliable and is shelf-stable, then it has been sugared. That means that for every pound of dried fruit you buy in that form, half of it is cane sugar.

Q: Can't we develop machinery to piece-cut fruits for processing?

A: It is very expensive. A contour peeler for papaya would cost about $100,000 to design and build. It would be expensive to run and difficult to maintain, and would have low throughput, not like a pineapple Ginaca machine.

FLORAL MANIPULATION IN MANGOS

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My research on mango flowering began about five years ago. By that time, smudging, the traditional Philippine use of smoke to promote flowering, had given way to the more convenient and efficacious use of ethephon (a compound that generates ethylene in plants) and potassium nitrate sprays. Not only were mango trees in the Philippines stimulated to flower out of season with these treatments, but irregularly-bearing trees could be stimulated to bear in most years. The connection between smoke (which contains ethylene), ethylene generated from ethephon, and flowering response led to the hypothesis that ethylene was the "hormone" which induced trees to flower.

Based on what we knew at the time, ethylene was a potential factor in flowering. In support of the hypothesis, we had observed epinasty, the temporary turning-under of leaves, occurring in leaves of flowering branches. Those involved in ethylene physiology recognize epinasty as one symptom of ethylene exposure, either endogenously produced or exogenously applied as a gas. Therefore, early in our experiments we measured ethylene production in buds, leaves, and developing panicles. The results of a number of experiments led us to the conclusion that enhanced ethylene production does not seem to be involved in mango flowering. We found that floral buds which should have been producing ethylene were not producing significantly more than plant parts at other stages of growth. The levels of ethylene observed in flowers were basically the same as background levels. We applied ethylene in the form of ethephon, causing the tissues to produce copious amounts of ethylene. It resulted in no stimulation of flowering. Moreover, potassium nitrate did not increase ethylene levels or stimulate flowering in either 'Tommy Atkins' or 'Keitt' trees.

Potassium nitrate (KNO_3) came into general use in the Philippines in the 1970s. It too was speculated to stimulate flowering through a wound-ethylene response. It now is widely used in Mexico as well. Although responses may occur at concentrations ranging from 1 to 8 percent, Mexican growers generally use 4 percent KNO_3 or 2 percent ammonium nitrate. Leaf tip burn also occurs in dry areas at these concentrations. The flowering response is cultivar-specific. 'Haden', 'Irwin', 'Carabao', and 'Manila', for example, respond well. Polyembryonic cultivars appear to respond most effectively. Response in others, such as 'Tommy Atkins', is more difficult to obtain.

The first dates in which they are able to get an efficacious response in responsive cultivars is in late October in the southernmost area of Chiapas, Mexico. Efficacy decreases, in terms of prolonging the date of first flowering response and increasing the amount of chemical necessary to obtain a response, in trees planted at latitudes further north. Growers in the state of Colima (mid-Mexico) stimulate early flowering by starting sprays in mid to late November. Trees growing in the area of Vera Cruz begin to respond slightly later in the year but lose the ability to respond altogether in areas north of 23° latitude. I have been told that even concentrations sufficiently high to cause substantial leaf burn (10 percent or more) are apparently not effective. Trees located in both Sinaloa (25° latitude, dry climate) and Homestead, Florida (25° latitude, dry climate) do not respond. This is also true for other higher-latitude areas such as in northern India, Australia, South Africa, and Israel.

Because only sections of trees flower in response to sprays, applications are made every two weeks. Generally, other sections of the trees flower with each application. If it occurs, the flowering response is virtually immediate, with buds swelling within two weeks after application. Full flowering occurs within one month.

One must be careful in interpreting such information. Many have found that if KNO_3 is applied too early in the season, they obtain a vegetative instead of a flowering growth response. The same is true for spring or summer applications. It is likely that KNO_3 is not inducing flowering directly, but is stimulating initiation of growth. If conditions are present to induce flowering, then growth will be reproductive. If, on the other hand, conditions are more favorable for vegetative growth then, that will be the response. This point is further discussed below.

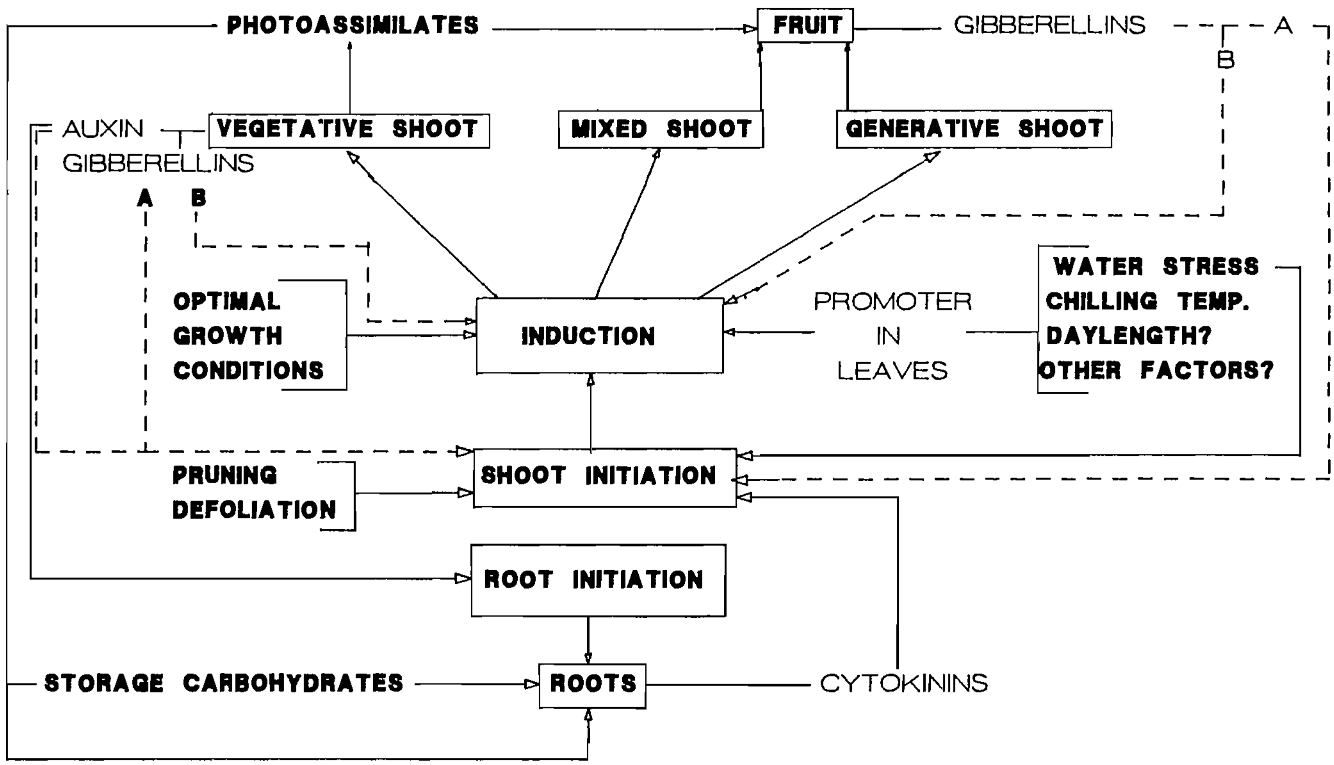

Figure 1. Conceptual model of mango flowering and vegetative growth.

In our research, we needed to produce large numbers of uniform, small plants for use in growth chamber studies. We could not use seedlings because of their juvenility characteristics; juvenile plants would not flower even when exposed to floral-inductive conditions. Experimental plants are produced by air layering, using an auxin, naphthaleneacetic acid (NAA), applied in lanolin to help stimulate root production in the air layer. Rooted air layers are planted in one-gallon pots for use in greenhouse and controlled environment studies. They can be manipulated by pruning or defoliation to manage initiation of new shoots or control leaf age. Mostly, we manipulate them by putting them into defined environmental conditions where we can investigate the effects of temperature, daylength, water stress, etc.

We have developed a conceptual model of flowering and vegetative growth (Figure 1). We are certain about some concepts which are incorporated into the model. Other concepts (such as the role of phytohormones, etc.), are hypotheses based on supportive literature on other plants. The model is thus in one sense a fairy tale, because we have not proved that all its relationships are true; however, it is a useful framework around which we can plan, conduct experiments, and test various hypotheses. So far, everything we have observed in the field seems to fit the model. The model is based on events occurring to individual buds and the forces impacting on those buds which direct its growth. In mango, clusters of stems tend to flush at the same time, although the entire tree may not do so. Upon close observation, one will generally find that these stems are ultimately connected at some common branch point. An astute observer will note that individual buds on mature mango trees rarely grow during the year. They flush only two or three times per year. One can clearly see the history of those flushes recorded in the branches.

There are two distinct switches that have to be turned on for flowering to occur. First, the shoot itself must be initiated to grow; something must cause the bud to go from a resting state to a growing state. I call this initiation. Once it begins to grow, the second switch has to be turned one way or the other to determine what kind of growth will occur: vegetative (producing leaves) or generative (producing a panicle). Sometimes, a confused mixture of the two is produced, which we call a mixed shoot.

If shoot initiation occurs when optimal growth conditions (warm, humid weather) prevail, it will develop into a vegetative shoot. The photoassimilates which the resulting leaves produce provide food for development of roots and other vital plant organs including fruit when available. They are either used immediately or stored in locations throughout the tree to be used at times when demand for carbon resources is greater than the current photosynthetic supply.

Vegetative shoots and fruit are also well known to be sources of two classes of plant hormones: auxins and gibberellins. These phytohormones may be involved in an internal cycle which regulates shoot initiation. For example, auxin is actively transported to roots from sites of production in shoots. Auxins are well known to stimulate root growth. This flush of root activity may either be a transient effect, or roots may grow somewhat continuously. Preliminary results in our lab and extensive research reported on other species indicate that the former may be the case, but results of others support the latter possibility. Regardless, shoots are rich in auxins as they develop; auxins are transported specifically downward from the shoot to roots, and as leaves age (the apical buds having gone back into the non-growing, rest stage) we assume (based on supportive research on other plants) that their auxin production declines. Thus, pulses of auxins may stimulate root initiation after vegetative flushing. The roots that develop from growth stimulation are known to be rich sources of cytokinins, which are major factors in stimulating shoot initiation.

We also know, however, that auxin is an inhibitor of shoot initiation. Auxin enforces apical dominance by preventing buds beneath the apex of stems from shooting. We envision a balance of shoot-produced auxin, diminishing as leaves age, and cytokinins in buds gradually increasing as they are transported upwards to buds and leaves through the xylem transpiration stream.

The initiation switch may be, therefore, dependent upon a balance of the two phytohormones rather than the absolute concentration of either one. High auxin levels, compared to cytokinin levels, may inhibit shoot initiation, and high cytokinin levels, compared to auxin levels, may stimulate shoot initiation. During a rest period, auxin is possibly decreasing, cytokinins are increasing, and at some point, the bud's initiation switch is triggered, stimulating it to grow. This conceptual model predicts that we should see initiation of buds in response to increasing cytokinins and decreasing auxins levels, and that in an opposing root cycle we would get the opposite conditions resulting in flushing of roots. The literature on apples and citrus supports this type of alternating flushing behavior. Our preliminary experiments, thus far, support these hypotheses. Nobody, however, has done the experimental work with mango, because it is difficult. You have to separate growing sections of the tree from other sections.

There is evidence that cytokinins have the effects that our model predicts. We have applied a synthetic cytokinin, such as 100 ppm thidiazuron, to resting buds. We obtained tremendous shoot initiation and proliferation in several experiments. If applied during an inductive period, i.e., the wintertime, we got proliferation of inflorescences; if applied during the summertime under non-inductive conditions, we got either normal shooting or a proliferation of shooting.

When buds begin to grow they are apparently influenced by ambient environmental conditions which determine the form of newly initiated growth. The floral-inductive condition assumes that a promoter is present in leaves. We and others have demonstrated that leaf removal prevents flowering of new shoots. During an inductive period (cool, winter nights), we girdled branches (to isolate them from the rest of the tree) and deblossomed the same branches (to stimulate new growth), and we defoliated some of those branches on day zero (when we deblossomed and girdled) and did the same to other branches on days two, five, and eight. We confirmed that leaves were required as sensory organs to measure the inductive conditions. All growth resulting from the treatment at days zero and two was purely vegetative. There was an increase in generative shoots following the day-five treatment, with a further increase after the day-eight treatment. Other experiments along these lines showed that with no defoliation at all, 100 percent of the new shoots were generative. We are, thus, fairly confident that leaves are the sensory organ, and the florigenic promoter is a labile compound that does not stay around for long. At some point from zero to 14 days after stimulating new growth by pinching off the stem apex, the florigenic promoter disappeared. As the time interval between defoliation and emergence of new buds got closer, the influence of leaves retained for longer periods became stronger. There seems to be about a one-week period required for the florigenic promoter to degrade to a point where it is no longer stimulatory.

In another experiment, branches were deblossomed (to stimulate new growth) and defoliated (to remove the florigenic promoter) on day zero, but each branch was girdled, thus isolating it, on day 0, 5, 10, or 15, to see if the putative florigenic promoter is available from other branches. Another set was left not girdled. Even if girdled on day 15, we saw only vegetative growth result. The non-girdled treatment, however, resulted in a reduction in the number of vegetative shoots and an increase in the number of flower-producing shoots. Those shoots were composed mostly of an atypical shoot type which started out purely vegetative but reverted to inflorescence formation in the latter half of shoot development. These were termed transition shoots, in contrast to mixed shoots which form both leaves and inflorescences in the same nodes at the same time. We have been able to duplicate formation of transition shoots in growth chambers by transferring plants from warm temperature to chilling temperature during early bud development. These results indicated that the florigenic component may be moving, possibly in the phloem, but arriving late from other branches to supply buds that were initially lacking a florigenic promoter due to defoliation.

Environmental conditions such as water stress, chilling temperatures, and possibly daylength have been suggested to provide the conditions necessary to induce flowering of mango. We have examined water stress (lack of water) in detail but have found no link of flowering to water relations. We have found the same lack of correlation of flowering with daylength. Chilling temperature, on the other hand, definitely has an impact. The threshold temperature to induce flowering of 'Tommy Atkins' appears to be about 65°F. Chilling temperatures need only to occur at night. Day temperatures are not so critical. Other cultivars likely have different thresholds of induction. At present, we feel that chilling temperature stimulates production of the putative florigenic promoter. It is, thus, reproducibly controllable with environmentally-controlled growth chambers. We are able to stimulate flowering of small containerized plants, propagated by air layering, at any time of the year.

We can also control what we perceive to be a flowering inhibitor (or inhibitors), which appears to occur in leaves as well. The presence and strength of that inhibitor seems to be influenced by the age of those leaves. Apparently, the older the leaf, the less impact the inhibitor has. For example, plants with leaves of different ages were placed in an environmentally-controlled growth chamber and stimulated to grow by pruning. Plants with older leaves flowered, whereas plants with younger leaves grew vegetative shoots. We are investigating the possibility that this inhibitor is a gibberellin, a large class of phytohormones exhibiting a variety of influences on plants from stem elongation to inhibition of growth and flowering. We have applied different levels of GA_3 to branches of both field and greenhouse plants and have found that it inhibited initiation of bud growth. The length of time in which initiation was inhibited was concentration-dependent, but panicles formed when initiation occurred regardless of concentration. Thus, it appears that a gibberellin closely related to GA_3 is involved in inhibition of initiation but not to inhibition of the induction switch. We speculate that there is another gibberellin which acts as an inhibitor of the induction switch. This suggestion is supported by the flower-promoting effects of gibberellin-synthesis inhibitors such as paclobutrazol. Fruit as well as vegetative shoots may produce these inhibitors based on the observed inhibitory effects of their presence on the tree.

Whether or not an initiated bud will be induced to vegetative or generative growth may not depend on the absolute amounts of promoter or inhibitor present in buds, but on the relative balance of the two. This theory may explain the observation that vegetative growth results if young, mature leaves are present on the stems subjected to marginally inductive conditions (high inhibitor, lower promoter) and that generative growth results when the night temperatures are chilling (45-60°F) even in the presence of relatively young leaves (high inhibitor, higher promoter). Similarly, when inductive temperatures are marginal, plants with old leaves flower (low inhibitor, higher promoter), or if plants with old leaves are placed in non-inductive conditions, then they grow vegetatively (low inhibitor, lower promoter). Our research has led us to the conclusion that the inductive switch is determined at the time of bud initiation, not before.

Flowering and vegetative flushes generally occur in sections of mango trees grown in the tropics, with different sections flushing at varying times. Trees in subtropical areas, which usually receive extended periods of winter chilling night temperatures, tend to produce synchronous flowering flushes, i.e., occurring throughout the tree at once. Trees on Oahu appear to have experienced long periods of cool nights this year. If winter temperatures are warm, then flowering becomes asynchronous similar to the tropical situation. To explain this phenomenon, I suggest that the tree be viewed as a community of organisms instead of one. Each is complete with roots, branches, and canopy. Each sector (organism) is on its own agenda of shoot flushes and root growth. Our experiments have shown that dyes which were applied to roots migrate up trees in the xylem stream to specific branches which are aligned with those roots. Little lateral movement of the dye occurred. The connection of roots to shoots follow their alignment as governed by the architecture of the tree. In order to profitably control flowering, we must create synchrony of growth. This can be achieved by pruning.

Synchronous growth can be initiated by lightly pruning entire trees. Ideally, it would be preferable to supply the flowering promoter at the time growth occurs and hopefully stimulate flowering at any desired time of the year. Unfortunately, no one has identified this putative promoter, much less put it in a bottle. Another way we can manipulate flowering is by manipulating the inhibitor. If, after the post-pruning flush has hardened off, we can stimulate trees to initiate growth with KNO_3, then the timing of that growth can not only be controlled, but made to occur synchronously throughout the tree instead of in patches as is commonly observed when using KNO_3 without synchronization. Trees should be sprayed after sufficient time has elapsed to reduce the level of inhibitor generated from the synchronized flush of leaves and at a time when the inductive conditions of cool temperatures are present to stimulate production of enough promoter to overcome the level of inhibitor.

How can we manipulate the inhibitor? Paclobutrazol is a gibberellin synthesis inhibitor which, when used appropriately, stimulates mango flowering. We have used this fact to connect our putative inhibitor with gibberellins. Application of paclobutrazol in conjunction with KNO_3 can stimulate early synchronized flowering during marginally- or non-inductive conditions when you would never normally see flowering. We believe this is the strategy being used on 'Irwin', 'Parvin', and 'Keitt' in Puerto Rico. They have reported summer flowering of 'Irwin' trees. 'Tommy Atkins' is a different story, because it is recalcitrant in its growth response to KNO_3, but it does respond to paclobutrazol by flowering. We are currently investigating use of cytokinin to stimulate floral initiation in the presence of paclobutrazol.

There are problems with use of paclobutrazol. Because it inhibits the gibberellin syntheses pathway, levels of the gibberellin which is responsible for internode elongation, possibly GA_1, are reduced. Although fruit set and yield may be increased, the product produces a compressed panicle which does not dry out very well and can develop powdery mildew or anthracnose even after a light dew.

Another problem is that when paclobutrazol is applied to soil in excess, under certain conditions, subsequent growth and normal development can be severely disrupted. There is a growing amount of literature on the use of paclobutrazol to get early and more uniform flowering in mangos. No response was observed in seven or eight months after applying paclobutrazol to trees in Homestead. The trees then went through a freeze, our irrigation system failed, and major scaffolding branches were killed. The trees were severely pruned to remove dead wood. The ensuing growth lacked normal node elongation. Trees having only 1 gram of active ingredient applied are still severely stunted after over six years. We investigated the possibility that pruning of the major branches following application was the cause of the undesirable stunting of growth. We applied paclobutrazol, in the same concentration, to trees and waited three years before severely pruning. There was no response to the product until after the trees were pruned. The resulting growth was as severely stunted as before. We believe that this material is chromatographing itself up through the xylem of the tree. It is apparently concentrating itself in main trunks and slowly metering itself out to the branches. When main branches are cut, forcing buds to grow in the area of high paclobutrazol concentration, then you see this strong effect. As long as you do not prune the tree, there appears to be no problem and a many-times limited effect. Recommendations used in Thailand of 1.5 to 2 g/tree/yr to stimulate more uniform flowering may eventually result in this kind of damage if and when they prune those trees for some reason.

Paclobutrazol is persistent in the soil. If a new tree is planted, it will show the same symptoms. Therefore, we have to be careful when recommending use of such a compound. Experiments are being conducted in Central America on 'Tommy Atkins'. They involve applying paclobutrazol sprays at 30 ppm, which is its solubility in water, to get it to the buds at the proper time to facilitate a flowering response.

In summary, the conceptual model presented in this talk appears to be consistent with growth and development patterns taking place in mango trees all over the world. It predicts what will happen under a defined set of circumstances and is being used to develop strategies which result in flowering at any time of the year. A grower in Puerto Rico utilizing concepts suggested by this model is getting flowering as early as September, and even in July in some cultivars. 'Haden' is an amenable cultivar for manipulation with KNO_3, but 'Tommy Atkins' generally does not respond to this treatment. Potassium nitrate itself does not appear to induce flowering. This point can be verified by spraying trees in the summertime without any positive effect. It is more than likely a combination of the age-dependent inhibitor and whether or not sufficient promoter is available in the leaves that determines the fate of initiated buds. In our hands, we can control both the inhibitory and promotive components. We can make a plant grow when we want it to, and we can make it flower or go vegetative when we want to. This is valuable from the scientific standpoint, because it means we can make biochemical and physiological observations to better understand the interrelationships between the florigenic promoter and inhibitor, and at some point we hope to identify and utilize these components.

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Q: Can't flowering be explained simply by the presence of an inhibitor in leaves rather than a promoter to obtain flowering?

A: No. If this were the case, then we would expect an increase instead of a decrease in flowering response when leaves were removed. We have observed that when one leaf located close to the tip is left on a branch which is otherwise defoliated, the bud just above that leaf will produce an inflorescence, whereas all the other buds will be vegetative. Moreover, the observation that flowering is graft-transmissible can only be explained by the presence of a promoter.

Q: Is paclobutrazol approved for use on any food crop in the U.S.?

A: No.

Q: What is the likelihood that it ever will be?

A: None. That's a problem. I work with several growers in Central America. I have talked to the people at ICI, which manufactures paclobutrazol, and at Sumatomo, which manufactures uniconazol, another product which is about 10 times more efficacious than paclobutrazol. Both companies have no current plans to clear them for use on food products. Paclobutrazol is marketed worldwide with the trade name Cultar for use on avocados, mangos, and other crops, but it is not cleared for use in the U.S. We are applying the material as a solution to branches long before any fruit is on the tree. The likelihood of residue in the fruit is virtually nil, but residue studies have to be done to test that.

Q: Is it possible that paclobutrazol might be approved for foliar application?

A: It's possible but not probable, because the cost of registering these compounds is so great. A company must anticipate a large profit to motivate them to invest the millions required to clear a compound for use. I doubt that would occur because the amounts of product we are using are very small, and the demand for the product in the mango industry overall wouldn't be very large.

Q: Might there be a move to examine mangos being imported into the U.S. for paclobutrazol residues?

A: There might. The only place where paclobutrazol is being used on mangos a lot is in Thailand, where ICI sales reps are strongly promoting its use as a soil drench. Australia is starting to use it as well. The advantage to developing a strategy using sprays at soluble concentrations on foliage prior to flowering instead of soil drenches is that the risk of residue in the fruit is substantially reduced. Regarding the potential stunting effect in pruned trees, I have tried to convince my cooperators in Guatemala and Costa Rica to "hat-rack" prune one of their trees to see the response, but they don't want to sacrifice a productive tree. Stunting too, along with the question of residue, is something that has to be examined.

Q: In the case of cold stress; is there a time factor?

A: In our experience in the growth chambers, it requires a week or two. Basically, those buds that initiate growth in the cold condition are induced to flower. The longer the plants are in the inductive condition, the greater opportunity there is for more buds to initiate panicles. In the field, we have seen that a period of several nights of temperatures down in the 60s is sufficient to cause them to flower, but we have no accurate figures on this. Bear in mind that cultivar differences exist, and the age of leaves varies, both of which factors impact plant flowering response. This year, we had a situation where we had relatively low night temperatures in November-December; they went up in January, then in mid-February they went back down to the 40s and 50s. Our day temperatures are generally in the mid-80s. Sections of some trees that happened to grow during that early part of the season flowered with full panicles. Other sections that grew during the period of higher temperatures grew vegetatively, and sections of the tree that are growing now are producing panicles. That fits with what our model would predict. The lower the temperature, the higher the level of promoter you would expect. I am saying this intuitively, from what we have observed in the field. We have not done experiments, and we do not have a means now to identify or measure this promoter. All we have is the plants' response under given conditions.

Q: Does compaction in the inflorescence as a result of paclobutrazol affect fruiting?

A: Paclobutrazol tends to increase fruit set. On the other hand, too much of the compound compacts panicles to the point where risk of early fruit loss due to disease is increased. The photos you saw were of trees treated with a higher concentration than one would want to use in a normal operating situation. The grower mentioned earlier is synchronizing growth of his 'Irwin' trees by lightly pruning them right after harvest to promote a uniform flush. Then he can regulate the age of his leaves and treat with paclobutrazol about two months later. Although he will not disclose the product he is using, the amount, or how it is applied, I feel certain that he is using a low enough concentration of Cultar to lower the inhibitor level without producing substantial compaction of the inflorescences. He then follows quickly with the KNO_3 to stimulate growth. Basically, he is synchronizing his trees so that all the leaves are the same age, he is reducing the level of inhibitor produced by those leaves with paclobutrazol, and then he is stimulating the tree to grow at that point. It is a smart strategy.

USE OF POTASSIUM NITRATE ON MANGO FLOWERING

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The mango (*Mangifera indica* L.), a member of the Anarcardiaceae, is a popular fruit of the tropics and occupies a position in the tropics similar to that of apples in temperate regions. Originating in the Indo-Burma region, the mango has since spread to nearly all tropical areas of the world. On the Indian subcontinent, it has been under cultivation for at least 4,000 years.

In the tropics, mangos are usually grown at elevations between sea level and 1,200 meters, but does best below 610 meters in climates with a pronounced dry season. In Hawaii mango will grow best at elevations from sea level to 457 meters (1,500 ft) (Chia et al. 1988). Mangos grow best at temperatures between 27–24°C and are susceptible to frost damage. Annual rainfall in growing areas ranges from 25 to 250 cm. In the wet-humid tropics, persistent rains and high humidity during flowering can cause a reduction in pollination and fruit set.

Flowers are borne on inflorescences (panicles) which are usually terminal, but panicles may also arise from axillary buds. Flowers are either male or hermaphroditic and may number from 300 to 3,000 on each panicle, depending on cultivar. The percentage of hermaphroditic flowers varies with cultivar and upon early or late emergence of the panicles (Chanda and Pal 1986).

Flowering period in mango is mainly related to weather patterns and to some degree to cultivar differences under the same climatic conditions (Singh 1960, 1977; Whiley 1985). Flowering in Hawaii usually begins in January, with fruit maturing from May–June through September (Hamilton et al. 1992; Yee 1979). In the milder southern and western regions of India, flowering begins in November or December; however, in northern areas where harsher climates prevail, flowering is more precise and occurs later, in February or March (Chanda and Pal 1986). Flowering in the U.S. occurs between January and March and in the Philippines from December to January.

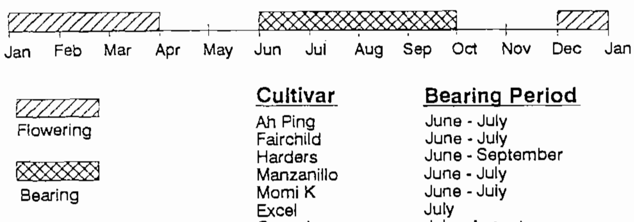
Recent studies in Florida suggest that low temperature is the environmental factor with the greatest influence on flower induction (Nuñez-Elisa and Davenport 1992). It was concluded that water stress was not responsible for flower induction, but could enhance the response to cool temperatures. Similar conclusions have also been obtained by workers in Australia (Whiley 1992).

Reliable flowering is necessary to obtain consistent mango production in the tropics. In Hawaii, the Pacific, and the Caribbean, where land is a limiting factor, mango is a potentially important fruit crop if increased production, reliable bearing, and off-season bearing can be achieved. In Hawaii, biennial bearing is common; a heavy crop one year may prevent further fruiting for two years or longer. In the Hawaiian Islands, leeward sections, which are drier during the winter months, are considered ideal for mango production (Yee 1979).

Regulating Mango Flowering

Tropical climates are conducive to year-round vegetative growth of perennial tropical fruit crops, but flowering and fruit set are usually seasonal. Flowering from one season to the next is unreliable, because the environmental signals for flower initiation are often inconsistent, subtle, or poorly defined. An alternative to dependance upon environmental signals for flower initiation is the development of management strategies that can substitute for these signals.

In Hawaii, one method to extend the availability of fruit within or slightly beyond the ripening period of May-June to September is by growing different cultivars. There are usually some seedling and off-season fruits available at other times. Figure 1 illustrates the bearing pattern for important mango cultivars in Hawaii. Bearing patterns in Hawaii show that 'Harders' produces late-season fruits in the fall; 'Keitt' and 'Rapoza' are also late season cultivars that mature from August through October (Hamilton et al. 1992). In Hawaii and other tropical areas with high rainfall, flowering, fruit set, and fruit quality are often diminished by pathogens favored by wet conditions that occur during or soon after the flowering season.



Cultivar	Bearing Period
Ah Ping	June - July
Fairchild	June - July
Harders	June - September
Manzanillo	June - July
Momi K	June - July
Excel	July
Gouveia	July - August
Pope	July - October
White Pirie	July
Keitt	August - October
Rapoza	August - October

Figure 1. Flowering and bearing pattern of mango cultivars in Hawaii.

Success has been achieved in stimulating mango flowering with chemical treatments. In the Philippines, smudging has been used to obtain earlier and increased flowering of 'Carabao' and 'Pico' mango (Dutcher 1972; Gonzales 1923; Madamba 1978). Ethylene has been identified as the active agent responsible for flowering during smudging (Dutcher 1972). Smudging is done continuously for several days and is stopped if flower buds do not appear within two weeks. The process may be repeated 1–2 months later, but results are uncertain. The ethylene-generating agent, ethephon, applied at 125–200 ppm, induced flowering of 'Carabao' mango in the Philippines within six weeks after treatment (Dutcher 1972). Flower induction also occurred at concentrations between 500 and 1,000 ppm; however, defoliation was also experienced at the higher concentrations (Bondad 1976). Ethephon has also been successful in India for increasing flowering of 'Langra and 'Deshehari' during "off" years (Chacko et al. 1972, 1974; Chanda and Pal 1986) and for inducing earlier production in juvenile plants (Chacko et al. 1974). In 10-year-old 'Haden', 500-1,000 ppm applied one month before the normal flowering date increased flowering by 40–55 percent (Nuñez-Elisea et al. 1980). These results are contrary to those obtained by Pal et al. (1979), who found ethephon ineffective after five consecutive years of treatment, and by Sen et al., who reported an increase in flowering during "on" years but failed to stimulate flowering during "off" years. Applications of giberellic acid (GA) to mango trees have been inhibitory to flowering (Bakr et al. 1981; Tomer 1984). Higher GA levels have been extracted from "off"-year shoots than from "on"-year shoots, suggesting that failure to flower was associated with higher GA levels in shoot tips (Pal and Ram 1978). Analysis of the xylem sap at various stages during shoot development have shown that low gibberellin content was associated with periods during flower bud formation (Chen 1987). Application of paclobutrazol, an inhibitor of GA synthesis, caused precocious flowering in young trees and promoted flowering in bearing trees (Kulkarni 1988). This finding supports the hypothesis that endogenous GA may play a regulatory role in mango by inhibiting flowering.

The first studies to demonstrate that potassium nitrate could induce flowering of mango trees were from the Philippines (Barba 1974, Bondad and Linsangan 1979; Bueno and Valmayor 1974). Flowering was evident within seven days after treatment and was effective on shoots that were between 4.5 and 8.5 months old when treated. Bondad and Linsangan (1979) reported that concentrations of potassium nitrate between 1 and 8 percent stimulated flowering of seedling 'Carabao' and 'Pahutan' trees and 'Pico' trees within one week after sprays were applied. The treatment was effective for stimulating flowering of trees that had remained vegetative well beyond normal bearing ages, for advancing the flowering and fruiting periods, and for breaking the biennial bearing habits of trees. Potassium nitrate is currently recommended in the Philippines for inducing uniform flowering and for the production of off-season fruits in the 'Pico' and 'Carabao' cultivars (Madamba 1978). In India, workers have reported variable results with potassium nitrate (Pal et. al 1979). Areas that have reported success with potassium nitrate include Trinidad with 'Tommy Atkins' (James et al. 1992), the Ivory Coast with 'Kent' and 'Zill' (Goguey 1992) and Mexico with 'Manila' and 'Haden' (Nuñez-Elisea 1985; 1986).

In Mexico, studies by Nuñez-Elisea (1986) have shown that 'Haden' shoots should be six months of age or older. In the case of 'Manila', shoots could be as young as 3-4 months of age and be responsive. Leaves should be dark green with a mature, "woody" texture and well developed terminal buds. Upon treatment with a 4 percent potassium nitrate solution, slight leaf wilting can be observed within two days, and at 10 days buds begin to swell. A second application is made at 15-20 days after the first application if the response is poor. Application should be made prior to emergence of the flowers, because flowers are

Table 1. Percent terminals flowering after foliar treatments of seedling mango trees at Kalapana, Hawaii. Treatment date: Feb. 6, 1986.

	Weeks after treatment 1	2	3	4	5
Control	0.4	1.9	7.7	12.4	17.2
Potassium nitrate					
2%	0	0.8	39.2	58.0	66.2
4%	1.2	1.6	51.0	76.3	83.7
Ethephon					
1000 ppm	0	0.6	0.6	0.6	0.6

Table 2. Percent terminals flowering after potassium nitrate foliar treatments of seedling mango trees at Kalapana, Hawaii. Treatment date: May 29, 1986.

	Weeks after treatment 2	3	4	5	6
Control	0	0	0	0	0
Potassium nitrate					
2%	1.3	4.4	11.1	12.1	13.1*
4%	1.0	4.0	10.0	11.9	15.9*

*Vegetative flushes also stimulated by potassium nitrate.

usually damaged by the potassium nitrate sprays. Harvesting occurs at about five months after treatment. Advancing the flowering season in Mexico has enabled growers to get fruits into the market at an earlier date, extend the harvest season, and harvest crops during the drier periods.

Work in Mexico showed that mango flowering could also be stimulated with ammonium nitrate sprays (Macias-Gonzales et al. 1992; Nuñez-Elisea 1988, Nuñez-Elisea and Caldeira 1992). Concentrations of 2 percent ammonium nitrate were sufficient to promote early flowering in 'Haden', 'Tommy Atkins', 'Kent', 'Diplomatico' and 'Manila'. The similar results between ammonium and potassium nitrate indicate that the nitrate ion is the active portion of the molecule.

Experiments in Hawaii by the authors showed that 2 and 4 percent potassium nitrate sprays applied to mature seedling trees early in the flowering season (February, 1986) stimulated flowering (Table 1). A single application stimulated flowering within three weeks after treatment, and maximum response was observed at about four weeks. A stimulation in flowering was not observed on terminals treated with 1,000 ppm ethephon.

Off-season flowering was also stimulated when application was made to seedling trees in May after the flowering season was completed (Table 2). Nearly 16 percent of the terminals treated with 4 percent potassium nitrate flowered by six weeks after treatment. Our results also showed that terminals that flowered were associated with specific trees; some trees in the test exhibited no response, while others produced vegetative terminals after treatment.

These results suggest that potassium nitrate did not induce flowering, but probably stimulated growth of terminal buds. Flowering was determined by the condition of the terminal bud or the environmental conditions at the time potassium nitrate application was made. Our results with seedling trees also showed that genotypic differences among trees exist with regard to flowering responses to potassium nitrate. Some trees were highly responsive to the treatment and flowered, while others produced vegetative shoots instead of panicles.

Potassium nitrate application to mature 'Haden' trees in Pahala and Waimanalo also showed that flowering was stimulated in October and November (Table 3 and 4). Stimulation of

Table 3. Percent flowering of 'Haden' mango terminals at three weeks after treatment with 4.0 percent potassium nitrate spray at Waimanalo, Hawaii. Treatment Date: Oct. 31, 1986

Control	0
Potassium nitrate	17.1*

*Significant at P = 0.05.

Table 4. Mango cultivar flowering response to potassium nitrate treatment. November 16, 1992; Pahala, Hawaii.

Haden	+ + +
Fairchild	+ *
Keitt	–

*Mixed panicles produced.

flowering during these periods could enable producers to obtain fruits five months later (April), which would be about two months earlier than the usual seasonal production in Hawaii. Preliminary tests with other varieties show that 'Fairchild' was not as responsive as 'Haden' to applications made in November, while no response was observed with 'Keitt' (Table 4). The mode of action for potassium nitrate during flower induction is not fully understood; therefore, an explanation for the variable results between cultivars and application periods remains unclear. The influence of endogenous GA levels (possible flowering inhibitors) and the interaction between shoot age and environmental conditions on the response to potassium nitrate are not known.

Critical to obtaining reliable seasonal and off-seasonal flowering in Hawaii is the identification of varieties that are responsive to potassium nitrate, determining the influence of application times and the type of shoots that will respond to potassium nitrate, and the development of management strategies that force development of responsive shoots at any period during the year. To use chemical treatments effectively to control mango fruit production, application should be assessed in relationship to the plant's growth phenology. The overall objective of future studies should be to develop a management system that ensures consistent seasonal yields. A successful management system could stabilize production by eliminating biennial bearing and by altering the time of production to off-season periods.

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Q: Will any form of nitrate work?

A: We suspect that the nitrate is the active part. Ammonium nitrate has been used in Mexico because it is cheaper than potassium, and the concentrations used were the same, about two percent.

Dr. Davenport: Roberto Nuñez-Elisea has looked at many different salts, and it appears that the nitrate is the active part. You can substitute the cation and still get the stimulatory effect as long as the nitrate is present, but without the nitrate, with potassium chloride for example, there is no effect. Ammonium nitrate is cheaper but you have to use about half the concentration, 2 percent, compared to the 4 percent routinely used with potassium nitrate. If more than 2 percent ammonium nitrate is used, they get leaf burn.

A: There are some reports that urea has a marginal effect, but that may vary with locations.

Q: What is the critical factor influencing the plant to change toward flowering or vegetative growth.

A: We need to speculate about that, but it is likely temperature. Dr. Davenport's work indicated that water stress is not the factor. The actual temperatures and durations required may be specific to variety. The variation we observed in response to spraying in a seedling orchard indicates a strong genetic component.

Q: What has to be affected by the temperature, the leaves, the roots, or both?

Dr. Davenport: The leaves. The promoter is in the leaves.

Q: Could you cool them by spraying with cool water at night?

Dr. Davenport: I have not done any experiments with that, but it is possible that misting to bring about evaporative cooling could have an effect.

Q: How low do night temperatures get in the summertime in Hawaii?

A: Perhaps the low 70s on a clear night.

Dr. Davenport: I can tell you that if you have a variety that responds to spraying, you can have a grove with rows that flower starting in early October and with other rows stimulated to flower every two weeks afterward, on a schedule. In the following year, you have the potential to move that schedule three months forward if you want to, because it will take about nine months to go through the reproductive process and get a new flush of leaves. This is being done. You can manage sections of your orchard to flower at any time you choose. You must be careful, however, about your rainy season, so that your flowers are not getting rained on. You have to be aware of your seasonal effects and the disease control you need to exercise to get quality fruits.

Q: Is there any regulation affecting our use of potassium nitrate sprays?

A: I spoke with the Hawaii Department of Agriculture about the legality of spraying the trees. I interpret it as applying foliar fertilizer, and there seems to be no problem with that.

Q: Why does nitrate sprayed on the leaves stimulate flowering while nitrate applied to the ground stimulates vegetative growth?

A: No one knows what the potassium nitrate does. It appears that this only works with mangos.

Dr. Davenport: It has also been used with grapes, which is where the idea came from to try it with mangos. But it is not true that fertilizing mangos with nitrogen will always promote vegetative growth and suppress flowering. Actually, nitrate applied to the ground also can stimulate flowering; if you stimulate the tree to grow at a time when it is capable of flowering, it will flower. In Jamaica, a person who thought it was the potassium that was stimulating flowering was applying potassium chloride to the soil. He fertilized his trees at the right time and got early flowering. This is why water stress will appear to work as well. If you have an extended period of water stress with none of the flushing that might have occurred during that period, the leaves maintain their capability for induction and the trees will flower when they are watered.

Q: How can growers using paclobutrazol in Central America export mangos to the U.S., where the chemical is not approved for mango?

Dr. Davenport: Actually, the grower I mentioned is exporting his mangos to Europe. The people at ICI claim that there are no residues in the fruit, even if the chemical is applied through the root system. This claim is consistent with results from research with deciduous fruits like apples and pears. Under the conditions that we are proposing to use it, as a foliar spray during vegetative growth phases, it is even less likely that it will be found in the fruits. As long as the inspection agencies find no residue, then there will be no problem exporting the fruits to the U.S. But there is always the risk, the possibility, that they will find a residue and refuse a whole shipment.

ENGINEERING A HYDROPONIC SYSTEM FOR GROWING MANGO TREES

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Abstract

A hydroponic system was designed to maintain uniform root environment for mango flowering manipulation. Round barrels 56 cm in diameter and 87 cm tall were used as planters. The barrels were filled with inert sand as planting medium. The sand provides temporary storage for water and nutrients. The sand also helps keep the trees in an upright position. An inverted V-shaped black plastic canopy was constructed to keep precipitation from falling on the sand. This roof structure also helps keep trees from toppling over. The sand moisture and nutrient levels are maintained by adjusting the irrigation frequency and the nutrient concentration of the irrigation water. A drain was installed on each barrel to collect excess water accumulated at the bottom. This drain was useful in collecting water samples for chemical determination and water budgeting. Eight different root environment treatments of four trees per treatment can be accommodated in the present design. Trees have been grown in these barrels for approximately three years.

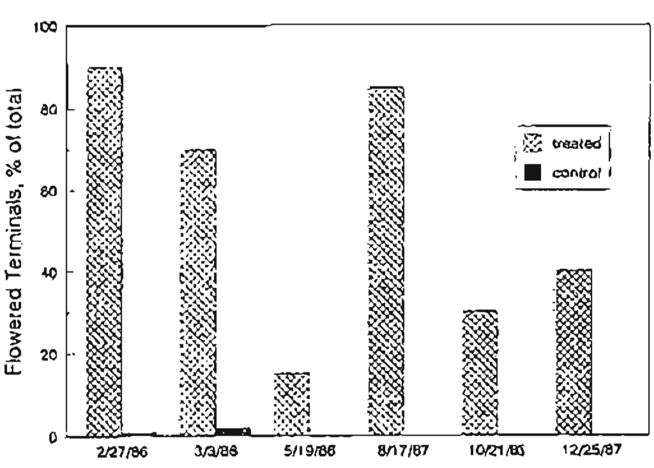

Figure 1. Potassium nitrate effect on mango flowering.

Introduction

Mango is a tropical fruit tree which usually flowers in spring and produces attractive fruits in June or July. Mangos, like many other tropic fruit trees, do not flower consistently. Inducing mango flowering was done in the past. Early experiments were aimed to induce early flowers. This experiment, however, focuses primarily on inducing flowering at any time of the year. With fruits available all year, the amount of mango which could be sold to the 6.5 million tourists to Hawaii can be very significant. Potassium nitrate solution was used to spray mango terminals for flower induction with some success. The spray concentration of 40 g potassium nitrate in 1 l of water was found to be the most effective. Terminals were induced to flower in all seasons (Figure 1). The success rate was, however, much lower in the summer months and a great deal higher in spring, or normal mango flowering season. Even during spring, terminals of approximately the same age do not all flower. Obviously, factors other than potassium nitrate played an important role in the mango flower induction experiment. Publications have identified soil moisture, soil fertility, temperature and terminal age as significant factors in mango flowering. Ability to keep root environment of all treatments under the same conditions can simplify the design and interpretation of results of flower induction experiments. Hydroponics was therefore selected to achieve uniform root environment.

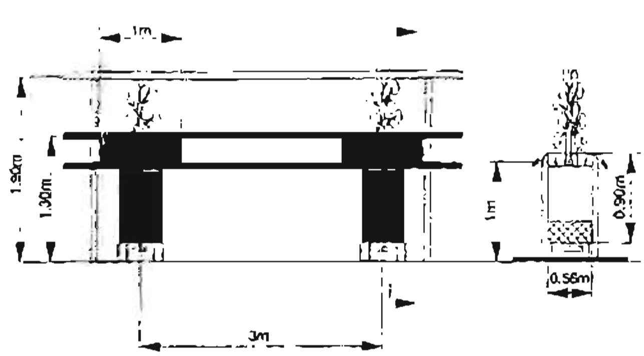

Figure 2. The planter.

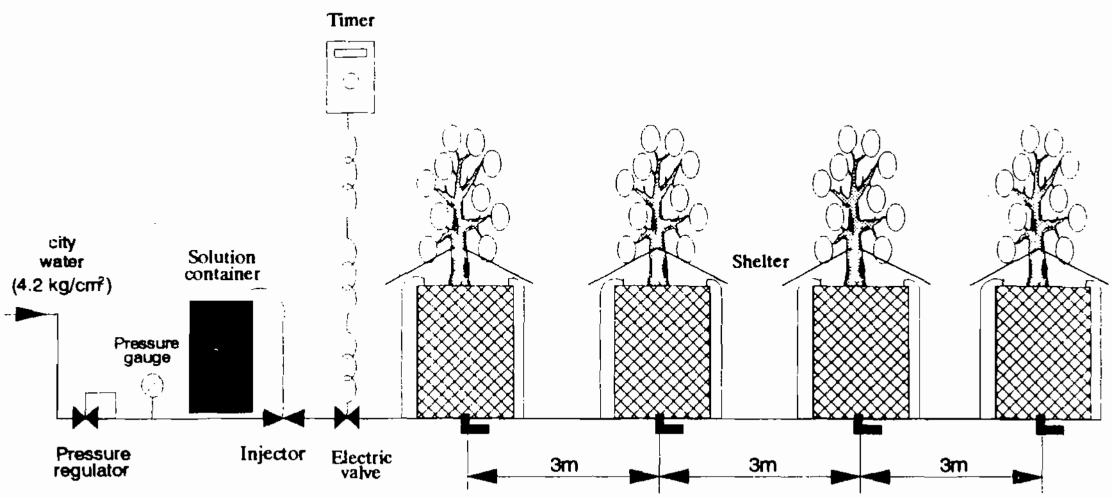

Figure 3. Irrigation components.

The Hydroponic System

The system must be able to provide mechanical support to hold the trees upright and deliver water and nutriment to each tree at minimal energy and cost. It is extremely important to keep the daily system maintenance low. The major components of the system are shown in Figure 2. A tubular frame was anchored to the ground and a V-shaped angle iron truss was attached to the tubular frame. Under the V-shaped truss, planters were arranged 3 m apart along the frame. Metal drums with plastic liners of 56 cm in diameter and 1 m high were used as planters, placed on cinder or hollow concrete tiles. Inert sand was placed on top of a layer of gravel on the bottom of the planters. A drain was also installed at the bottom of each planter. On top of the truss, a black plastic sheet was installed to keep the sand surface in the dark and prevent any weeds from growing in the planter. The mango canopy, however, is kept above the plastic sheet on the V-shaped truss and exposed to sunlight. The floor was covered with a black plastic weed-control cloth to keep the ground free of weeds.

Planters are arranged 3 m apart along the tubular frame (Figure 3). Tap water was used for irrigation. Major components used for irrigation and fertilizing, as shown in Figure 3, include city water pressure regulator, pressure gauge, fertilizer injector and a container holding fertilizer solution. The water pressure and the concentration of fertilizer in the solution determines the nutrient concentration of the solution. The timer and solenoid valve determine how long or how much the trees will be irrigated. Experiments were conducted to verify whether the irrigation system performed satisfactorily. To make the drawing in Figure 3 easy to understand, a tubular frame was not shown. Furthermore, the V-shaped truss was also turned 90 degrees. The system is an open one; in other words, irrigation water was not recirculated. The drain valve in each planter was always kept open and the excess water, if any, was drained automatically. This open system was selected to minimize fabrication effort and reduce the spreading of disease. The entire experimental hydroponic system consists of four 25-m long tubular frames providing supports and shading for a total of 32 trees.

The quantity of parts and materials and their cost per barrel or tree are listed in Table 1. The most expensive items for each tree are the planter barrel and inert sand. For this experiment, soybean-paste containers were obtained at nominal cost as planters. They have stood well and no rust can be found after three years in use. Any food containers made of lasting materials can be reused for this purpose at very low or even no cost. Silica sand #12 was not easy to purchase in Hawaii and, therefore, a high price was paid for the sand. This amount of sand or similar material with the same texture can be purchased at a small fraction of the cost elsewhere. The material and parts cost of establishing a tree for most locations probably can be controlled under US$70.00.

In addition, there was a component cost common to a line of trees under the same irrigation treatment (Table 2). The first four items can be shared by all trees if they are under the same treatment. When all trees are treated or

Table 1. Planter parts and their cost.

Description	Quantity	Cost, US$
Grafted mango tree	1	20.00
Barrel (55 gal)	1	5.00
2B coarse rock	62.3 l	1.40
#12 silica sand	158.6 l	53.00
Concrete tile or block (16 x 16 x 8 in)	3	4.00
Emitters	2	2.00
Emitter tubing (1/8 in)	2	2.00
Fittings incl. tank adapter, elbow, and pipe drain	1	5.00
Weed control cloth	4.5 sq m	4.00
Plastic covers (30 x 54 in)	2	8.00
Angle iron (1 x 1 x 3/16 in)	4.57 m	8.00
1-1/2 in EMT conduit	2.13 m	11.00
Poly pipe	3.05 m	1.60
Total		125.00

Table 2. Common irrigation components.

Description	Quantity	Cost, US$
Pressure regulator (3/4 in)	1	40.00
Filter (3/4 in)	1	30.00
Backflow preventer	1	20.00
Solenoid valve	1	40.00
Timer (mechanical)	1	40.00
Barrel for fertilizer	1	5.00
Fertilizer-metering injector	1	40.00
Electrical		15.00
Poly pipe		15.00
Pipe fittings		20.00
Total		$265.00

irrigated in the same manner, the items listed in Table 2 should serve a large number of trees, except that a multiple-channel timer must be purchased.

System Performance

An experiment was conducted to determine the evapotranspiration, or the water requirement of each tree. It was felt that the most accurate way of accomplishing this objective was to water the planters in different amounts and collect water

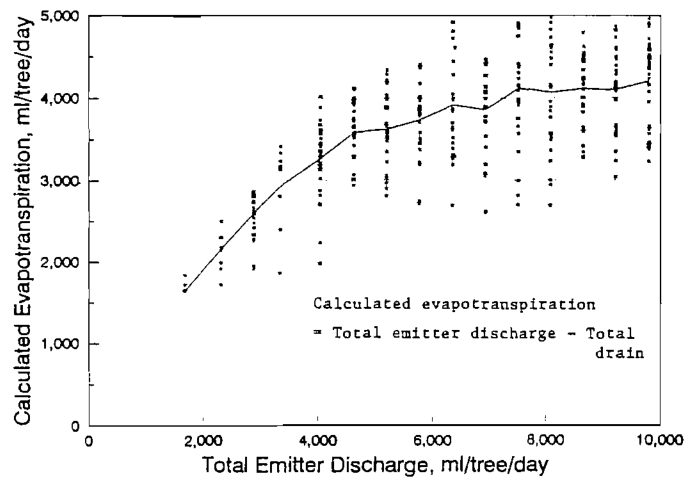

Figure 4. Evapotranspiration.

drained from each planter. Solar radiation was used to estimate the potential evapotranspiration, which was used as a reference for determining the range of water amounts to be used in the experiment. Approximately 15 levels, or amounts, of water were used. At low levels of water application, there was little drained water. The difference between water applied to each planter and the drain water collected was assumed to be equal to the evapotranspiration of the planter. The results of this experiment were plotted in Figure 4. The evapotranspiration of each tree seems to be 4 l/day. As trees grow bigger, it is expected that the water requirement should increase. The small spacing between trees and the fixed planter size would probably limit the tree to a certain size and, hence, limit the maximum water requirement.

Besides delivering the desired amount of water to each tree daily, it is also important to maintain the correct fertilizer amount or nutrient level in the irrigation water. Technology used in fertigation was used to achieve this objective. The principle is based on a venturi injector connected to a pressured water source and to fertilizer dissolved in water in a container. The chemical content of the fertilizer used is displayed in Table 3. The fertilizer solution is connected to the injector port under a suction created by the flow of water under pressure. A test was conducted first to determine if the flow of liquid fertilizer can be adjusted by selecting the injector type and water pressure. Eight tests were run and the results are plotted in Figure 5. The dark bar represents the desired flow and other bars show the actual flow measured. Even in the worst case, the discrepancy

Table 3. Fertilizer chemical content.

Element	Weight (%)
N	9.25
P_2O_5	7.5
K_2O	13.0
Ca	9.5
Mg	1.8
S	2.25
B	0.095
Cu	0.025
Fe	0.2
Mn	0.105
Zn	0.025
Inert material	56.25

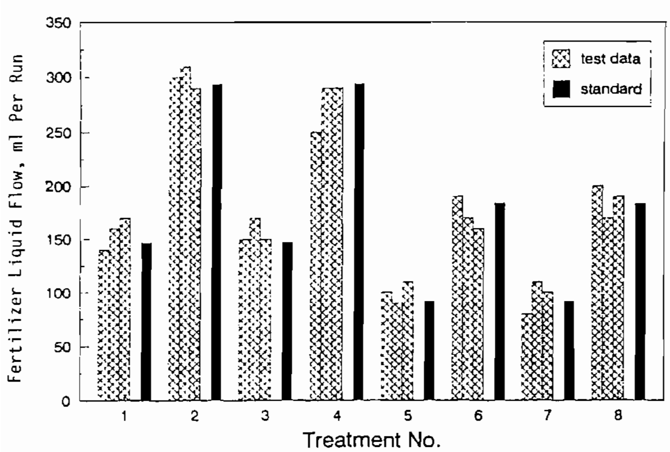

Figure 5. Calibrating fertilizer solution flow.

is less than 5 percent. Similar tests were conducted to determine the total emitter discharge. The results are displayed in Figure 6. The error or discrepancy was negligible. It may be safely stated that the desired irrigation amount and nutrient level in the irrigation water can be achieved.

Trees were first irrigated and fertilized at eight different levels to determine the best level of irrigation and fertilization. The circumference of the trees was used as the measure of irrigation and fertilization effectiveness. Unfortunately, this experiment was conducted before the evapotranspiration was determined. All trees were under-irrigated. Therefore, no difference were found between the treatments. However, the trees did grow more than 20 percent in three months (Figure 7) during this short period of time.

Conclusion

Mango trees have been grown hydroponically for over three years. Tree trunks have grown from pencil size to more than 4 cm diameter. The amount of irrigation was determined by minimizing the amount of water flowing out of the drain. However, attempts to determine the optimal fertilizer level were not successful. An acceptable way to prune or shape the trees remains to be determined. Flowering induction experiments must wait until these two problems are solved.

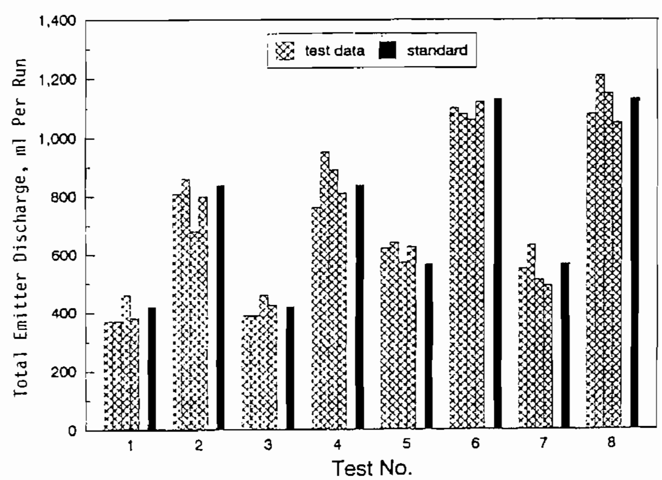

Figure 6. Calibrating total flow.

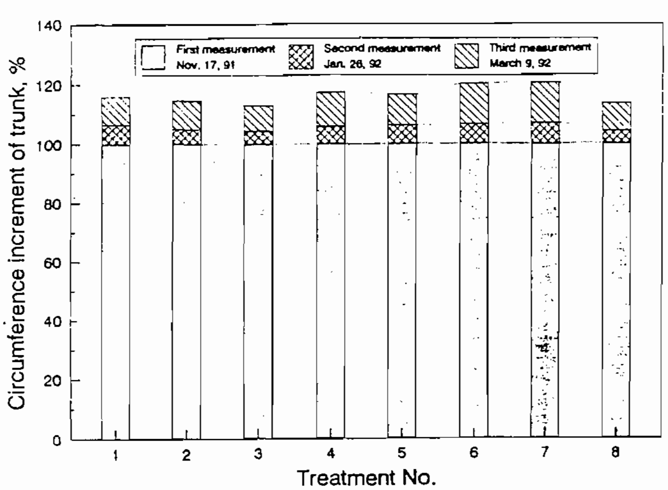

Figure 7. Tree trunk growth.

A MOLECULAR MARKER SYSTEM TO DETERMINE MANGO LEAF AGE

Samuel S. M. Sun[1], Xiaohui Zhou[1], Lynn Godfrey[1], and Tung Liang[2]
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College of Tropical Agriculture and Human Resources
University of Hawaii at Manoa

Application of potassium nitrate to mango leaves has been shown to stimulate flowering. However, the developmental-physiological state of leaves receptive to this stimulation has not been critically defined. The use of this practice to manipulate mango production is thus uncertain and not cost effective at the present time.

We are interested in developing a molecular system to mark the developmental/physiological stages of mango leaves. Once established, this marker system can be used to link the developmental-physiological stage(s) of mango leaves with their responsiveness to potassium nitrate stimulation for flowering. The ultimate goal is to develop a simple yet reliable diagnostic test for effective application of this stimulator to manipulate mango production.

The protein profile of mango leaves, as generated by the technique of sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE), was selected for evaluation as a marker system. The objective is to identify developmental-physiological stage-specific protein(s) and use them as molecular markers or indicators to time the application of potassium nitrate for flower induction.

Pilot experiments have been carried out to find if the protein profiles of mango leaves at different developmental stages show distinction in their polypeptide species. A procedure was established to extract total protein from mango leaves using a buffer containing 0.05M Na phosphate buffer, pH 7.5, 0.1M NaCl, 2 percent 2-mercaptoethanol and 1 percent SDS. The total proteins from leaves of three developmental stages were then extracted and analyzed by SDS-PAGE. Results indicate that distinct protein species can be detected in leaves at different developmental stages.

To improve the resolution of proteins, a two-dimensional gel electrophoresis procedure was established for mango leaf proteins. Total leaf protein was prepared by extracting leaf acetone powder with 50mM Tris buffer, pH 6.8, containing 2% SDS and 2mM EDTA. The leaf proteins were first separated by isoelectric focusing (IEF) (pH range 4.5-6.5) and then by SDS-PAGE. Results reveal that many proteins differing in charge as well as size can be detected by this technique. Use of silver instead of Coomassie staining can further enhance the number of detectable proteins, but the background of the gel is higher. This 2-D gel system was applied to analyze the proteins of 2-, 8-, and 13-week-old leaves. Results reveal that although most of the proteins are common to these leaves, there are proteins specific to each of the developmental stages.

Finally, we explored the use of an in vivo labeling technique to further enhance the sensitivity of protein detection. Freshly harvested leaves were incubated with 35[S] methionine for one hour before their proteins were extracted. The radioactive proteins were then separated by 2-D gel electrophoresis and detected by autoradiography. Figure 1 shows the labeled protein profile of a 10-week-old mango leaf; many proteins can be clearly detected and identified in the autoradiogram. When this technique was used to analyze the leaf protein profiles of 3-, 13-, and 20-week-old leaves, distinct proteins, qualitatively and/or quantitatively, specific or characteristic for each of the leaf ages, can be identified (Figure 2).

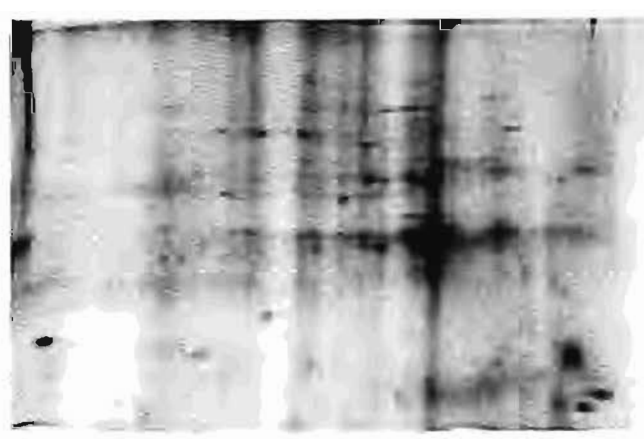

Figure 1. Two-dimensional gel electrophoresis of in vivo labeled mango leaf proteins (horizontal separation by IEF, vertical separation by SDS-PAGE).

In summary, we have developed a molecular marking system, which involves 2-D gel electrophoresis and in vivo protein labeling techniques, for mango leaf proteins. It has high resolution and sensitivity in detecting mango leaf proteins. Using this system, proteins specific to leaf ages can be identified. Further development and extension of this system to establish a diagnostic test for effective application of potassium nitrate to manipulate mango production appears promising.

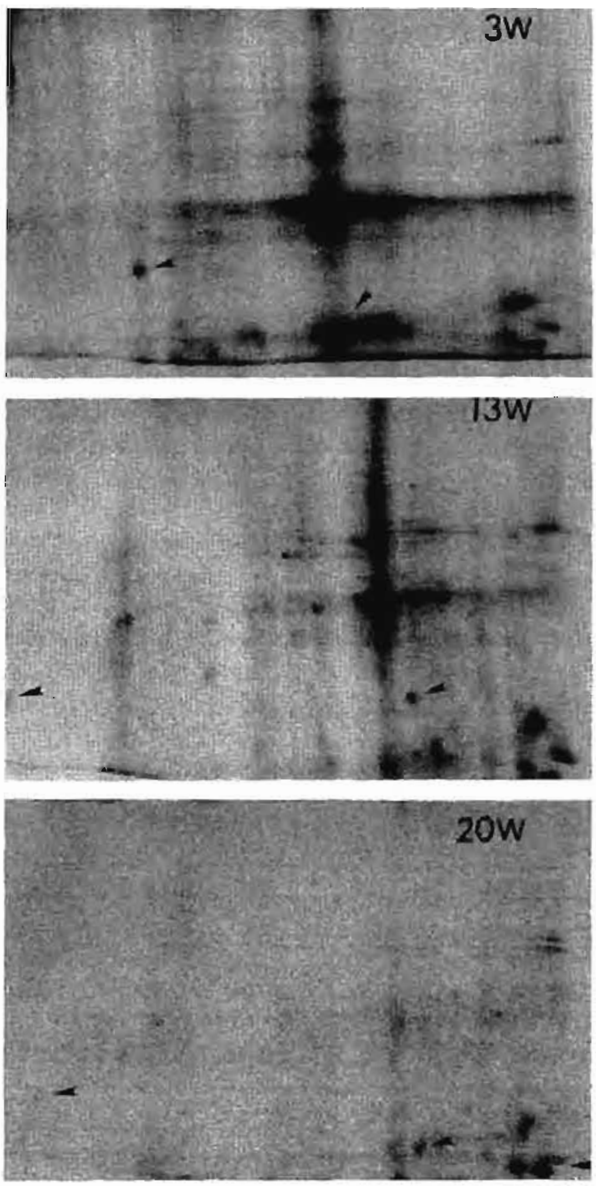

Figure 2. Two-dimensional gel electrophoresis of in vivo labeled proteins of 3-, 13-, and 20-week-old mango leaves (horizontal separation by IEF, vertical separation by SDF-PAGE).

GROWING MANGOS IN HAWAII: A SMALL ORCHARD GROWER'S PERSPECTIVE

Warren Yee
Waianae

It has been about 16 years since I retired from the University of Hawaii as a fruit and nut extension specialist. Since then I have been growing mangos for the local market. I had dealt with the subject of mango growing for so long, I wanted to see if I could make a profit doing it. I have always told people that if it were done right, you can make some money growing mangos, and if you were to go into the mango business, the best thing to do would be to plant something that your competition does not have.

I had hoped to get a really good piece of land, flat and easy to cultivate with no rocks, good soil, and a stream to save money on water. What I got was four acres of subsoil good for taro paddy, which cracks when it dries out. It has been a challenge to see whether mangos can grow under such soil conditions. It has seemed to work out. If you put a lot of water on, the cracks close up. I tried to increase the soil organic matter by letting the grass grow tall in my field to make a mulch for the soil during the hot, dry summer months. It helped, but when you have a dry spell in Waianae, nothing can stop the cracking.

When I started, I did not know what variety of mango I wanted. I did know that I should grow a late variety, because the market was flooded during the main season, and it would be difficult to sell during that time. So I dropped out of the 'Haden' field, leaving that to my brother Wilbert on Maui. I had to choose between 'Kent', 'Keitt', and 'Brooks Late', which I thought would likely come out after the 'Haden' crop. I chose 'Keitt' because in 1946 when I was stationed in Orlando, Florida, I had seen a beautiful 'Keitt' tree growing in a yard, with nicely colored mangos on it.

What you see in Florida and what you see here, in the same variety, can be very different. When I brought my first mangos to the market, nobody knew what a green 'Keitt' was. I labeled my mangos with my brand, and brought them to a retail outlet when I had fruits, to see if it would move or not. It was very slow catching on. Nevertheless, I have now marketed green 'Keitt' mangos here for more than a decade, and 'Keitt' has established itself as a good quality mango.

I planted other varieties to see how they would do in Waianae. I planted 'St. Francis', or what they call 'Francine', from scions I obtained from Dr. Campbell in Florida. I planted 'Carrie', 'Palmer', 'Parvin', 'Early Gold', 'Zill', 'Kent', 'Brooks Late', 'Sensation', and 'Irwin', some of the Hawaii varieties like 'Pope', 'Ah Ping', 'Waianae Beauty', and 'Pirie', and more recently 'Exel', 'Rapoza', 'Manzanillo', 'Wong', 'Fukuda', 'Tommy Atkins', and 'Glen'.

The problems with growing mangos in Waianae are probably similar to other areas. You have a long time before you can pick the first fruits, and that is where a lot of people get discouraged. It took me four to five years before I could produce fruits to see how they did in Waianae, how the coloring came out. I was a little disappointed, because they did not look as nice as in Florida. I have tried to fertilize to improve the color, and it may have helped.

I had worked very closely with Dr. Henry Nakasone and thought that during the early years it might be good to grow his 'Waimanalo' papaya cultivar between the mango trees. But my dark gray soil is poorly drained, which is not very good for papayas after a heavy rain. That idea might be good for growers with better soils. Intercropping with some short-term fruit or vegetable crops would be helpful during the orchard establishment phase.

I heard about using potassium nitrate and thought it might be useful to eliminate the erratic production of the 'Haden' mango. I also tried it on 'Keitt' and some of the varieties I grow a few of, like 'Waianae Beauty' and 'Wong'. I found that it works. I settled on using 10 lb of potassium nitrate in 100 gal of water. When I spray now, I spray the whole orchard. I started spraying in September, October, November, and December. Before I spray I observe whether most of the shoots are mature. Potassium nitrate works for me on 'Haden' mango during November. If I spray before then, it does not work, and if I spray later than January or February, it also does not work. If my first spray in November has no effect, I repeat it before the end of December. I have also seen that 'Exel' sprayed with potassium nitrate can come into production as early as two years after planting, if you want it to. I have about six young 'Tommy Atkins' trees and can get them to flower with potassium nitrate by spraying every two or three weeks.

My production records are not as good as I would like them to be, but they indicate a fairly steady level of production from year to year. From my yield records, I estimate that if you do a fairly good job you should be able to get about 15,000 pounds per acre from 'Keitt'. I don't have enough trees to estimate yields for the other varieties.

Although the mango weevil is a major problem affecting export of fresh mangos to the U.S. mainland, it has not been a production or marketing problem in Hawaii. In ten years of marketing, I can recall only two incidents when customers have returned mangos because of mango weevil damage. My brother, who has been growing mangos since 1943, says that the best way to keep weevils down is to feed your seeds and surplus mangos to the hogs and cattle.

I do some of my own marketing, and I have wholesalers who help me with most of my crop. I like to have two or three wholesalers to give my fruits to so I can compare the prices they give me and make sure I get about the same price. I deliver to some retailers. Marketing mangos in July and August is terrible, with the prices so low, but I follow the trend and accept what they give me at the time.

I attended the 4th International Mango Symposium in Florida last July and was impressed by the large number of countries that were growing mangos and wanting to ship to the U.S. I was also surprised that the Mexicans were growing some of our varieties such as 'Momi K', 'Ah Ping', 'Gouveia', 'Joe Welch', and 'Pope'. They seemed to be impressed by the 'Ah Ping'. I had grown 'Ah Ping', and although I think it is a beautiful mango in appearance, I prefer mangos that are stronger in flavor, so I cut them down.

Different people have different tastes. Mr. Uyeda, who is a nurseryman, sells more plants of 'White Pirie' than he sells 'Haden'. That may be one of our problems, that home gardeners are buying a lot of trees, planting them, and bringing their fruits to the market. I don't blame them; I would do the same thing if I were them.

The possibility of organizing a mango growers' group in Hawaii was mentioned earlier. I like the idea, and we should think about that. We are a small group, but we can have a larger voice if we speak together. While on the University staff, I worked with many of the industry organizations, such as the macadamia, banana, and papaya associations, and I have seen that the benefits of being organized are tremendous. For example, we got the legislature to allow a six-year exemption on taxes on lands going into macadamia and other tree crops (including mango) that take a long time to get into production. That was accomplished by the Hawaii Macadamia Producers Association. Another thing they did was to ask for a high-elevation macadamia selection trial, and they got it by working with the state legislators. We might want to get a nucleus started to move toward our goals. We may not get irradiation approved right away, but maybe we can get it approved sometime in the future if that is what we want.

Q: Does anthracnose bother your 'Exel'?

A: I spray Benlate and when I feel it is time for a change I spray tribasic copper.

Q: Is the mango midge a problem for you?

A: It wiped me out one year.

GROWING MANGOS IN HAWAII: A CORPORATE GROWER'S PERSPECTIVE

Steve Kai
Ka'u Agribusiness Co., Inc.

C. Brewer and Company's interest in diversified crop research dates back to the mid-1950s, when then-president Boyd MacNaughton organized a committee to find alternative crops for non-sugar lands in the Ka'u and Hilo coast areas. Emphasis was in the Ka'u area, where Brewer controlled over 200,000 acres at that time. The criteria for selection of possible crops was quite modest. The requirements were low need for hand labor, and a gross return of $500 per acre. A total of 16 different crops were tested, and seven were considered to have some commercial potential. Of these seven crops, macadamia and guava were the crops that became commercial ventures for Brewer. Mango was considered potentially profitable if the problems of fruit flies and the mango seed weevil could be solved. The local market was thought to be insignificant at that time.

More recently, with the continuing economic pressures facing the sugar industry, we at C. Brewer are continuing the efforts of crop diversification. Macadamia plantings on marginal sugar lands will result in a more stable economic base in the Ka'u and Hilo areas. The orange and mango test plantings at Ka'u are the latest efforts of our crop diversification strategies.

Changing demographics in the local market and the potentials of newer foreign markets revived our interest in mangos as an economically viable crop. The luxury hotels whose clientele is willing to pay top dollar for tropical fruits, the increasing number of condo and apartment dwellers who do not have a mango tree in their yard, and the increasing emphasis on health and wellness have, we feel, contributed to a very different local market than was perceived 20 years ago. In addition, the opening of foreign markets is considered essential for the success of our venture.

Our project is located at 200 feet elevation in the Palima area below the town of Pahala. The project site has an annual rainfall of 10-20 inches. The plantings are on pahoehoe lava overlain with 2-4 feet of mill waste-water deposits. The land was formerly used for grazing. Those of you who are familiar with the Ka'u area know that the major limiting factor is the lack of rainfall and irrigation sources. What we are presently doing is utilizing mill waste water for irrigation, a resource that has never been tapped before. We use settling ponds to remove most of the soil, and micro-sprinklers to minimize clogging of the emitters.

We presently have 5 tree-acres planted using a 10 x 8 foot spacing, a very high density of 545 trees per acre. The plantings were installed in 1992 and growth has been excellent, so far. Because of windy conditions at the site, windbreaks are placed at 250-foot intervals.

Variety selection for our project was based on several criteria, including quality, yield, time of predominant fruiting, and shelf life. The varieties included are 'Keitt', 'Pope', 'Exel', 'Brooks', 'Zill', 'Manzanillo', 'Pirie', and 'Rapoza'. Additional plantings will include 'Haden', 'Ruby', 'Momi K', 'Joe Welch', and 'Ah Ping'.

Pruning and management of these extremely high density plantings are subjects we need to learn a lot about. Controlling time of flowering and fruiting, we feel, is essential to marketing success. We are low on the learning curve at this time. Manipulation of irrigation, use of growth regulators, and pruning are all methods we hope to use. Nutrition, irrigation, and pest control are other subjects we need to learn about. Research is ongoing to help answer these questions.

Disinfestation, processing, and postharvest handling are obviously areas of interest to us.

I feel it is fair to conclude that we at Ka'u Agribusiness have a lot more to learn about all aspects of this business. However, we are very serious about making this a successful venture. We would like to thank CTAHR for sponsoring this conference and for all the help that Mike Nagao, Mel Nishina, Phil Ito, and others have given us.

THE MANGO INDUSTRY IN THE AMERICAS

Tom Davenport
Department of Horticulture
University of Florida

I will present a brief overview of production in Florida, some data on production in South and Central America, and some remarks on production in Mexico and Central America.

We had more than 2,000 acres of mangos in south Florida the day before Hurricane Andrew. The hurricane destroyed about 60 percent of the trees. Many are still dying as a result of the storm, so the final toll won't be known for some time. About 60 to 70 percent of these were 'Tommy Atkins', with the balance composed primarily of 'Keitt' and 'Van Dyke'. The age of groves broadly ranges from about three years to more than 40 years old. In general, the young growers are rather pessimistic about rebuilding a Florida mango industry in the face of overwhelming amounts of fruit being imported from Mexico. Other sources of income are being considered, including sugar apple, carambola, lychee, vegetable crops, and tract homes. Urban sprawl is taking over many areas suitable for mango production.

Many orchards in Central America are less than four years old. Much of that acreage is in 'Tommy Atkins'. Because they were advised that it is our best seller (which, in fact, it is in the U.S.), and it is an excellent shipper, they elected to plant many acres in this cultivar. Unfortunately, it does not perform as well in the tropics, particularly with regard to flowering and manipulation of flowering with KNO_3. It is a cultivar which was originally selected in the South Florida subtropics. It flowers much better in Florida than in more tropical climates such as Central America, where night temperatures do not get low enough to promote flowering, particularly in the warm, coastal regions. Large-scale growers are considering topworking to more reliable cultivars.

Table 1 lists tropical American countries with 10,000 metric tons or more of production. Pre-hurricane Florida had the least production, with just over 1,000 hectares. Mexico is by far the largest producer, with over one million metric tons annually. Most of their export production, about 75 percent, is 'Tommy Atkins' and 'Haden', but they also export 'Keitt', 'Kent', 'Irwin', and 'Sensation'. The primary production for domestic use in Mexico is 'Manila'. Brazil is the next largest producer, but most of that is shipped to Europe. Mexico only exports about 5 percent of its production, mostly to the U.S. They have hot-water treatment facilities throughout the production areas, especially in the northern parts of the mango producing states.

Q: How do yields in Florida compare with other locations?

A: I think we are getting around 500 bushels per acre. This is not my specialty, and I don't keep these numbers in my head. You may be able to calculate comparative yields from the data in the table.

Q: Is Florida the only U.S. mainland state that produces mango?

A: Yes. There are a few acres in California, but that is not much in terms of production. In Florida, the growing area is limited to about 50 square miles located south and west of Miami. Most production in the Homestead area is on small orchards of 5-10 acres managed by retired people. J. R. Brooks & Sons packing house is doing a lot of importing these days from areas with USDA-approved treatment facilities, such as Haiti. Treatment facilities are being developed in Guatemala, Nicaragua, and Costa Rica for exporting mangos to the U.S.

Table 2 lists Tropical American countries producing less than 10,000 metric tons. Some of these figures may be questionable. Jamaica is trying to develop an export market. Most of their export production now goes to Europe, but they want to set up a treatment plant for exports to the U.S.

As an aside, one exciting prospect for the future is a hyperbaric storage system developed by Stanley Burg. He has a design for an aluminum, refrigerated, vacuum-storage unit that is light, portable, and costs about the same as a standard refrigerated container. Growers will be able to put this container near their production area and load it with fruit as it is harvested and graded. The container will maintain the fruit for about four months, with improved shelf life once removed. It

Table 1. Tropical American countries with 10,000 metric tons or more estimated annual production of mango

Country	Area (ha)	1990 production[z] (metric tons)	Commercial cultivars[y]
Brazil	36,490	415,000	Rs, Es, Ir, Hd, Ex, Rn, Sr, Tm, Vd, Pl, Kt, Ls
Colombia	3,000	30,000	Tm, Kt, Vd, Ir, Kn, Hd, Pl, Yl, Sf, Az
Costa Rica	5,000	12,500	Kt, Tm, Kn, Hd, Ls
Cuba	12,000	85,000	
Dominican Republic	18,000	150,000	Tm, Kt, Ir, Hd, Mf, Kn, Pl, Bn
Ecuador	4,300	35,000	Hd, Pl, Sn, Kt, Tm, Vd, Ed, Gl, Ls
Florida, USA	1,170	10,000	Tm, Kt, Vd, Kn, Hd, Pl, Zi, Sn, Pr, Sm, Fs
Guatemala	5,000	10,000	Tm, Hd, Kt, Ir, Mf, Kn, Zl, Pl, Vd, Ls
Haiti	36,000	300,000	Mf, Tm, Bp
Honduras	1,500	10,000	Hd, Tm, Kt, Kn, Ps, Ls
Mexico	109,700	1,122,000	Mn, Tm, Hd, Kn, Ls
Paraguay	2,700	19,000	
Peru	7,000	60,000	Hd, Kn, Kt, Tm, Ed, Ls
St. Lucia	6,500	46,000	Jl, Im, Gr
Venezuela	8,500	127,000	Hd, Tm, Sp, Fd, Pl, Gl, Bc, Hl

[z]Source: FAO production yearbook, Vol. 44, 1990, except for Mexico, which is a 1992 estimate from a private source. Table from C. Campbell and C. W. Campbell, poster presented at the 4th Internatioal Mango Symposium. Central American acreage figures from J. R. Mondonedo, PROEXAG, Guatemala.

[y]Cultivar key: Azucar (Az), Banilejo (Bn), Baptista (Bp), Bocado (Bc), Espada (Es), Edward (Ed), Extrema (Ex), Fascell (Fs), Ford (Fd), Glenn (Gl), Graham (Gr), Haden (Hd), Hilacha (Hl), Imperial (Im), Irwin (Ir), Julie (Jl), Keitt (Kt), Kent (Kn), "Local selections" (Ls), Madame Francis (Mf), Manila (Mn), Palmer (Pl), Parvin (Pr), Pespira (Ps), Rosa (Rs), Rosinha (Rn), Sensation (Sn), Springfels (Sp), Smith (Sm), Sufaida (Sf), Supresa (Sr), Tommy Atkins (Tm), Van Dyke (Vd), Yulima (Yl), Zill (Zl).

is quite remarkable. They are building the prototype and trying to raise funds to get into full production.

Mexico.

Most mango production in Mexico and Central America is on alluvial plains adjacent to mountain ranges bordering the Pacific Ocean. Orchards in Mexico are often interplanted with other crops, such as coconut palm. The trees get little or no fertilizer, although they are irrigated, usually by furrow. The polyembryonic cultivar 'Manila' first comes into production around February in the southernmost region of Chiapas, using potassium nitrate to simulate flowering. Fruits from this area are not available for export due to the Medfly quarantine. Trees become responsive later and later the further north they are planted, and even if the spray concentration is increased, leaf burning results with no inducing effect. For example, KNO_3 stimulates flowering in October in Chiapas but not in Colima (18°N), where it isn't until late November when they begin to get a response to spraying. Four percent solutions of KNO_3 or two percent solutions of ammonium nitrate are typically used. Increasing amounts of chemical are needed to obtain a response from about 20°N to 23°N. Trees in latitudes north of 23° have no predictable response, regardless of spray concentration. I don't have an explanation for that. In Mexico, tip burn is used as an indication that they sprayed the tree effectively, but that is not so in other areas; it may be because of the dry climate in Mexico.

Table 2. Tropical American countries with less than 10,000 metric tons estimated annual production of mango fruit.

Country	Area (ha)	1990 production[z] (metric tons)	Commercial cultivars[y]
Antigua	150	1,000	Jl, Gr, Im
Argentina	280	2,000	
Belize	1,500	1,000	Tm, Kt
Bolivia	850	6,000	Ls
Dominica	400	4,000	Jl, Im, Gr
El Salvador	150	1,200	Ls
Grenada	280	2,000	Jl, Gr
Guadeloupe	280	2,000	Ls
Guayana	420	3,000	Ls
Jamaica	440	4,000	Jl, Bm, Tm, Kt, Pl, Hd, Vd
Martinique	110	1,000	Ls
Nicaragua	1,400	5,000	Hd, Tm, Kt, Kn
Panama	570	4,000	Jl, Fr, Hd, Kn, Zl, Fc
Puerto Rico	650	6,000	My, Mz, Cb, Pt, Kt, Pl, Dh, Pr, Ir, Tm, Kn, Os, Sp
St. Vincent	280	2,000	Jl, Im, Gr

[z]Source: FAO production yearbook, Vol.44, 1990. Table from C. Campbell and C.W. Campbell poster presented at the 4th Internatioal Mango Symposium. Central American acreage figures from J. R. Mondonedo, PROEXAG, Guatemala.

[y]Cultivar key: Bombay (Bm), Cubano (Cb), Davis-Haden (Dh), Francisque (Fr), Graham (Gr), Haden (Hd), Imperial (Im), Irwin (Ir), Julie (Jl), Keitt (Kt), Kent (Kn), "Local selections" (Ls), Mayaquezan (My), Manzano (Mz), Osteen (0s), Palmer (PI), Parvin (Pr), Pasote (Pt), Springfels (Sp), Tommy Atkins (Tm), Van Dyke (Vd), Zill (Zl).

Q: Why do they use the hot-water bath?

A: They must meet USDA quarantine requirements for fruit fly control. They do not have the seed weevil, but they do have the Mexican fruit fly. The plants are all monitored by USDA personnel; accurate records are kept, and the process is tightly controlled. The fruits go through a barrier to keep flies out of the packing area. The fruits are either submerged in batches or run under the water in a continuous-chain conveyor for the prescribed amount of time. The fruits slowly cool down before transfer to a cold room prior to loading on trucks. Trucks back up to the loading doors with sealed edges to prevent entry of flies into the truck.

One problem associated with the hot-water treatment is shrinking of the fruit shoulders accompanied by white, pulpy voids inside the fruit. This appears to be related to harvest of immature fruits. The Mexicans tend to ship a lot of immature fruit. Florida learned long ago that shipping immature fruit, or fruit of less than good quality, ruins the market, especially if it is a developing market.

Central America.

Guatemala has about 5,000 acres in mango, one-third of which are under four years old. Most of that is along the coast in the Chiquimula area. Zacapa is another area of production. It is a dry area with water available for irrigation.

Honduras has about 1,500 acres, also with one-third of the trees under four years old. Much of the production, by necessity, is near the main highway through the country, so that it can get to a port for export shipment.

El Salvador has only about 150 acres in production, mostly on small farms around San

Salvador.

Nicaragua has one area of production, San Francisco, along Lake Managua, a very dry area that requires irrigation. The planting is about 1,400 acres, but the company is in receivership.

Belize has limited production at Stan Creek, about 1,500 acres on humid, coastal land better suited for bananas. I think that company, too, is in receivership.

Costa Rica is vigorously working toward export to the U.S. Most of their production is in the area of Orotina and Guanacaste near Liberia, with several very large plantations, mostly in 'Haden' and 'Tommy Atkins'. They are doing an excellent job of production management. There is a lot of interest in mango production, with plenty of government support.

Q: Are there any plantings north of Miami?

A: There are no commercial plantings. Mangos do not do very well north of Miami because of periodic freezes.

Q: Do you know how the Mexicans are financing their large plantings?

A: The government is helping them, although I am not sure exactly how, or how extensive the assistance is. I think much of the growth in the Mexican mango industry has been due to the success of their exports. They get better prices than locally distributed fruit.

MARKET STATISTICS FOR MANGO

Stuart Nakamoto
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College of Tropical Agriculture and Human Resources
University of Hawaii at Manoa

This is a graphical presentation of market information that is available for mangos. Statistics are presented for Hawaii, the U.S. market, and some foreign markets. Two points are highlighted: first, it is difficult to get good market statistics for mango, and second, a pattern emerging from the available data is the tendency to import mangos from nearby producers.

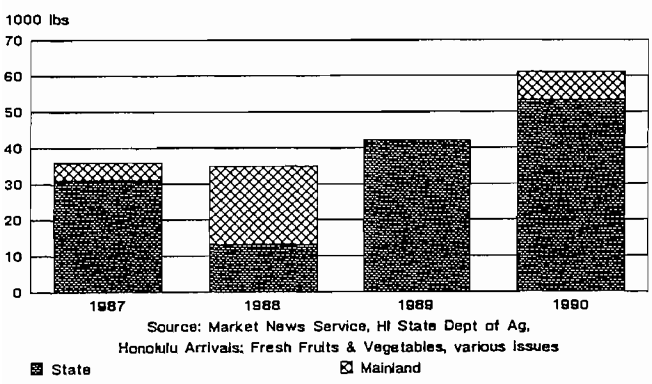

Figure 1. Arrivals of mango in Honolulu, 1987-1990.

Most of the mango consumed in Hawaii comes from backyards of friends and family. Very little passes through the marketplace, and even less through wholesale markets. Figure 1 shows the volume reported by Honolulu wholesalers for recent years. In 1990, these arrivals were a little more than 60,000 pounds. No arrivals were reported for 1991 and 1992. Depending on the year, the amount coming from the U.S. mainland varies. Prices wholesalers charge their customers typically fall in the 35-45¢/lb range, and as for timing, mangos are available during mango season. This is June to October, but especially July and August.

There is not much more information from Hawaii. Figures 2a and 2b help point out why. In Figure 2a, again looking at unloads, we see how mango compares to some other fruits. Figure 2b puts this in even better perspective. The relative size of mango unloads compared to other fruits and vegetables makes it difficult to gather data continuously, especially with the limited resources to do the work.

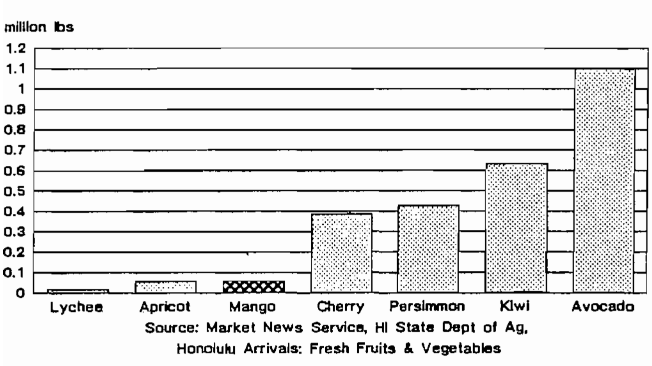

Figure 2a. 1990 Honolulu unloads: Relative importance of selected fruits.

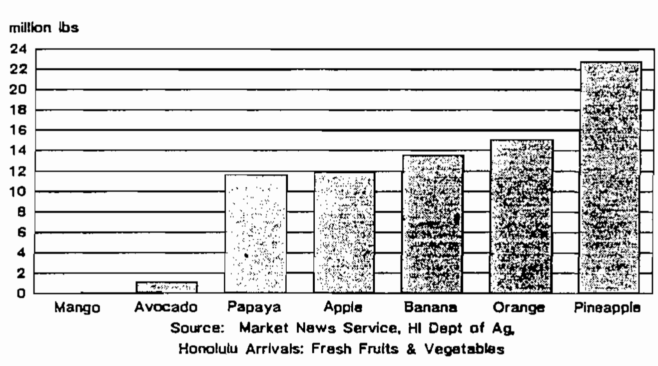

Figure 2b. 1990 Honolulu unloads: Relative importance of selected fruits.

Moving on to the U.S. market: in Figure 4, we see fresh mango imports in the past decade. Notice that from 1989 mangos are combined with guavas and mangosteens. This reflects data problems at the national level (guava producers are also unhappy about the data being aggregated). Note that in Figure 4: (1) data are for only fresh product (203 million lb in 1991); there were also imports of puree (23 million lb), frozen product (0.9 million lbs. and dried product (0.5 million lb); and (2) statistics are for imports. Other U.S. states (notably Florida and California) also produce mangos.

The largest supplier of fresh imports to the U.S. is Mexico (Figure 5). In Figure 6, the prices for Mexican imports follow a consistent pattern. They start high in the beginning of the season, then decline as supplies increase and other fruits come into season.

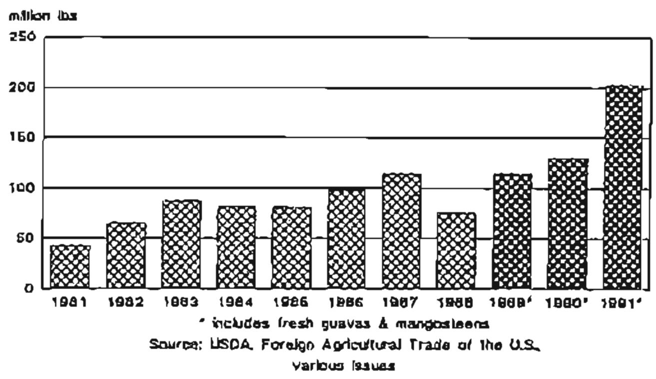

Figure 3. U.S. imports of fresh mangos, 1981-1991.

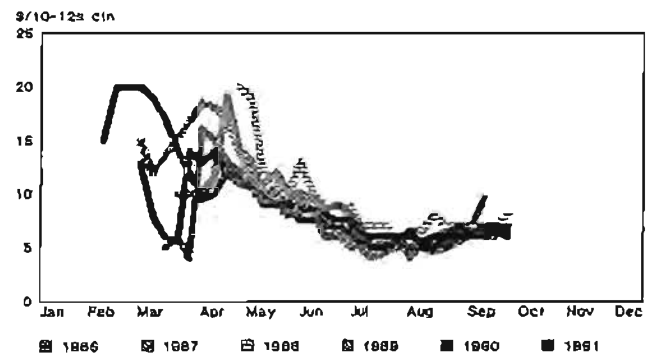

Figure 5. Weekly wholesale price for Mexican mangos in Los Angeles.

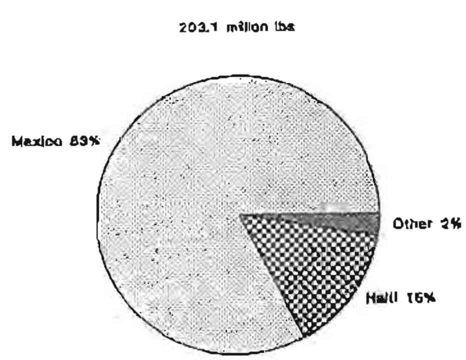

Figure 4. U.S. imports of fresh mangos, guavas, and mangosteens by major suppliers, 1991.

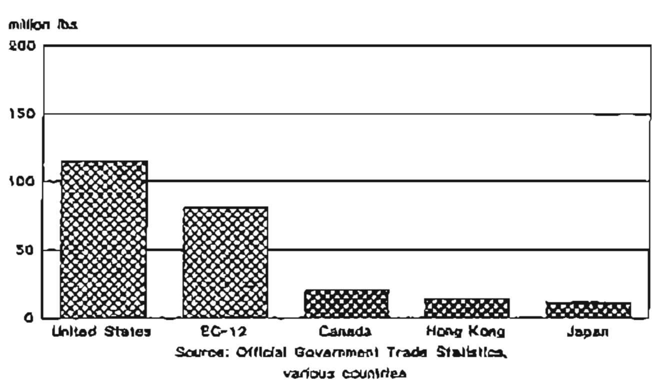

Figure 6. Selected import markets for mango, 1989.

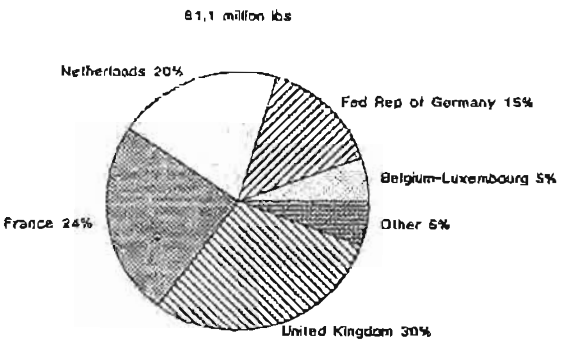

Figure 7. EC-12 imports of fresh and dried mango, guava, and mangosteen by major importers, 1989.

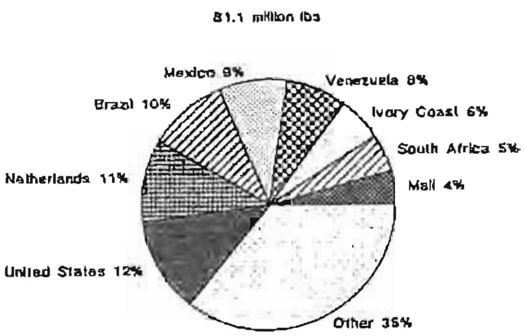

Figure 8. EC-12 imports of fresh and dried mango, guava, and mangosteen by major suppliers, 1989.

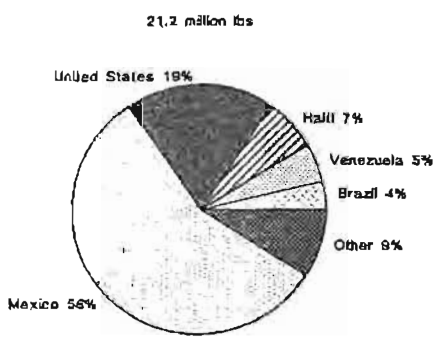

Figure 9. Canandian imports of fresh mangos, guavas, and mangosteens by major suppliers, 1990.

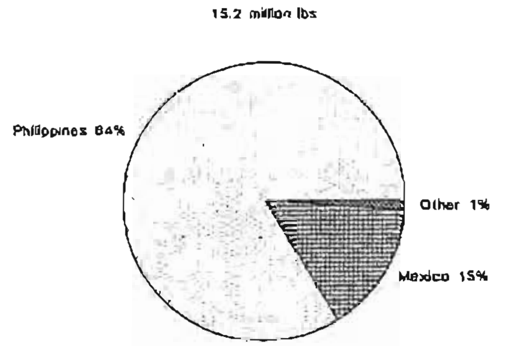

Figure 10. Japan imports of fresh mangos by major suppliers, 1991.

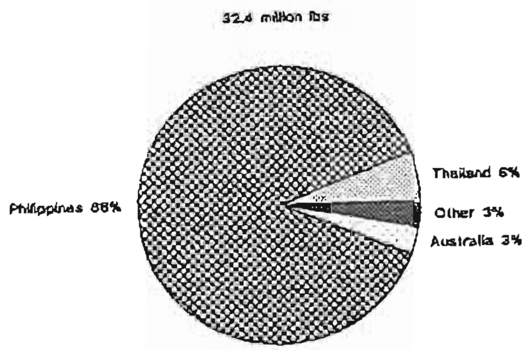

Figure 11. Hong Kong imports of fresh mangos by major suppliers, 1991.

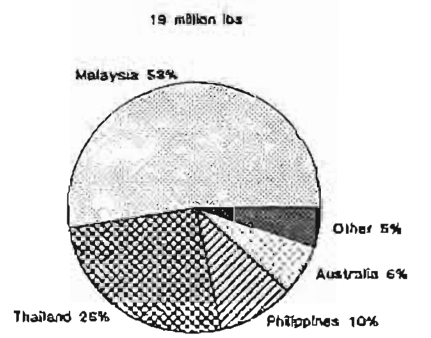

Figure 12. Singapore imports of fresh and dried avocado, mango, guava, and mangosteen by major suppliers, 1991.

Figure 7 compares mango imports for the most recent year, 1989, where data are available for all the countries being considered. A mix of products is being compared. Canada, Hong Kong, and Japan report fresh mango. The U.S. figure is for fresh mango, but includes guava and mangosteen. The EC-12 figure is for fresh and dried mangos, guavas, and mangosteen.

The U.S. is probably still the largest importer. U.S. imports have grown from around the 120 million lbs. reported in Figure 7 to over 200 million lbs. in 1991. The European Community as a group is second, with 81 million lbs. Figure 8 gives a further breakdown of Europe by country. Immigration is one reason for mango's popularity in many countries, so the major importers reflect populations that come from mango producing areas. The Netherlands has a large share because it re-exports product.

The role of the Netherlands is evident in Figure 9, which divides the European pie according to supplier. There is no dominant supplier, and a lot of smaller suppliers make up the 35% "Other". For 1989, the U.S. had the largest share with about 10 million lbs.

Similar to the U.S. case, Mexico is the largest supplier to the Canadian market (Figure 10). The U.S. share is about 4 million lbs. of the 21 million lb. total.

Moving across the Pacific, Japan's market is dominated by the Philippines with Mexico also having a large share (Figure 11). Hong Kong (32 million lbs.) imported twice as much as Japan (15 million lbs.), in part because Hong Kong is a major re-exporter (Figure 12). Again, the Philippines is the main source, with Thailand and Australia also having shares.

At first glance, market shares seem quite different in Singapore, but Figure 13 includes many other products. This leads back to one of our conclusions: it is difficult to get data on mango market and the data that is available often includes other products. With this in mind, the major observation from the information presented here is that markets seem to be supplied by neighboring producers. So, the Philippines is a major supplier for Japan and Hong Kong, and Mexico is dominant in North America. Europe seems to have no close neighbors who grow mango, so is supplied by many countries. This applies even in Hawaii, where backyards and neighbors provide the fruit.

Q: I noticed that mango imports to Hawaii are very small compared to many other fruits that are imported. Does year-round availability of fruits such as apples, bananas, and pineapples influence the overall size of the market for a fruit in Hawaii?

A: I think the bigger impact on the amount of mango imports is that so many people in Hawaii have dooryard mango trees.

Q: What about the tourist market for mangos? Shouldn't that be tremendous?

A: It could be large, but we get our data from the wholesalers and not from the end users, so we don't know how much is sold to hotels and restaurants.

Q: Papayas started out as a backyard crop, but now they have a marketing order, which has made a major difference.

A: The structure of the market and the organization of the people involved does contribute.

Q: Do you think that organizing the mango growers in Hawaii into some kind of cohesive unit would help the industry develop?

A: Producers typically don't have the same amount of influence as the buyers; producers are much smaller. So organizing is one of the ways that producers can deal more effectively in the market.

HAWAII GRADING STANDARDS FOR MANGOS

Samuel Camp and Isabelo Palalay
Commodities Branch
Hawaii Department of Agriculture

Throughout this conference you have heard speakers stress the need to maintain quality in the mangos that you market. Grade standards, certification, and enforcement are some of the ways the Department of Agriculture can assist the industry in assuring that quality fruit reaches the market.

The Commodities Branch establishes grade standards in cooperation with the industry, enforces grade labeling and minimum export requirements desired by the industry, and provides certification of commodities on a fee-for-service basis when requested by a financially interested party. The branch can perform these functions for both fresh and processed products. Because the commercial market for Hawaii-grown mangos has not been developed, you have probably had little contact with our program.

Let's look at why we have quality and condition grades:

1. They establish standards that are widely recognized.
2. They serve as the guidelines for communication between buyers and sellers of a product.
3. They allow the sale of goods by sample or description, sight unseen.
4. They improve the efficiency of the marketing system.
5. They allow for more meaningful price quotations, because there is a more direct relationship of price to quality.
6. They allow consolidation of products for shipment to reduce transportation and handling costs.
7. They may increase consumer demand based on greater consumer confidence in the product due to quality consistency.
8. They contribute to faster and more satisfactory settlement of loss or damage claims.
9. They permit consumers to communicate their preferences back to the producers.
10. They may serve as a standard for regulatory action if industry desires.

The standards for grades of Hawaii-grown mangos were first adopted in 1954 and have not changed substantially since then. There have never been any grade standards adopted for mango products.

Internationally there has recently been action taken by the Codex Alimentarius Commission, FAO–WHO, to establish international standards for mangos. These standards may have an effect on the market when the North American Free Trade Agreement takes effect. The September 1991 draft of these standards and the May 1992 amendment are given in Appendix 1. We believe that these are the latest proposals and that they have not yet been adopted. The current Hawaii grade standards for mangos are given in Appendix 2.

In developing the requirements for grade standards the state takes its guidance from the wishes of the majority of the industry. The industry includes not only the growers and the handlers but also the wholesalers, retailers, and consumers.

The following steps are necessary to develop or update standards:

1. The industry submits a request either to develop or update grade standards to the Department of Agriculture. The DOA may also query the industry to see if they desire changes, if no request for changes have come in for an extended period of time.
2. The industry should appoint a standardization committee to work with the DOA staff to avoid miscommunication, confusion, and duplication of effort. Working through a standardization committee has, in the past, proven to be the most effective procedure.
3. The DOA meets with the standardization committee or industry representatives to draft tentative standards. This step may take an extended period of time, depending on the level of advanced preparation by the standardization committee.
4. The tentative standards are field tested to evaluate their effectiveness and determine whether they are practical. This step may be eliminated if minor revisions are being made or timing is critical.

5. If the tests show positive results, the proposed standards are presented to all known members of the industry for their review, comments, and indication of acceptance or rejection.

6. If the majority of the industry indicates approval of the standards as proposed, the State of Hawaii administrative procedures are followed to adopt the standards as rules. This involves preliminary Board of Agriculture and Governor's approval, advertisement, public hearings with testimony, final BOA and Governor's approval, and filing with the Office of the Lieutenant Governor. This last step can take up to six months.

An important point to remember is that after the grade standards have been adopted as rules they have the force of law and cannot be changed without going through the formal procedures. Because of this, the implications of any change to grades must be thoroughly evaluated before the change is made.

The Hawaii grade standards for mangos have not been extensively used, because there has not been a large commercial market for mangos. If the industry feels that there have been substantial changes in the varieties of fruit marketed or that changes are needed to expand the potential for growth in the local or export market, then there is a need to investigate revising the standards. It must be remembered that grade standards should set the basis for quality and condition; they should not try to solve specific marketing problems.

If this is the desire of the industry, then a standards committee should be set up to look at the existing grade standards and the minimum export requirements for mangos. This committee should have a serious commitment to reviewing the grade standards in a reasonable length of time. The committee should be prepared to make recommendations for the basic requirements that meet the needs of the whole industry under the current production methodology, quarantine requirements, packing, transportation, and marketing practices, and the markets served. The committee also has to recognize the regulatory viewpoint that grade standards need to be easily enforceable without undue cost to the industry through lost time, cost of inspection, or product destruction.

Administrative Procedures for Adopting Standards

1. The standards are drafted in Ramseyer and standard formats.

2. The language of the proposed standards is reviewed by the Office of the Attorney General and the format is reviewed by the Revisor of Statutes.

3. Preliminary approval is obtained from the Board of Agriculture to conduct public hearings on the proposed standards.

4. Approval is obtained from the Governor to conduct public hearings on the proposed standards.

5. A notice of public hearing is prepared, approved by the Office of the Attorney General, and published in the newspapers of all affected counties.

6. The public hearings are held no sooner than 30 days after the publication of the notice of public hearing. Verbal and written testimonies are accepted at the hearings. Written testimony may be submitted for at least five days after the last public hearing.

7. Following the hearing, the hearing officer submits a report to the Board of Agriculture. This report includes all verbal and written testimony and recommendations on the action to be taken by the board.

8. If the Board of Agriculture approves adoption of the standards without substantive changes, they are submitted to the Governor for approval and signature. If substantive changes are proposed as a result of the public hearing, a new notice of public hearing must be published and another series of hearings must be held.

9. The rules are filed with the Office of the Lieutenant Governor and become effective 10 days later.

Length of Time to Amend Rules

It takes at least 180 days from the time that the workable language for the grade standard is finalized.

The time may be increased depending on time delays in review at the Office of the Attorney General or at the Governor's office. Delays may also arise if the timing is not right to meet the monthly Board of Agriculture meeting.

Notice of Hearing and Public Hearing

The notice of hearing is published in a newspaper of general circulation (*Star Bulletin* or *The Honolulu Advertiser*) and in a paper in each county. If the commodity is of particular importance to Molokai or Kona subdistricts, the notice may also be published in their local newspapers.

Public hearings are held in each county affected by the rule change. (Honolulu, Kahului/Wailuku, Lihue, and Hilo). If the commodity is important to Molokai or Kona, hearings are also held in those areas.

The hearings are usually held in the evening for the convenience of the working farmer.

Q: Is there a federal U.S. standard for mangos?

A: No. The only one I could find is the international standard from Codex. Dr. Davenport tells me that in Florida there is an industry agreement about what to pack, and in Mexico there are no established standards. We may have the only mango standards other than the Codex standards. The U.S. could establish standards for mangos imported from other countries. USDA recognizes our standards as the standards for Hawaii mangos. Other states could ask other countries to ship mangos that conform to the Hawaii standards; they couldn't call them "Hawaii No. 1," but they could ask them to meet the standards.

Q: I often see green mangos on sale in Chinatown. Would they be in the category "nongraded"?

A: They would be "off grade." It is not mandatory that you put the grade on the fruit, but if you use the grade, it must meet the grade. If you make no claim, it is up to the consumer to evaluate the product and decide if the price is right for what they are getting.

Q: Where does the DOA get involved with grading: in the field, on the shelf?

A: There is no mandatory grade labeling. We would assist the farmer by teaching how to grade the product if, for example, the grower was being asked to provide fruit meeting a certain standard. We would enter into an enforcement mode if the producer or wholesaler started to write the grade down on the box. If it didn't meet the grade, we could act against them for not labeling it properly. We would also enter into the transaction if the wholesaler had asked for a grade from the farmer and didn't think they were getting that grade; we would become the arbiter, and we charge for that. All our other activities are free, but if you ask for a certificate, we charge for that. If you are not shipping to stated grade standard, that certificate can be used to make a claim against you. Also, if you ship your mangos out of state and ship No. 2 mangos, we would stop you from doing that, because our minimum export standard is No. 1.

23-27 SEPT 1991

DRAFT WORLDWIDE CODEX STANDARD
FOR MANGOES
(At Step 8)

1. DEFINITION OF PRODUCE

This standard applies to commercial varieties of mangoes grown from *Mangifera indica* L. of the *Anacardiaceous* family to be supplied fresh to the consumer, after preparation and packaging. Mangoes for industrial processing are excluded. (1)

2. PROVISIONS CONCERNING QUALITY

2.1 Minimum Requirements

In all classes, subject to the special provisions for each class and the tolerances allowed, the mangoes must be:

- whole;
- firm;
- fresh in appearance;
- sound; produce affected by rotting or deterioration such as to make it unfit for consumption is excluded;
- clean, practically free from any visible foreign matter;
- free from black necrotic stains or trails;
- free from marked bruising;
- practically free from damage caused by pests;
- free from damage caused by low temperature;
- free from abnormal external moisture, excluding condensation following withdrawal from cold storage;
- free of any foreign smell and/or taste;
- sufficiently developed and display satisfactory ripeness;
- when a peduncle is present, it shall be no longer than 1.0 cm.

The development and condition of the mangoes must be such as to enable them to ensure a continuation of the maturation process until they reach the appropriate degree of maturity corresponding to the varietal characteristics, to withstand transport and handling, and to arrive in satisfactory condition at the place of destination.

In relation to the evolution of maturing, the colour may vary according to variety.

2.2 Classification

Mangoes are classified in three classes defined below:

2.2.1 "Extra Class"

Mangoes in this class must be of superior quality. They must be characteristic of the variety.

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(1) Governments, when indicating the acceptance of the Codex Standard for mango, should notify the Commission which provisions of the standard would be accepted for application at the point of import, and which provisions would be accepted for application at the point of export.

They must be free from defects with the exception of very slight superficial defects, provided that these do not affect the general appearance of the produce, the quality, the keeping quality and presentation in the package.

2.2.2 Class I

Mangoes in this class must be of good quality. They must be characteristic of the variety. However, the following slight defects may be allowed provided that these do no affect the general appearance of the produce, the quality, the keeping quality and presentation in the package:

- slight defects of shape;
- slight defects of the skin due to rubbing or sunburn, suberized stains due to resin exudation (elongated trails included) and healed bruises not exceeding 3, 4, 5 cm^2 for size groups A, B, C respectively.

2.2.3 Class II

This class includes mangoes which do not qualify for inclusion in the higher class, but satisfy the minimum requirements specified in Section 2.1 above.

The following defects may be allowed provided that the mangoes retain their essential characteristics as regards the quality, the keeping quality and presentation:

- defects of shape;
- defects of skin due to rubbing or sunburn, suberized stains due to resin exudation (elongated trails included) and healed bruises not exceeding 5, 6, 7 cm^2 for size groups A, B, C respectively.

In classes I and II, scattered suberized rusty lenticels, as well as yellowing of green varieties due to exposure to direct sunlight, not exceeding 30 percent of the surface and not showing any signs of necrosis are allowed.

3. PROVISIONS CONCERNING SIZING

Size is determined by the weight of the fruit. Mangoes are sized according to the following size groups:

Reference Letter	Weight in Grammes
A	200-350
B	351-550
C	551-800

The maximum permissible difference between fruit in the same package belonging to one of the above mentioned size groups shall be 75, 100 and 125 g. respectively.

The minimum weight of mangoes must not be less than 200 grammes.

4. PROVISIONS CONCERNING TOLERANCES

Tolerances in respect of quality and size shall be allowed in each package for produce not satisfying the requirements of the class indicated.

4.1 Quality Tolerances

4.1.1 "Extra Class"

Five percent of the number or weight of mangoes not satisfying the requirements of the class, but meeting those of class I or, exceptionally, coming within the tolerance of that class.

4.1.2 Class I

Ten percent by number or weight of mangoes not satisfying the requirements of the class, but meeting those of Class II or, exceptionally, coming within the tolerances of that class.

4.1.3 Class II

Ten percent by number or weight of mangoes satisfying neither the requirements of the class nor the minimum requirements, with the exception of fruit affected by rotting, marked bruising or any other deterioration rendering in unfit for consumption.

4.2 Size Tolerances

For reference letter A, 10 percent by number or weight of mangoes less than 200 grammes with a minimum weight of 180 grammes. For reference letter B, 10 percent by number or by weight of mangoes. For reference letter C, 10 percent by number or weight of mangoes greater than 800 grammes with a maximum weight of 925 grammes.

The 10 percent tolerance for off-size mangoes may vary above or below the weight range of the specified size group by one-half the difference between the sizes in the group.

5. PROVISIONS CONCERNING PRESENTATION

5.1 Uniformity

The contents of each package must be uniform and contain only mangoes of the same origin, variety, quality and size. The visible part of the contents of the package must be representative of the entire contents.

5.2 Packaging

Mangoes must be packed in such a way as to protect the produce properly.

The material used inside the packages must be new, clean, and of a quality such as to avoid causing any external or internal damage to the produce. The use of materials, particularly of paper or stamps bearing trade specifications, is allowed provided the printing or labelling has been done with non-toxic ink or glue.

Mangoes shall be packed in each container in compliance with the Code of Practice for Packaging and Transport of Tropical Fresh Fruits and Vegetables.

5.2.1 Description of Containers

The containers shall meet the quality, hygiene, ventilation and resistance characteristics to ensure suitable handling, shipping and preserving of the mango. Packages (or lot is product is presented in bulk) must be free of all foreign material and smell.

6. MARKING OR LABELLING

6.1 Containers destined for the final consumer:

In addition to the requirements of the Codex General Standard for the Labelling of Prepackaged Foods (CODEX STAN 1-1985) the following specific provisions apply.

6.1.1 Origin of the Produce

If the product is not visible, each package shall be labelled as to the name of the food and may be labelled as to the name of the variety.

6.2 Non retail containers

Each package must bear the following particulars, in letters grouped on the same side, legibly and indelibly marked and visible from the outside, or in the documents accompanying the shipment (2).

For products transported in bulk these particulars must appear on a document accompanying the goods.

6.2.1 Identification

Exporter, Packer and/or Dispatcher.

6.2.2 Nature of Produce

Name of produce if the contents are not visible from the outside.
Name of variety or commercial type (if applicable).

6.2.3 Origin of Produce

Country of Origin and optionally, district where grown or national, regional or local place name.

6.2.4 Commercial Identification

- Class
- Size (Reference letter or weight range)
- Number of units (optional)
- Net weight (optional).

6.2.5 Official Inspection Mark (optional)

7. CONTAMINANTS

7.1 Pesticide Residues

Produce shall comply with those maximum residue limits established by the Codex Committee on Pesticide Residues for this commodity (see CAC/VOL. XIII - Ed. 2, Supplements 1 and 2).

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(2) *Governments, when indicating their acceptance of this Codex Standard, should notify the Commission as to which provisions of this section apply.*

Plenary Meeting of the OECD Scheme for the Application of International Standards for Fruit and Vegetables. 46th Session, Paris, 25-27 May 1992

a) Draft Explanatory Brochure on the Standard for Mangoes

To improve comprehension in the last paragraph of the standard, referring to the definition of Class II, the Plenary Meeting agreed to propose a new text to the UN/ECE Secretariat for follow-up, namely:

"In Classes I and II, the following conditions are also allowed:

- scattered rusty lenticels;
- yellowing of green varieties due to exposure to direct sunlight, not exceeding 40 percent of the surface, excluding necrotic stains."

Furthermore, in order to harmonise presentation of the standards, the Meeting agreed to request that the paragraph on minimum weight be placed immediately after the sentence on sizing.

Hawaii Grading Standards for Mangos. Appendix 2: Description of the Hawaii Standard.

Hawaii Department of Agriculture
Marketing and Consumer Services Division
Commodities Branch

March 24, 1986

STANDARDS FOR HAWAII-GROWN MANGOES*

> This UNOFFICIAL COPY of standards for mangoes, rewritten for easy interpretation, is based on Chapter 4-41, Hawaii Administrative Rules, Standards for Fresh Fruits and Vegetables. The general provisions of this Chapter, summaries of standards for other fruits and vegetables, and official copies of the complete chapter are available in each county.

HAWAII FANCY (GRADE AA)	HAWAII NO. 1 (GRADE A)	HAWAII NO. 2 (GRADE B)
Basic Requirements	**Basic Requirements**	**Basic Requirements**
Single variety	Single variety	Single variety
Mature (1)	Mature (1)	Mature (1)
Not overripe (2)	Not overripe (2)	Not overripe (2)
Clean (3)	Clean (3)	Clean (3)
Well trimmed (4)	Well trimmed (4)	Well trimmed (4)
Well formed (5)	Fairly well formed (6)	Not badly misshapen (7)
Smooth (8)	Smooth (8)	Smooth (8)
Small seeded (9)	Small seeded (9)	Small seeded (9)
Free From	**Free From**	**Free From**
Anthracnose or other decay	Anthracnose or other decay	Decay (except anthracnose)
Wormholes	Wormholes	Wormholes
Insect stings (10)	Insect stings (10)	Insect stings (10)
Freezing injury	Freezing injury	Freezing injury
Bruises (11)	Bruises (11)	Bruises (11)
Cuts	Cuts	Cuts
Punctures	Punctures	Punctures
Cracks	Cracks	
Free From Injury (12) Caused By	**Free From Injury (12) Caused By**	**Free From Injury (12) Caused By**
Fibre	Fibre	Fibre
Discoloration		
Russeting	**Free From Damage (13) Caused By**	**Free From Serious Damage (14) Caused By**
Scars	Discoloration	Discoloration
Disease	Russeting	Russeting
Insects	Scars	Scars
Mechanical or other means	Disease	Disease
	Insects	Insects
		Anthracnose
		Cracks
	Mechanical or other means	Mechanical or other means

*Numbers in parentheses following grade terms indicate where such terms are defined under "Definitions."

Size Requirement

A numerical count or minimum diameter (15) or size classification shall be used to describe the size of mangoes in any container.

When the numerical count is specified, the diameter of the largest mango in any container shall not exceed the diameter of the smallest mango by more than 1/2 inch when most of the mangoes are 3 inches or larger in diameter, nor by more than 3/8 inch in diameter when most of the mangoes are less than 3 inches in diameter.

Size classifications which may be used to specify size in connection with the grade are as follows:

Small	Under 2-1/2 inches in diameter
Medium	2-1/2 to 3 inches in diameter
Large	Over 3 inches in diameter

Tolerances (count basis)	Tolerances (count basis)	Tolerances (count basis)
Defects: Total 10%; provided not more than 5% damage and anthracnose, including 1% decay other than anthracnose.	Defects: Total 10%; provided not more than 5% serious damage and anthracnose, including 1% decay other than anthracnose.	Defects: Total 10%; provided not more than 1% decay other than anthrocnose.
Off-size: Total 10%.	Off-size: Total 10%.	Off-size: Total 10%.

OFF-GRADE. "Off-Grade" is not a grade within the meaning of these standards, but is a descriptive term applicable to mangoes which have a market value, and designates a quality lower than the lowest applicable Hawaii, other states or the United States grade for mangoes.

APPLICATION OF TOLERANCES. Averages for the entire lot, based on examination of representative samples, shall be within the tolerances specified, but the contents of individual containers in any lot may vary from the specified tolerances subject to the following limitations:

When the tolerance specified is more than 5 percent, individual packages in any lot may contain not more than 1-1/2 times the tolerance, provided that at least one specimen which fails to meet the requirements shall be permitted in any container.

When the tolerance specified is 5 percent or less, individual packages in any lot may contain not more than double the tolerance, provided that at least one specimen which fails to meet the requirements shall be permitted in any container.

APPLICABLE GRADE TERMS. Mangoes shall be classified in accordance with the grading system designated below:

Wholesale Quantities - HAWAII FANCY, HAWAII NO. 1 or HAWAII NO. 2, whichever is applicable.

Consumer Packages and Bulk Displays - HAWAII GRADE AA, HAWAII GRADE A or HAWAII GRADE B, whichever is applicable.

MINIMUM EXPORT GRADE. Mangoes for export shall at least meet the requirements of Hawaii No. 1 mangoes.

DEFINITIONS.

(1) "Mature" means the mango has reached the stage of growth which insures a proper completion of the ripening process.

(2) "Overripe" means dead ripe, very soft and past commercial utility.

(3) "Clean" means practically free from dirt, dust, spray residue or other foreign matter and the amount of sap on the fruit is not excessive.

(4) "Well trimmed" means the stem is neatly and smoothly cut or broken off at a point not more than 1/2 inch beyond the shoulder of the fruit.

(5) "Well formed" means the mango has a shape typical of the variety and is symmetrical and without irregularities in shape.

(6) "Fairly well formed" means the mango may be slightly abnormal in shape, but not to an extent whereby its appearance is materially affected.

(7) "Badly misshapen" means the mango is seriously irregular or abnormal in shape.

(8) "Smooth" means there are no ridges, grooves or other irregularities of the skin of the fruit. Rough scars or cracks shall not be considered a factor of smoothness.

(9) "Small seeded" means the weight of the seed in any fruit does not exceed 25 percent of the total weight of the fruit.

(10) "Insect stings" means punctures made by insects that can be identified as such with the naked eye without cutting the fruit.

(11) "Bruises" means bruising injury other than those incident to proper handling and packing.

(12) "Injury" means any specific defect described in Table 1, Classification of Defects; or an equally objectionable variation of any one of these defects, any other defect, or any combination of defects which appreciably detracts from the appearance, or the edible or shipping quality of the mangoes.

(13) "Damage" means any specific defect described in Table 1, Classification of Defects; or an equally objectionable variation of any one of these defects, any other defect, or any combination of defects which materially detracts from the appearance, or the edible or shipping quality of the mangoes.

(14) "Serious damage" means any specific defect described in Table 1, Classification of Defects; or an equally objectionable variation of any one of these defects, any other defect, or any combination of defects which seriously detracts from the appearance, or the edible or shipping quality of the mangoes.

(15) "Diameter" means the distance across the smallest round opening through which the mango will pass without pressure.

Table 1. Classification of Defects

FACTOR	INJURY	DAMAGE	SERIOUS DAMAGE
Fibre	Flesh of fruit fibrous in areas not immediately adjacent to the seed; or fibres normally present in areas immediately adjacent to the seed are so long as to appreciably affect palatability.		
Discoloration	Aggregating an area more than 3/8 inch in diameter.	Aggregating an area more than 2-1/2 percent of the surface.	Affecting more than 1/3 of the surface.
Russeting or scars	Light colored, smooth and aggregating and area more than 3/8 inch in diameter; rough scaly, dark or prominent and aggregating an area more than 1/8 inch in diameter; or affected area is sunken.	Light colored, smooth and aggregating an area more than 10 percent of the surface; rough, scaly, dark or sunken and aggregating an area more than 1/2 inch in diameter; or so deep as to materially affect appearance.	Rough, scaly, dark or prominent and aggregating an area more than 1-1/2 inches in diameter; or so deep as to seriously affect appearance.
Anthracnose			Any single spot more than 1/8 inch in diameter; or when affected areas aggregate more than 1/2 inch in diameter.
Cracks			Unhealed; not shallow; or affecting an aggregate area more than 1 inch in diameter.

MARKETING MANGOS IN HAWAII

Ronald Yamauchi
Yamauchi Produce, Honolulu

I manage a small produce wholesaling business in Honolulu that sells to retail markets in Honolulu, including some supermarket chains. Mangos are a small item for us. We bring some in by airfreight from Mexico through California. During the Hawaii mango season, we generally do not sell mangos. Late in the Hawaii season, we market some mangos provided to us by Mr. Warren Yee. We do not export mangos.

We recently began bringing in Mexican 'Haden' mangos. They are packed by count in boxes, ranging from 8-count to 20-count. The popular sizes in the retail markets here are the 10s and 12s. The boxes average 12-14 pounds, but we buy by the box, not by weight. Prices range from an early-season high of close to $20.00 to as low as $4.00 per box during peak season. Right now the Los Angeles price is around $12.00 per 12-count box, and airfreight will add about $3.00 per box to the cost of bringing it in. We bring in a few hundred pounds a week. They sell now at around $3.00 per pound in the retail markets. As the season progresses, prices will drop to around $7.00 – 8.00 per box, FOB Los Angeles.

Generally we bring in 'Haden', and later on, in April or so, we will start to get 'Tommy Atkins'. Demand drops as the California summer fruits like peaches and nectarines come into season and there is more competition for space on the retail market shelves.

We do not handle Hawaii mangos very much. We find that retail markets buy directly from backyarders who take fruits to the supermarket and sell them for whatever price they can get. There are also people whom I call "opportunistic harvesters," who go around the neighborhoods and offer so many dollars a tree, harvest everything on the tree from immature to ripe, and sell them for whatever they can get. They may come to wholesalers and offer a price, but usually we find it not a good proposition, because the quality includes discards and offshape and varies from immature to overripe. With most of the retailers getting their Hawaii mangos through their back door, we can't compete with backyarders on price; they are happy to receive whatever they can, and they don't have that much invested in terms of growing the mangos. Late in the season Mr. Warren Yee's mangos come in, and we do find an opportunity there to market these commercially grown mangos.

Q: What about the tourist market?

A: We sell to retail markets, not to hotels and restaurants. I know they buy, but I don't know to what extent. As Hawaii mangos become available, I know they start including it in their menus, but I have no idea how much they are importing.

Q: During the season, do you think there would be room in the retail channel for a graded product?

A: The potential for a bigger volume on the retail level is there. The retailers are looking for a more consistent supply. Consistent quality in terms of standardized packs with uniform sizes and good color would be of importance to retailers, because they like their shelves to look nice. I think retailers feel that there is good money in mangos, but the problem is supply. Also, when there is a bumper crop of mangos it means that less peaches, nectarines, and other fruits are going to be sold.

Q: When do the Mexican mangos start coming in?

A: We just started about two weeks ago. Demand will drop off as Hawaii's season progresses.

Q: Could you comment on the quality of the imported mangos? What do you look for?

A: We like to have mangos with good color, a lot of red. The firmness is important; we have some problems with arrivals that come in too soft. Appearance is important. Price is not a major factor.

GOVERNMENT ASSISTANCE IN MARKETING AND PROMOTING HAWAII'S AGRICULTURAL PRODUCTS

Janet Leister
Market Development Branch, Marketing Division
Hawaii Department of Agriculture

I would like to introduce you to the Department of Agriculture's Market Development Branch (MDB), explain how it operates with industry groups, and describe MDB programs pertaining to promoting agricultural products. This presentation will concentrate more on the programs that are pertinent to the mango industry than on other MDB programs such as those for floral and manufactured foods.

We hope that this presentation will give you ideas on how your industry may work with MDB as it continues to grow and develop.

MDB of the State Department of Agriculture develops and promotes Hawaii's agriculture, floriculture, and manufactured food products and industries locally, nationally, and internationally. Agriculture diversifies our economy, lends character to the state, and provides aesthetic benefits. Agriculture also faces significant challenges in Hawaii, with relatively high production costs, a small local market, a far distance to overseas markets, and stiff competition from U.S. mainland and foreign competitors.

MDB attempts to structure programs to address these challenges while seeking to best utilize Hawaii's advantages. The branch also assesses the stage in which various industries are developed in order to plan suitable programs. Since the branch cannot actually sell products, we try to create an environment to assist industries to market their products. In other words, the branch tries to help industries help themselves.

Agricultural marketing is a complex process, with a variety of marketing channels and procedures depending on the product and the target market. This can be quite an undertaking considering the wide variety of products available throughout the state. This presentation describes some of our activities and the rationale for those activities in assisting Hawaii's agricultural industry.

Marketing Channel

The following is a simplistic diagram showing the flow of products from the farm through the trade to the consumer:

Farmer-----> Trade -----> Final Consumer

The "trade" is the wholesaler, importer, manufacturer, or retailer. Final consumers are any one of us that go to supermarkets, restaurants, or any other marketing outlet to purchase products for consumption. The bulk of agricultural sales are conducted through this basic flow. However, some farmers sell directly to the final consumer, as in the case of roadside sales. This basic diagram is used here to help explain the rationale for certain of our branch's market development and promotional activities. For the purpose of this presentation, promotions that focus on final consumers are referred to as "consumer promotions." Some examples are television and radio commercials and newspaper advertisements.

How MDB Operates with Industry Associations

MDB works with industry associations and organizations rather than individual companies. Some examples of associations are the Hawaii Food Manufacturers Association, Hawaii Association of Nurserymen, Papaya Administrative Committee, Pineapple Growers of Hawaii, Hawaii Avocado Association, and Hawaii Egg Producers Association. In the case of mangos, MDB has worked with the Hawaii Tropical Fruit Growers (HTFG).

The larger associations, such those for as pineapple, papaya, and eggs, work on a contract basis. They do a three-year marketing plan, develop a promotional program, and then MDB works with them. Industry associations may also do single promotional projects which require a proposal and evaluation of the project. These contracts and proposals are funded on a 50-50 basis with industry matching 50 percent of the total cost and MDB paying for the other half.

Some projects are funded 100 percent if the project is considered multicommodity or generic, such as trade shows and some printed materials.

Most recently, MDB has worked with HTFG to produce a tropical fruit brochure. The brochure displays mangos prominently and also includes lychee, atemoya and cherimoya, rambutan, and star fruit. The brochure also mentions several other fruits, such as the durian, mangosteen, and jackfruit.

The brochure is the result of HTFG identifying a lack of awareness among the trade, foodservice, and consumers characterized by not knowing what fruits we have, their seasonality, or how to prepare them. The brochure answers these questions as well as emphasizing the fruits' delicious tastes and uses. It is targeted to trade and foodservice market segments because the cost is fairly high--around $14,000 for 10,000 copies.

Local Market: Selected Projects And Activities

The State of Hawaii is a relatively small and compact market. Consumer promotions through such media as television, radio, and newspapers can generally reach a significant percentage of consumers. Because of the relatively small market, the trade, such as wholesalers, are generally aware of the products Hawaii suppliers have to offer. Therefore, local market programs concentrate more on the consumer than the trade.

Island Fresh Program

The purpose or the Island Fresh Program is to increase consumer awareness and consumption of fresh local products. There is a special Island Fresh logo that is used in the supermarket point-of-purchase promotional materials to identify local products, and the logo is also used with special promotions such as on shopping bags at the Hawaii State Farm Fair. Part of the program includes recipes displayed in the supermarkets. MDB staff can work with you on printing Island Fresh mango recipes.

Feature stories on certain fruits and vegetables are also part of the program. Feature stories can be targeted when there is an oversupply of the product, to encourage consumption.

The Island Fresh program also includes the Hawaii State Farm Fair. Industries can exhibit products, and a tabloid is also published in the newspaper regarding Island Fresh products.

One of the more successful components of this program for smaller commodity crops is the in-store demonstration of the product. Recently, MDB assisted the Hawaii Avocado Association (HAA) and HTFG with a joint demonstration of 'Sharwil' avocado and starfruit. Three demonstrations were conducted, in December, February, and March. Each demonstration was for three days at eight supermarkets on Oahu. Recipe cards were developed and printed and included storage, ripeness, and nutritional information to inform the consumer about the fruit.

Both fruits face the challenge of differentiating the better quality commercial fruit from the "backyard" fruit. Mango, of course, faces a similar challenge in the local market. Avocado faces the additional challenge of the California 'Hass'.

Foodservice/Chefs Program

HTFG developed a marketing plan which targets the foodservice industry as a promising target market for tropical fruits. MDB also recognizes that targeting the food service industry develops another market locally for Hawaii's food products and at the same time targets tourists.

To develop this market, MDB works with Hawaii Regional Cuisine and American Culinary Federation chefs to create a unique Hawaii cuisine using Hawaii products. MDB also assists in producing the Hawaii Cooks television show to promote our fresh products.

In working with the foodservice industry, the mango industry needs to find out what are the food service industry's needs and preferences, since they are often different from the mass consumer/supermarket needs and preferences.

Ag Day

DOA sponsors a special Ag Day in conjunction with the national Agriculture Week to highlight Hawaii's new agricultural products. The event is targeted to key decision-makers and involves demonstrations and sampling. Some tropical fruits have been represented at past Ag Days.

Tourist Promotions

As part of their marketing program, the papaya and pineapple industries have done a Chefs' Recipe contest and have advertised in the tourist media for the carry-home market. Currently, DOA is sponsoring a special reception for the Pacific Asian Travel Association press. The reception will feature Hawaii Regional Cuisine and will also feature tropical fruits as part of the food display.

U.S. Mainland Market

Since the presence of fruit flies is a barrier that restricts entry of the mango into the mainland market, this presentation will not cover MDB's mainland market programs. However, I will cover foreign markets, because mangos can be imported into several of these markets.

Foreign Markets: Selected Projects and Activities

Language and custom differences, foreign currency fluctuations, and foreign trade barriers such as tariffs and quotas are additional obstacles that increase the challenge of developing foreign markets. However, some foreign countries offer promising opportunities for Hawaii's products, especially those countries with high incomes that do not produce the same crops as Hawaii, such as Western Europe, East Asia, and Canada. Western European countries and Canada are not concerned with fruit flies and permit entry of our fresh produce. Japan has strict quarantine requirements on fresh produce but is a good target market for those products that are not restricted due to its high income and appreciation of Hawaii.

Hawaii is not currently marketing large volumes of agricultural products to foreign markets, except for fresh papayas and flowers to Japan. Therefore, the MDB has placed a major emphasis on targeting the trade segment in the marketing channel to establish or increase distribution of products, like in the mainland. Consumer promotions are also sometimes conducted in cases where a critical volume exists in retail outlets.

A great benefit to the state is that the department is the only state agency with access to federal funds for agricultural marketing assistance targeting foreign markets. These funds have been used for trade development, promotion, and research projects.

Trade Shows

As in the U.S. mainland, trade shows are used to gain a beach-head in distribution in foreign markets where the trade sector is generally unaware of Hawaii's products. The MDB has organized Hawaii firms for ANUGA and SIAL, the two largest food trade shows in the world, which are held in Europe. The branch has also been involved in shows conducted in Canada and Asia. The two Canadian trade shows are the Food and Hospitality Show and the Grocery Showcase West, both in Vancouver.

Research

The MDB conducts research on a variety of topics to prepare activities. For example, the branch draws information from parties interested in department-sponsored trade shows to determine if they are suited and ready for the event. The MDB also commissions market research studies to help the branch and various industries obtain information to prepare developmental and promotional activities.

As your industry continues to grow, we hope that you can benefit and profit from some of our programs.

EXPORTING MANGOS TO CANADA

Sam Hugh
Ham Produce & Seafood, Honolulu

We have been exporting mangos to Canada for about 15 years. In the beginning there was no competition from Mexico or Florida, and we shipped a lot more then. Nowadays we only ship ripe mango when it is off-season for Mexico and Florida. We ship a lot of green mango to Vancouver, which has a large ethnic market. We prefer to ship green mango, because it does not bruise and get damaged as readily as ripe mango. Freight to Canada is about 28–35¢ per pound, depending on how much you ship. These days we never ship full LD3 containers of mangos to Canada; they are always mixed with other produce such as papaya, taro, or herbs. We ship mangos to Hong Kong, but they only take the 'Pirie' variety, and we cannot get a lot of 'Pirie'. Whenever we ship to Hong Kong, we ship mangos and papayas.

Q: When you ship green mangos, do you ship certain varieties of mango or just common green?

A: We ship the 'Chinese' variety, which is available sporadically, and during 'Haden' season we try to get the immature, smaller 'Haden', because when it gets bigger the flesh gets yellow, and they can't use it; they like it solid green. We ship year-round.

Q: What is the freight to Hong Kong?

A: We get a good freight, about 40¢ per pound LD3 rate, because when they fly back they carry next to no cargo. They may be losing money at 40¢, but they would rather have that than nothing. They charge us per case, $4.00 per case, so the freight per LD3 varies.

Q: What are green mangos being used for?

A: Mostly they pickle it. The West Indians chop it up and use it in cooking and mixed in salads. They like green 'Haden' because it is less fibrous than 'Chinese'. Mexico doesn't ship green mangos, so even when they are shipping ripe mangos to Vancouver, we still can ship 1,000–2,000 pounds a week of green mangos.

Q: What growth stage is "green" mango?

A: Not full size; about halfway developed, as immature as possible. We get them mostly from backyard growers. We belong to the Hawaii Tropical Fruit Co-op, and some of our growers have mangos. Last year 'Haden' was really plentiful, and the price was better for green than for ripe, so we asked growers to harvest earlier.

Q: Is the price for green mango stable through the year?

A: During the off-season we pay maybe 60, 70¢ for 'Chinese' mango, and anywhere from 40 to 50¢ for 'Haden'. We also buy from what Ron Yamauchi calls "opportunistic harvesters," because there are not that many commercial farms producing mangos.

Q: Do you ship mixed containers because of demand constraints?

A: No, it's supply. We never have problems selling green mango.

Q: What is the net weight on an LD3?

A: The maximum is 3,200 lb, but on a mixed load you get maybe 2,000. Straight papayas or mangos would be about 2,500.

Q: What is the shelf life of green mangos?

A: They have a good shelf life, maybe 10 days after they arrive, if you don't chill them. If you chill them, they get soft. They ship well and do not require as much care in packing as ripe. We ship ripe mangos in 10-lb boxes, but the green ones can be shipped in 30-lb ginger boxes.

Q: Do you ship to other places in Canada besides Vancouver?

A: Calgary and Edmonton take a little. There are a lot of West Indians and Vietnamese in Vancouver. The market in Canada is getting bigger. There is immigration from Hong Kong, and the Chinese population is growing, especially around Toronto. Hong Kong people like the smell and color of 'Pirie' mangos, but they don't like 'Haden' at all. There is no quarantine restriction to Canada. During the summer Canadian Air restricts us to a certain allotment of container space per day. It may be hard to get space if you do not have a year-round relationship with the carrier. Continental also flies to Vancouver.

EXPORTING MANGOS TO EUROPE

Michael Kohn
Equipment Team Hawaii, Kaneohe

My company has a strange name, but in Europe I market as Hawaii Fruit Co., so they know what I am dealing with. I have been in the fruit export business since 1987, and I started shipping mangos in 1989. I work exclusively with the European market.

Mangos are a very small portion of my business. I wish that it could be more. The problem is mostly of supply. I ship ripe mangos. I cannot sell green mangos in Europe; if there is an ethnic market for them, I have not discovered it. The mangos I ship must be of very high quality, otherwise you cannot justify the high air freight to Europe. If they are of poor quality and you have to give credits, profits can go down quickly. My approach is that everything that goes must be nearly perfect. I have to be 100 percent satisfied that there are no bruised fruits and no disease. To ensure that, I only ship fully ripe mangos.

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Q: What is the freight to Europe?

A: It starts around $1,900–2,000, sometimes a little less, for a container. I can pack a bit more than the 2,500 lb that Sam Hugh mentioned, which is about the industry standard. I have tried to find ways to get more in a container because of the high air freight.

Q: Do you ship to wholesalers?

A: They are not really wholesalers; they are importers. They are not necessarily large companies. I am working with a niche market, for a very high-priced commodity. Being from Hawaii, it is hard to compete with mangos exported to Europe from Africa, Israel, and Brazil, some of which is transported by ocean. My customers are mostly in Germany, although I have some in France, Italy, Great Britain, and Austria.

Q: Who is your principal market: restaurants, wholesalers?

A: It started off with high-end wholesalers in Germany who thought they had a few customers who would pay that much if the fruit is that good. They in turn sell to small, high-quality retail outlets, which died out in the 1960s and 1970s as supermarkets took over but are coming back now. Large supermarkets are not interested in a high quality mango; they are interested in long shelf life and competitive price. If their mango costs $1.99 or less, my mango cannot cost more; when the freight alone is $3.00, there is no further discussion possible. When I make these remarks, I am speaking largely from my experience with papaya, really, because I have not shipped much mango. I think the example of papaya can be used with mango.

I do not think you can deal with chains without a very broad supply basis. Even if you can convince them to pay the high price, they can be very picky, demanding all one size; this week one container, next week three, the week after none. Mangos and papayas do not grow like that, and my workers want to be employed on a steady basis, and certainly the fruits do not all grow to size 9.

Q: Do you identify your product as being Hawaii-grown?

A: It helps in the initial introduction, because for many Europeans, Hawaii is the number one tourist destination. In the end, the fruit itself has to show its merits; the name will not be enough.

Q: Is there any interest in Europe for organically produced fruits?

A: I have asked some of my customers about this but have not pursued it in depth. The response from them was, "Well, how much do you have?" The answer is not much, so there is little sense in talking about it. There is also a prohibitive price difference. With the little that we have, it is probably not worth the effort, unless they know we can build it up. There is a growing market for organically grown foods, but I do not think it is as well developed in Europe as in the United States.

Q: What do you pay for mangos now?

A: If I can get first quality mangos, the limit at the moment is about 55 cents a pound, maybe 60. The quality has to be so good that I hardly have to sort anything out.

Q: What about off-season prices? Our local market pays well for off-season fruits.

A: It seems like when Hawaii 'Haden' mangos are available, that is the off season in Europe; there is less supply to their markets. So it fits nicely in that timeframe. Even if I could get mangos in the wintertime, I could not give much better prices because the competition is stiff in Europe at that time.

Q: When you say you are shipping ripe fruit, what do you mean?

A: I mean picked fully ripe from the tree; still firm but fully ripe. There can be a little bit of green left, but the fruit must be 75 – 100 percent fully ripe. The taste will be excellent. I can be assured that the fruit has not been bruised, as it might if fruits were injured when harvested green and then showed the bruise upon maturing. Most likely if there is disease, it would be showing by that stage. I ship the fruits chilled.

Q: How long does it take to get the fruit to the consumer?

A: Usually 24 hours freight time, and two to three days from the importers to the retail outlets; maybe three to five days overall.

Q: It has been mentioned that 'Haden' is not a good shipper; what have you found?

A: I have not had any quality problems, as long as I am sure of the quality when I ship them. We pack carefully and handle the boxes carefully.

Q: Who are your suppliers?

A: Backyard producers. I put an ad in the paper, and they come to me. I am always looking for suppliers.

Q: Do you get any complaints of spoilage at the other end?

A: Not really. When I started out I had a shipment of papayas that was a loss; I determined that would never happen again, and took measures to ensure that, such as the ripeness factor I mentioned. For mangos, I have had no complaints, but we check every fruit carefully, and if there is any suspicion of disease, we discard it.

Q: I have observed that 'Haden' is fully delicious with a fair amount of green still on it, and if you pick them too late they get that jelly-seed problem where they get soft around the seed. Also, fruits that are fully ripe are more bruisable than when they are still a little green. I prefer to get them just before fully ripe so I can let them ripen on the table and choose just the right time to eat them.

A: We have had no problems with fully ripe fruits. We chill them as soon as possible. I buy only 'Haden' now because my experience with them has been very positive, but I am willing to be educated about other varieties.

Q: Do you wrap or trade-pack your fruits?

A: No, I just place them in a 10-lb box, separated with a cushion to protect them and make the box look a little nicer.

MARKET NICHES FOR MANGO PRODUCTS

Aurora S. Hodgson
Department of Food Science and Human Nutrition
College of Tropical Agriculture and Human Resources
University of Hawaii at Manoa

As you have heard, the marketing techniques explained by my colleagues in this Marketing Panel focused on fresh Hawaii mango, which is the form that is currently the most sought after. This is probably because consumers, living outside mango-producing areas, are unfamiliar with the fruit.

However, as we also know, there are importation problems associated with fresh mango. Dr. Kefford, at the beginning of this conference, challenged us to determine whether or not this problem is perceived or real. But in either case, the problem of what to do with mangos which are found unsuitable for the fresh fruit market, sometimes also called *cull* mangos, needs to be resolved.

Value-Added Products

To utilize *cull* mangos, many retailers still sell the fruits fresh in the local market. Others are processed to increase consumer applications and also to add value to the resulting products.

Fruit Leather. Fruit leather (also called *Fruit Roll*, *Roll-ups*, etc.) is a way of utilizing fruit puree and concentrates. A mango product would be similar to the apricot fruit roll made by Sunkist, which is 0.75 oz in weight and costs $0.50 a piece. The product was packed for a company in New Jersey and was made from apricot concentrate.

Fruit leather satisfies market demand for "natural" sweet snacks perceived by the homemaker as "good" and "healthy." This product is popular with children and some adults.

Mango Pudding. This product, whose brand name is Yeo's, is a formulated food using mango puree and is prepared by a company in Singapore. This is an aseptically packaged food (i.e., it is shelf-stable under normal non-refrigerated conditions of storage and distribution) and is very reasonably priced at $0.89 for 8.8 oz.

Mango Pudding is likely to be considered a dessert-type product in the United States, that may find its use as a snack for children's lunch boxes. It has the consistency of tofu.

Mango Beverages. *Mango Nectar.* This is a shelf-stable formulated product using imported mango puree. It is made by Kern's of California. The beverage costs $1.09 for 12 fluid oz. It is popular with ethnic populations familiar with the characteristics of mango. Adults and children alike drink this beverage. In most other countries, aseptically packaged juices, from single to multiple servings, are a very common item.

Orange and Mango Sparkling Water and Fruit Juice Beverage. This Koala Beverage, made in Canada, uses mango concentrate. A 25.4 fluid oz bottle costs $1.65. Most of the flavored water beverages in the market use fruit flavors. However, this product addresses consumer demand for beverages with some fruit juices. This is popular with the adult population.

Carbonated Mango Juice Drink. Again prepared by a company in Singapore, this Yeo's beverage uses mango puree as the fruit ingredient and is competitively priced at $0.60 for an 11 fluid oz aluminum soft drink can. Carbonated drinks are always enjoyed by a broad age group. However, for a mango juice drink to dent the soft drink market even just slightly, it strongly needs to be supported by heavy advertisements.

Frozen Mango Orange Blend. Distributed by a company in Hawaii, this is a frozen product that uses mango puree. Hawaii's Own costs $1.59 for 12 fluid oz of Blend or 48 fluid oz of finished drink after dilution with three cans of water.

Because mango is an expensive ingredient, the name "mango" is almost always found on the product label when used as an ingredient. For example, this Juice Blend would not have used mango as an ingredient if mango would not be part of the product name.

Mango Slices. This is a can of mango slices packed in light syrup. It is manufactured by a company in Thailand and costs $0.89 for 15 oz.

Dole Packaged Foods also has a similar product, also manufactured in Thailand, but packaged in a No. 1-1/2 can. Although I was unable to secure a labeled can, I was able to sample some product. Dole mango slices are about 3 inches long by 1-1/2 to 2 inches wide. The texture is slightly chewier than that of canned peaches. The perceived flavor is mainly sweet with very little acidity, if any. Color was yellow-orange. It is mainly sold in the European market. It is also found in Asia, but Asians prefer to consume the fresh fruit instead (which might also be less expensive at a certain time of the year). Some homemakers serve the slices as a dessert, as is, *a la mode* or in a salad. It is also used as a topping for cakes or as fruit particulates in other bakery products. This is mostly popular with adults.

Dried Mango Slices. I found five brands of dehydrated mango slices in local markets, each packaged differently. All of these products use mango slices prepared in Asia. Their prices range from about $0.33/oz for the Thailand product to $0.84/oz for the Philippine product. All of these products have been sulfited to preserve the color, which then varied from yellow-orange to orange-brown. They have been coated with a protective layer of fine sugar to prevent individual slices from sticking to each other. Texture is slightly chewy due to the moisture retained in the slices. Flavor is sweet. This product has a wide range of applications, from trail mixes to cookies to cereals, or as is. I personally think that this product can compete with other dried fruits if it is strongly promoted.

Northwest Delights. An 8 oz package costs $4.69 and is distributed by a company in Washington.

Yick Lung. A 2 oz package costs $1.49 and is repacked in Hawaii.

AFT. Repackaged in Hawaii into a 4.5 oz covered plastic tray, this product of Thailand costs $1.50.

Bells & Flower. Also a product of Thailand, a 3.5 oz package costs $1.35.

R & M. Showing the most expensive packaging of the group, this Philippine product costs $2.95 for 3.53 oz (bought at a Honolulu International Airport shop).

Cracked Seeds. Local delicacies, shredded mango and mango seed, may be imported from Asia and repacked in Hawaii, prepared in Hawaii, or both. These products are flavored with licorice and also sometimes colored according to tradition.

Yick Lung Shredded Mango. Packed in Hawaii, this product costs $1.49 for 2 oz.

Jade Food Products Mango Seed. Declared as made in Hawaii, this product costs $1.35 for a 2-1/4 oz package.

Mango Jam. There are several packers of Mango Jam in Hawaii. *Maui Jelly Factory, Kukui,* and *Hawaiian Sun* are some Hawaii manufacturers. Mango is considered a tropical fruit. Thus, many local residents purchase this product as a gift for friends and relatives abroad.

Old Hawaii Recipes. Distributed by a company in Hawaii, this product uses mangos and costs $2.59 for a 10 oz jar.

Maui Jelly Factory. One 8 oz jar costs $3.00 for this product made in Maui.

Mango Chutney. The same manufacturers of Mango Jam also produce Mango Chutney. Some other mango chutneys found in Hawaii are imported from England and India. Chutney uses green mangos, and one local company employed 4-H program young adults to purchase green mangos from backyard producers for chutney production. The company used about 3 tons of green mangos last year to make this product.

Kukui. This product uses mangos and is produced by a company in Hawaii. It costs $3.65 for a 9 1/2 oz jar.

Maui Jelly Factory. An 8 oz jar of this mango chutney made in Maui costs $3.00.

Other mango products

Mango Puree. This form was discussed in detail by Dr. Chan of USDA-ARS. There are many product applications for the puree, ranging from baby foods to fruit leathers.

Mango Juice. Juice is usually prepared from puree and may either be pulpy or clear. Tropical fruit juices, still or carbonated, are used by beverage manufacturers to introduce an exotic item and to satisfy the demand of certain ethnic populations.

Mango Particulates. This product may be in a syrup or juice medium or be in a dried form. Its size would be smaller than mango slices. It would be used as fruit particles in bakery and dairy products.

Pickled Mango. In the local dialect, "pickled mango" means preserved mango. Thus, *cracked seeds* are also considered pickled. However, the pickled mangos that most consumers are familiar with are sold in a brine, brine-vinegar, brine-sugar, or brine-vinegar-sugar medium, with or without additional spices for flavoring.

These are only some of the mango products available in Hawaii. There may be other forms prepared according to ethnic traditions.

Defining Marketing Niches

If you would like to market mango products, you can introduce either an existing product or a new one.

An existing product can be marketed several ways:

As an exact copy with no additional features,

As a cost-reduced copy (costs less),

As an improved copy (with better quality; costs more),

By *buying out* the manufacturer.

A new product will be entirely new. In either case, for a product to be successful in the marketplace, it has to have a defined market niche, and you have to advertise. Consumers should have a need for the product so that there is a reason for sales volume. Develop product applications so that manufacturers and consumers would know how to use mango products as ingredients.

Many food entrepreneurs have approached me, both here and abroad, about a sensational product that their parents and friends all swear should be marketed. However, when asked which population will be buying this product, what are the characteristics of the population, their likes and dislikes, their purchasing power, and for other types of information, the entrepreneur usually does not have the answer, because no market research has been done. Product introduction in this case can be very frustrating and expensive for the unprepared entrepreneur.

On the other hand, knowing what your consumers want and staying in touch with what they want is a powerful key to product success. This information is very important in defining the viability of the product during introduction and at succeeding points in time. A certain population might really need the product but might also ask for changes in some of its product characteristics or packaging. Full product potential is realized with careful market research.

Therefore, value-added products have to address a certain consumer need. To reduce the risks of product failure, the market needs to be defined first before developing the product.

CONCLUDING REMARKS

(The participants were invited to comment on the conference.)

Tom Davenport: I don't know what you intend as an industry here, but I think there are many opportunities and that it would be exciting to see Hawaii's mango industry develop. From my brief observations of what is going on here, I think organization is the key. Get yourselves organized, get some goals in mind, and grow with it. From my point of view as someone interested in flowering manipulation, I think you have some interesting options such as controlling temperature with elevation, manipulating water, and utilizing your locations in dry areas. Finally, I want to thank you all for your hospitality and for bringing me here. Good luck.

Comment: I would like to thank the organizers for conducting this conference. It has been extremely useful and educational for me. The wide assortment of speakers was very good. Thank you very much.

Q: Where do you get money for mango research?

C. L. Chia: Arranging that is the next step.

Warren Yee: As a grower, I am aware that there are some here who would be interested in forming a mango growers' association, and I myself would be interested in that.

C. L. Chia: I have a suggestion. Why not call it the "mango industry association" and include the marketers?

W. Yee: That would be fine, because there are not that many growers.

C. L. Chia: I will leave it to Warren to come out of retirement and get a mango industry association started. I would like to thank you all for coming and for participating in the discussions of these three days. I sense that there is tremendous interest in mango here.

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