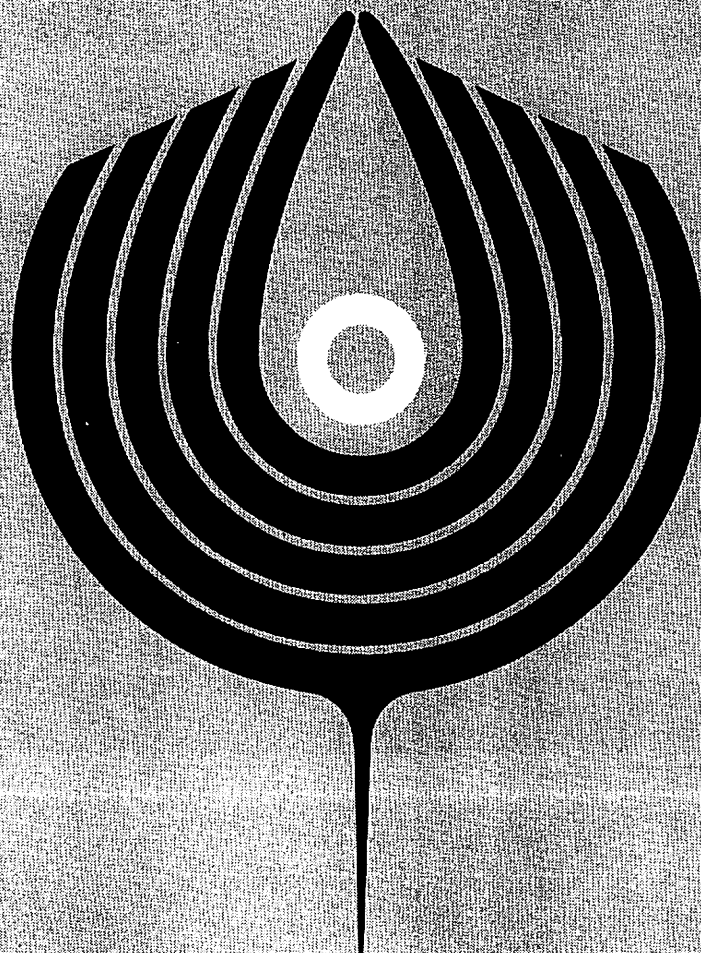


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**TEN TROPICAL FRUITS OF POTENTIAL VALUE
FOR CROP DIVERSIFICATION IN HAWAII**

R. A. Hamilton

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



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TEN TROPICAL FRUITS OF POTENTIAL VALUE FOR CROP DIVERSIFICATION IN HAWAII

R. A. Hamilton

INTRODUCTION

More than 700 edible fruits are native to humid tropical areas of the world. Approximately 200 of these have been imported and test-grown in Hawaii since the estimated arrival of the first Polynesian voyagers about 1000 years ago. About 30 tropical fruits are cultivated and marketed on a commercial scale around the world.

Ten of the most important tropical fruits chosen for discussion here are listed in Table 1 and described and discussed in some detail under separate headings. Ten additional fruits considered to have good potential for improvement and increased development are listed in Table 2. Sixteen botanical families are represented. This wide spectrum of different families includes one palm, one vine, two herbaceous plants, and 16 woody dicotyledenous trees, totaling 18 dicots and two monocots.

There is a fairly wide range of adaptability among these fruits, although all are native to the humid tropics. Six of the 20 species can also be grown successfully under irrigation in frost-free subtropical areas. These are avocado, guava, papaya, yellow passion fruit, banana, and pummelo. Durian, breadfruit, peach palm, and rambutan, on the other hand, grow and produce best in warm, humid tropical climates.

In addition to the 20 important fruits listed in Tables 1 and 2, there are 700 to 740 other edible fruits native to the humid tropics. Most of these are considered minor fruits because they are not widely known and are grown and used principally in the geographical areas where they originated. There is an urgent need in Hawaii and the American tropics for improved cultivars of all 10 important American fruits listed in Tables 1 and 2. Although there are a few clonal selections of guava, sapodilla, and red sapote, much of the commercial production of these fruits is from unselected seedlings. In fact, there are relatively few good cultivars of any of the 10 native American tropical fruits listed. These fruits are grown mainly from unselected seedling trees.

On the other hand, the tropical fruits of Southeast Asia listed in Tables 1 and 2 have many selected clonal cultivars, except for jackfruit and pulusan, which are generally grown as seedlings. When grown in Hawaii or Southeast Asian countries, several of the

tropical American fruits, including West Indian avocado, guava, and sapodilla, are often propagated by budding, grafting, or marcotting. It is not entirely clear why varietal improvement of these fruits by selection and vegetative propagation is much more popular and widespread in Hawaii, Florida, and Southeast Asia than in tropical America. In the case of other well-known fruit trees such as mango and citrus, no such difference exists.

Native fruits of the humid tropics are often grown successfully under irrigation in relatively dry tropical and subtropical areas of many countries. Avocado, banana, papaya, and yellow passion fruit are examples of this practice. Certain other fruits, such as mangosteen and peach palm, thrive only in humid, warm tropical climates but not in drier or cooler areas.

TROPICAL AMERICAN FRUITS

West Indian Avocado (*Persea americana*)

Distribution. Avocados consist of three horticultural races differing widely in climatic requirements. Only the West Indian (W.I.) race, which is well adapted to humid tropical areas, is discussed here. Guatemalan and Mexican race avocados are not well adapted to the humid tropics, but are better adapted to cooler, drier climates. The W.I. race of avocados is native to warm, humid, tropical sections of Central America and the central and northern portions of South America. This is the predominant type of avocado commonly grown in humid tropical areas of the world.

Avocados are well known and appreciated in Hawaii but not very well known or widely used in most countries of Southeast Asia, in spite of their excellent food value, palatability, and exceptionally high vitamin A content. They are, however, grown and appreciated in the Philippines, Indonesia, and Vietnam.

Description. W.I. avocados are characterized by large, rough seeds, usually loose in the cavity. They have thin, pliable skins, which may be green, yellow, reddish, reddish-purple, or purple, depending on the particular seedling grown. The shape and size of fruits vary, and they may be round, oval, or pyriform, weighing about 10 oz to 2.5 lb or more. The flesh is smooth, buttery, delicately flavored, and in some selections slightly sweet.

Table 1. Ten important fruits native to the humid tropics of Central America, South America, and Southeast Asia

Fruit	Genus and species	Family
Tropical American Fruits		
1. West Indian (W.I.) avocado*	<i>Persea americana</i>	Lauraceae
2. Guava*	<i>Psidium guajava</i>	Myrtaceae
3. Yellow passion fruit*	<i>Passiflora edulis</i> f. <i>flavicarpa</i>	Passifloraceae
4. Papaya*	<i>Carica papaya</i>	Caricaceae
5. Peach palm*	<i>Bactris gasipaes</i>	Palmae
Southeast Asian Fruits		
6. Banana	<i>Musa</i> sp. (hybrid)	Musaceae
7. Breadfruit	<i>Artocarpus altilis</i>	Moraceae
8. Durian	<i>Durio zibethinus</i>	Bombacaceae
9. Pummelo	<i>Citrus grandis</i>	Aurantaceae
10. Rambutan	<i>Nepheltum lappaceum</i>	Sapindaceae

*Improved cultivars urgently needed.

Table 2. Additional fruits of the humid tropics with a potential for improvement and increased importance in Hawaii

Fruit	Genus and species	Family
Tropical American Fruits		
1. Chico sapote*	<i>Manilkara achras</i>	Sapotaceae
2. Cupuacu*	<i>Theobroma grandiflorum</i>	Sterculiaceae
3. Soursop*	<i>Annona muricata</i>	Annonaceae
4. Red sapote*	<i>Calocarpum mammosum</i>	Sapotaceae
5. Sapota	<i>Matisia cordata</i>	Bombacaceae
Southeast Asian Fruits		
6. Carambola	<i>Averrhoa carambola</i>	Oxalidaceae
7. Jackfruit*	<i>Artocarpus heterophyllus</i>	Moraceae
8. Lansone	<i>Lansium domesticum</i>	Meliaceae
9. Pulusan*	<i>Nepheltum mutabile</i>	Sapindaceae
10. Mangosteen	<i>Garcinia mangostana</i>	Guttiferae

*Improved cultivars urgently needed.

Table 3. Nutritive values of 100 g samples from selected fruits of the humid tropics

Fruit	Mois- ture %	Food energy Cal.	Pro- tein gm	Fat gm	Total carbo- hydrates gm	Fiber gm	Ash gm	Cal- cium mg	Phos- phorus mg	Iron mg	Vit. A value IU	Thia- min mg	Ribo- flavin mg	Nia- cin mg	Ascor- bic acid mg
1. Avocado (W.I.)	82.9	98	1.4	8.2	6.5	1.5	1.3	5.0	80	0.6	540	.06	.12	1.5	13
2. Banana*	71.1	102	1.5	0.2	26.5**	0.6	0.8	4.0	23	0.3	172	.03	.04	0.7	6
3. Bread- fruit*	61.8	134	0.07	0.2	36.8	1.5	1.2	20.8**	48	0.3	41	.12	.06	1.5	21
4. Durian	66.8	124**	2.5	1.6	28.8**	1.4	0.8	20.0**	63	0.9	10	.27	.29	1.2	37
5. Guava*	84.4	55	0.3	0.1	14.8	2.4	0.5	15.0	16	0.3	109	.06	.06	1.3	70-350**
6. Papaya*	86.8	46	0.4	0.1	12.2	0.6	0.6	30.0	12	0.2	1093**	.03	.04	0.3	84**
7. Peach palm	50.5	196**	2.6	4.4	41.7**	1.0	0.8	14.0	46	1.0	670-3600**	.05	.16	1.4	35
8. Pummelo*	89.9	34	0.8	0.1	8.8	0.2	0.5	7.4	21	0.2	0	.03	.03	0.2	40
9. Rambutan	82.0	64	1.0	0.1	16.5	1.1	0.4	20.0**	7	0.8	0	trace	.03	0.3	23
10. Yellow passion fruit*	84.9	53	0.7	0.2	13.7	0.2	0.5	4.0	25	0.4	2419**	trace	.10	2.2**	20

*These values are from Wenkam and Miller, 1965, pp. 30-35.

**Excellent sources of food energy and nutrients.

Propagation and culture. W.I. avocados are usually grown from seed of selected seedlings, and although some clonal selections have been made in Hawaii, Florida, Puerto Rico, Cuba, and elsewhere, no outstanding commercial cultivars have become widely established. Seedling W.I. avocados lack uniformity and have remained heterozygous because of a pollination mechanism in which flowers of any given tree or cultivar do not shed pollen during the same part of the day that the pistil is receptive. This results in a high incidence of cross-pollination by insects carrying pollen between different seedlings.

Harvest and yield. Yields of W.I. seedling orchards vary greatly, but yields of up to 10 T/A are possible in mature, well-managed orchards. W.I. avocado fruits mature four to eight months after flowering. Flowering characteristically takes place in the spring and fruits usually mature in late summer and early fall.

Nutritional value. Avocados are generally considered to be the most nutritious and healthful of all tropical fruits, and W.I. avocados contain up to 10 percent oil and up to 2 percent protein. They are a good source of riboflavin and niacin and are high in vitamins A and E. The energy value of W.I. avocados is high, about equal to that of bananas and breadfruit, and exceeded only by durian and peach palm (see Table 3). Avocado is one of the finest salad fruits of the world. The flesh is consumed fresh, and world consumption is increasing in temperate zone countries.

Use. There are many ways of serving avocados, but perhaps the most common and popular method is as a half fruit with suitable seasoning added, such as salt, pepper, chili sauce, catsup, sugar, soy sauce, lime juice, vinegar, or mayonnaise. Mixed salads and milk shakes are other popular ways of serving avocados.

Outlook. Because of their high food value, palatability, and ease of production, avocados should be more widely grown in tropical and subtropical areas throughout the world. The best-yielding trees with superior fruits should be selected and propagated by grafting.

Guava (*Psidium guajava*)

Distribution. Guavas are native to tropical America and are found growing wild in frost-free areas throughout the world, from about 27° north latitude to 30° south latitude. They are the most important and best known fruit of the family Myrtaceae. When introduced to new areas, guavas often spread rapidly as birds and animals eat the fruit and eliminate the still

viable seeds. Because of its versatility and widespread use, guava has been appropriately called "the apple of the tropics."

Description. Guava fruits vary widely in form, color, shape, size, and seediness, so there is ample opportunity for improvement by breeding and selection. Guavas range in size from about 10 g to 2 lb and may be round, oval, or pyriform in shape. Many guavas are excessively seedy but others are thick fleshed with small seed cavities and are almost seedless. Some seedless guavas have been found to be triploids (Hirano and Nakasone, 1969). The flesh may be yellow, cream colored, white, pink, or red; pink and red flesh are more common in wild guavas.

Propagation and culture. Most guavas grown throughout the world are of seedling origin, although there are notable exceptions. In South Africa a single clonal variety is grown in commercial orchards and forms the basis for excellent guava products including juice, guava confections, canned guava halves, and canned guava shells. In India, Thailand, and Malaysia sweet guava clones are propagated, grown in orchards, and the fruits marketed as dessert fruits (Gandhi, 1963). There are at least 15 or more named clonal selections grown in India, Malaysia, Indonesia, Thailand, South Africa, Florida, Brazil, Puerto Rico, and Hawaii, but their total acreage is small compared to that of seedlings. Guavas grown commercially in Cuba, Brazil, the Dominican Republic, Mexico, and the Philippines are mostly seedlings. There is no doubt that selected clonal varieties are superior to seedlings. The myth persists that seedlings can be of uniformly high quality, but they almost never are.

Guava flowers are attractive to insects, and considerable cross-pollination takes place. Wild guavas exhibit wide variation in size, shape, color, and quality, making guavas an ideal fruit for improvement by selection and clonal propagation. In spite of this, most guavas grown in orchards or collected in the wild are from open-pollinated seedlings.

In the past, most horticulturists have considered guavas difficult to propagate asexually. Root suckers, tip cuttings, root cuttings, and air-layers are the propagation methods most often used. Work in Hawaii has shown that guavas can be propagated easily and rapidly by patch (Forkert) budding, or from leafy tip cuttings under mist (Nakasone and Bowers, 1956). Because patch budding and tip cuttings under mist provide faster, more effective methods of propagation, there is presently no valid reason for planting seedling guava orchards.

Harvest and yield. Guavas are relatively delicate and easily damaged when ripe. They should be harvested in the mature-green stage before they turn yellow and become so soft and easily bruised that they are unacceptable for the fresh fruit market. When picked fully ripe, guavas have a short shelf life and are often infested with fruit fly larvae. Carefully handled mature-green guavas last about a week in refrigeration. Because fresh guavas have a relatively short shelf life, manufactured guava products offer a considerable advantage in handling and transport. The characteristic strong odor of soft, fully ripe guavas is not generally appreciated by people not accustomed to it.

Under favorable conditions, guavas fruit heavily and annual production of up to 30 T/A is possible. There are usually two crops per year: a heavy summer or fall crop and a smaller winter crop. Guavas are produced on new growth, and time of cropping can be controlled by judicious pruning of medium-sized branches, with 1- to 2-in diameters, to force growth of new fruiting shoots.

Nutritional value. Guavas are an excellent fruit nutritionally. They blend well with other fruits in salads and mixed fruit juices and are an excellent source of vitamin C. On an average, guavas contain about twice as much vitamin C as oranges. Vitamin C is concentrated in the outer rind of the fruit, and small guavas contain more vitamin C per unit of weight than larger guava fruits. Selected guava clones have been found with up to 16 percent total soluble solids (TSS) and more than 500 mg of vitamin C per 100 g of pulp.

Use. A wide variety of good manufactured guava products are marketed and used around the world. These include vitamin C supplement, jams, jellies, juices, juice blends, juice concentrate, dehydrated guava powder, guava paste, guava leather, guava candy, canned shells, canned halves, and several others.

Outlook. The common guava is a much neglected fruit of great promise for future development.

Yellow Passion Fruit (*Passiflora edulis* f. *flavicarpa*)

Distribution. Yellow passion fruit is a vigorous, prolific vine native to the humid tropics of the Amazon basin in Brazil. It is grown commercially in Australia, Brazil, Colombia, Panama, Venezuela, South Africa, and Hawaii. Most of the juice is canned, usually after concentration. Brazil is a major producer, and several thousand acres are presently grown in the state of Bahia.

Description. The fruits are oval, weighing from 150 to 250 g each, and containing about 40 percent juice.

Propagation and culture. The vines are grown on trellises and are very vigorous. Individual vines are cross-compatible but self-incompatible, so that pollinating insects are necessary for good production. Propagation is mainly by cross-pollinated seed, which results because of self-incompatibility factors. Consequently, considerable variation commonly occurs in commercial plantings. Grafting is possible and is sometimes done in Brazil, Australia, and South Africa to minimize root problems and provide more uniformity. *Passiflora alata* is one of the rootstocks used.

Harvest and yield. Cropping is ordinarily for two or three years, and annual yields of up to 30 T/A are possible. The vines are relatively easy to grow, and very productive. The fruits are harvested as they mature and fall to the ground. They can be kept in good condition in unrefrigerated storage for a week or 10 days, but are generally used soon after harvesting. Centrifugal juice-extraction equipment is used to separate the juice from the seeds.

Use. Yellow passion fruit juice is an excellent flavor product and is very popular in the bar trade. It is used either fresh or as a canned juice concentrate. The juice blends well with other fruit juices and is used in canned or fresh fruit salads. It can also be used as a natural concentrate. One part yellow passion fruit juice and three parts water, sweetened to taste, is an excellent breakfast drink. There is a good demand for canned passion fruit juice concentrate in Europe and the United States.

Outlook. Because of the genetically controlled pollination mechanism in passion fruit and widespread use of open-pollinated seed, little if any improvement in planting material has occurred. If selected vines with high production of good quality fruit were planted and maintained in isolation as seed gardens, some improvement could be accomplished. Unfortunately, this has not been done.

Papaya (*Carica papaya*)

Distribution. Papayas are one of the most important, popular, and widely distributed fruits of the humid tropics. They are considered native to warm, high-rainfall areas of Central America and southern Mexico. Papayas are the most widely distributed fruit crop native to the American tropics and the only member of the family Caricaceae to achieve the status of a major fruit crop.

Description. Although the papaya plant is commonly referred to as a "papaya tree," it is really not a tree, but actually a large, tall, usually unbranched, herbaceous shrub. Grown under favorable conditions in fertile soil, a papaya plant can reach a height of 30 ft and girth of 3 ft at the base in five to 10 years. Papaya fruits vary widely, from seedy, thin-fleshed fruits of about 1-in diameter, growing spontaneously in Central America and Mexico, to large, thick-fleshed fruits up to 20 in long, weighing up to 15 lb.

Papaya plants may be female, male, or hermaphrodite. Female plants are stable and always produce female flowers, but the hermaphrodite and male plants often exhibit seasonal changes in flower type, ranging from androecious to gynecious. The basic difference between hermaphrodite and so-called male plants is one of peduncle length, since both exhibit a similar range and type of cyclical sex changes. In other words, there are really only two sex forms in papaya: the females, which are stable, and the extremely variable, unstable types of male and hermaphrodite plants, which have peduncle length as their major difference (Hamilton and Izuno, 1967).

Propagation and culture. Papaya seeds retain their viability for more than a year and have been carried by birds, animals, and people to all tropical and most subtropical countries, where they often become naturalized. Vegetative propagation is possible from cuttings or grafting, but the resulting plants are so weak, expensive, and generally unsatisfactory for fruit production that they are seldom used. Propagation is therefore almost exclusively by seed. Seedling populations tend to be variable because they are usually grown from open-pollinated seed. If open-pollinated seed is from female fruits, it is 100 percent cross-pollinated, and the resulting seedlings are genetically heterozygous and phenotypically variable. Seed from hermaphrodite fruits is often, but not always, self-pollinated seed and may occasionally produce relatively uniform seedling progenies.

There are only a few true breeding papaya cultivars in the world, the 'Solo' papaya of Hawaii being the outstanding example. This is because hermaphrodite flowers of this cultivar are 100 percent bud-pollinated and the 'Solo' papaya has become predominantly homozygous and highly inbred. The 'Maradol' papaya of Cuba is another fairly uniform cultivar when grown from seed of hermaphrodite plants. Many other recognizable papaya types occur throughout the world and have been given names, but are rarely true-breeding enough to be considered legitimate

cultivars. The seed usually planted is open-pollinated seed frequently obtained from female fruits. If the seed is hand-pollinated, or if the plants used to produce seed are grown in isolation, the resulting seedlings may be acceptably uniform, but this is rare. The most uniform and widely grown papaya cultivar is presently a highly inbred, red-fleshed 'Solo' strain called 'Sunrise Solo', which is presently the major export papaya cultivar in the world. 'Sunrise Solo' originated in Hawaii (Hamilton and Ito, 1968), but is grown principally in Brazil and tropical Africa. A somewhat similar yellow-fleshed 'Solo' papaya is grown mostly in Hawaii for domestic use and for export to the mainland United States.

Harvest and yield. Reported papaya yields vary greatly. This is due in part to the fact that many papayas have a genetically controlled sterile period of several months in the year, during which little or no fruit is set. Recorded annual yields of well-grown 'Solo' papayas in Hawaii range from 30 to 80 T/A. Annual yields reported from other countries are generally much lower, ranging from 5 to 15 T/A.

Nutritional value. Papayas are considered an excellent fruit from the nutritional standpoint. They are an excellent source of vitamin A and vitamin C and a fair source of calcium. Papayas are also considered to be a digestive aid.

Use. Papayas are used primarily as a dessert fruit, eaten alone or in mixed fruit salads. Processed papaya products are beginning to be used to a greater extent as canning methods improve. Aseptically processed papaya puree is a promising new product (Chan and Cavaletto, 1982). Papaya chunks and pieces are also becoming an increasingly important and desirable ingredient in canned tropical fruit salad.

Outlook. There is an urgent need to develop high quality, uniform, inbred papaya cultivars in most areas where papayas are grown. The present progenies planted are not true breeding enough to be considered cultivars and usually fail to produce uniform, high quality fruit suitable for export. They are also marginal for domestic use but continue to be used because better planting material is not available.

Peach Palm (*Bactris gasipaes*)

Distribution. Peach palm is a tall, elegant, usually spiny but occasionally spineless, palm bearing large clusters of nutritious, palatable fruit. It is considered native to the Amazon River basin and has spread northward from Bolivia to Costa Rica and Honduras. It is called "pupunha" in Brazil, and Arkcoll (1983) lists 11 synonyms

from seven countries. Several additional synonyms are known.

Description. Peach palm fruit is borne in clusters weighing 7 to 22 lb. Fruit from different trees varies in size, shape, and color. The largest fruits may have a diameter of 2½ in. Peach palm fruits range in color from green to yellow, orange, or red. Individual fruits resemble small peaches in shape and color, hence the English common name "peach palm."

Propagation and culture. Propagation is by seeds, and seedlings are quite variable. Trees with good quality fruit are kept for fruit production, while seedlings with inferior fruit are often cut down to provide an excellent source of edible palm hearts. Closely spaced seedling plantings of this palm have been made in Costa Rica for the sole purpose of harvesting the palm hearts. Peach palms develop multiple trunks from suckers or offshoots arising from below ground level, and these suckers may be planted like banana suckers to reproduce the mother plant. Because the offshoots are considered rather difficult to transplant successfully, commercial plantings are now made almost entirely from seedlings. A recent development in Costa Rica is clonal propagation of selected peach palms by tissue culture. This development in technique could make possible massive asexual propagation of superior palms, which could then be used to establish much improved commercial plantings.

Harvest and yield: Seedling palms spaced 12 x 12 ft in well-managed plantations can produce up to about 15 T/A of fruit. If clonal plantings of selected palms were established, yields could probably be doubled.

Nutritional value. The starchy, sometimes oily, edible mesocarp of the fruits is nutritious, palatable, and an excellent source of carbohydrate food energy. It is exceptionally rich in vitamin A but a poor source of vitamin C. Protein content is usually low, averaging about 2.5 percent, although in exceptional cases it is reported to be as high as 14.7 percent (Arkcoll, 1983).

Use. There are many recipes and possible methods of preparing and using peach palm fruit, but the principal use is as a basic food eaten after boiling in salt water. It is common to use various seasonings and condiments with the boiled fruit to supplement or enhance the flavor. These include salt, pepper, chili sauce, soy sauce, mayonnaise, catsup, lime juice, and vinegar. Although peach palm fruits are primarily a basic carbohydrate food useful in supplying food energy, they are frequently used as a snack or luxury food item. Because they are extremely

well liked wherever they are known, they are often in short supply and expensive.

Outlook. This elegant, useful palm produces highly palatable, nutritious fruit and deserves much wider use and recognition throughout the humid tropics, especially in Southeast Asia and Africa, where it is virtually unknown. Peach palm is well adapted to climatic areas where African oil palm, coconuts, and cacao are grown and could form a valuable addition to diets in such areas. This palm is not well known or widely grown in Hawaii, but experimental plantings at the University of Hawaii experimental farms at Waiakea and Kona produce good quality fruit.

SOUTHEAST ASIAN FRUITS

Banana (*Musa* sp. Hybrid)

Distribution. Bananas, which include the starchy types often referred to as "plantains," are the most important fruit crop of the tropics. About half of the total world production is eaten raw and the other half after cooking. Bananas of all types belong to the family Musaceae. The vernacular name "plantain" and its Spanish counterpart "platano" are redundant but so well established that they cannot be ignored, abandoned, or restricted (Simmonds, 1972). In this publication, sweet dessert bananas and starchy cooking bananas (plantains) are discussed together since they are of common origin, differing mainly in starch and sugar content.

Bananas, regardless of name, originated in tropical rain forest areas of Southeast Asia, the probable area of origin being the Assam-Burma-Thailand area (Purseglove, 1972). Two diploid species, *Musa acuminata* and *M. balbisiana*, are the parental species. Almost all of the edible bananas are seedless triploid clones evolved naturally from these diploid ancestors.

Description. If we use A to designate *M. acuminata* and B for *M. balbisiana*, the genetic constitution of almost all sweet dessert bananas is either AAA or AAB, while that of starchy cooking bananas is AAB or ABB. A few parthenocarpic diploid and tetraploid cultivars exist but are rare. There are also a dozen or more *M. troglodytarum* cooking banana cultivars with upright fruit bunches found in Tahiti, Fiji, and other islands of the South Pacific area (Simmonds, 1972). Considering edible bananas of all types, there are thought to be approximately 300 banana cultivars in the world (Simmonds, 1972). About half of these are starchy types used primarily after cooking, while the remaining half are sweet dessert cultivars usually consumed raw. There is no exact dividing line between the two types; the so-

called dessert bananas are often cooked in the immature green stage before their starch content has turned to sugar. In many areas where bananas are grown, they are a major staple food boiled, roasted, or fried in various ways. In other areas, including Europe, Canada, Japan, and the United States, bananas are usually consumed raw as dessert fruit.

About 25 banana cultivars were introduced to Hawaii by early Hawaiian immigrants prior to the rediscovery of the Hawaiian islands by Captain Cook in 1778. These are primarily cooking bananas grown on a small scale, mostly in home gardens or dooryard plantings. Since 1855, 27 additional banana varieties have been introduced to Hawaii from Tahiti, Latin America, India, and the Philippines. Twenty of these are primarily dessert varieties, and seven are cooking varieties.

Propagation and culture. Propagation of all bananas is from suckers, which are offshoots arising from axillary buds on the main corm. Older fruiting and nonfruiting corms are also sometimes trimmed and used as planting material. Tissue culture is possible and sometimes used for rapid aseptic multiplication when there is a shortage of conventional planting material.

Harvest and yield. Bananas are a high yielding crop, and when well grown on suitable soils, high yielding dessert clones can produce annual yields of up to 25 T/A; yields may be up to 16 T/A for cooking bananas, which generally have large fruits but relatively small bunches. Average yields are generally less than half of maximum yields. Bananas have excellent postharvest characteristics for export because they can be picked mature-green, transported to market by ship, rail, or truck in this green stage, and ripened artificially several weeks after harvesting.

Nutritional value. Bananas are a very good source of sugar and readily digestible starch, but their vitamin content is relatively low (see Table 3). They are, however, a very good source of potassium.

Use. Bananas of all types are palatable, popular, and highly acceptable food crops. Because of these qualities and their ease of production, bananas, particularly the cooking types, deserve promotion and expansion throughout the tropics. The use of processed banana products such as pasteurized puree, banana figs, and dehydrated banana chips should also be promoted and expanded.

Outlook. Cooking bananas are already an important staple food in many tropical countries. Because of their ease of culture,

palatability, and wide acceptance, all types of bananas deserve wider use in areas where they can be grown.

Breadfruit (*Artocarpus altilis*)

Distribution. Breadfruit, one of the most important fruits of the family Moraceae, is an important staple food crop in most of the islands of Polynesia, Melanesia, and Micronesia. It is also important in parts of the Malay archipelago. Breadfruit is considered native to the Malay archipelago, probably New Guinea. It has been carried to practically all of the inhabited tropical islands of the South Pacific in migrations and by travelers. Breadfruit has been used in Polynesia for more than 2000 years (Molesworth Allen, 1967) and although it is often believed to be native to that area, there is good evidence that it is not. Breadfruit was a staple food of ancient Hawaiians, and breadfruit trees are still found growing around old home sites on all of the major Hawaiian islands.

Breadfruit is used to a lesser extent in Southeast Asia and India. It was imported to Jamaica as early as 1793 (Purseglove, 1968). It has not become important as a food crop in the Western Hemisphere, although it is still used to some extent in Jamaica, Trinidad, and several other islands of the West Indies. Breadfruit is also used to a limited extent in Guyana, Surinam, Brazil, and most of the Central American countries. There are only a few different clones in the Western Hemisphere, and perhaps not more than three or four cultivars are grown in the area. Only one clone has been observed in Brazil and Mexico, although there may be more.

More than 100 seedless cultivars have been selected and are presently grown in the Polynesian and Micronesian islands of the South Pacific where breadfruit is an important staple crop. There are also about 70 different named cultivars from Fiji, Samoa, and Tahiti, several of which are apparently synonyms. There are 12 distinct cultivars grown on the small island of Kosrae alone (Chia, 1983). Seedless cultivars have been exchanged and taken to other islands, where they are often given new names. Because of this, there are many synonyms and it would be difficult to accurately estimate the actual number of cultivars involved.

Description. Breadfruit is a tall, handsome tree sometimes growing up to 60 ft high (Purseglove, 1968). It produces well under warm, high-rainfall conditions and deserves to be grown as an ornamental fruit tree in all of the high-rainfall islands of Micronesia, where it is well adapted (Sprout, 1968). In addition to the seed-

less breadfruit there are seedy forms, and the boiled or roasted seeds are the part consumed. Although of the same species, the seedy diploid forms are called "breadnuts" and do not compare with the seedless breadfruit as a food source.

Propagation and culture. It is not known how so many seedless breadfruit cultivars evolved, but there are two apparent possibilities. One is that seedless clones arose by bud mutation of seedy types. The other is that seedless clones originated from triploid seed resulting from fertilization of an unreduced diploid egg cell by haploid pollen. Both methods are possibilities, and seedless forms are logical to select because the fruit has more edible pulp. In any case, many good clones exist in the South Pacific islands, differing in size, shape, flavor of fruit, season of maturity, and leaf type. There does not seem to be any urgent need for plant breeding efforts to develop new breadfruit clones. The numerous excellent seedless breadfruit cultivars grown in Oceania and Southeast Asia have been selected to provide a wide range of fruit sizes and flavors, as well as early, late, and midseason cultivars to increase the period of availability.

Breadfruit trees are tolerant of brackish water and require little care other than occasional applications of organic fertilizer.

Harvest and yield. Breadfruit does not keep long after ripening and is used primarily as a fresh vegetable. It can be stored a few months if sliced and sun dried. Surplus fruits are sometimes fermented in pits to produce a doughy paste called breadfruit poi, which keeps well for several weeks because of its acidity.

Yields of breadfruit are almost impossible to estimate because they are always grown as dooryard trees and rarely if ever planted in orchards. Well-grown mature trees may produce 200 lb of fruit, which, if spaced 40 x 40 ft, could produce about 5 T/A. This is considered a good yield of breadfruit.

Nutritional value. Breadfruit contains very little fat and protein but is an excellent source of carbohydrates and food energy. It is a good source of calcium but low in vitamin A and ascorbic acid.

Use. Breadfruit is used primarily as a cooked vegetable and carbohydrate source. It may be boiled, roasted, fried, or grilled, either alone or mixed with other food and seasonings.

Outlook. Breadfruit is an excellent, easy-to-grow, palatable, high energy fruit, and is fairly well known in Hawaii. Because of its ease of culture and palatability, breadfruit deserves much wider attention and expanded use, especially in tropical America.

Durian (*Durio zibethinus*)

Distribution. Durian, the most important fruit in the family Bombacaceae, is native to the Malay archipelago and has been grown in Southeast Asia for hundreds of years. The genus *Durio* contains about 27 species, at least six of which produce edible fruit (Soegeng, 1962). *D. zibethinus*, the cultivated durian, is by far the most important of these. Durians are grown throughout Southeast Asia, being especially well known and highly esteemed in Thailand, Malaysia, the Philippines, and Indonesia, where more than 50 clonal cultivars have been selected. Although rare in Hawaii, durians are occasionally grown as dooryard fruit trees in favorable locations by those who know and appreciate their distinctive flavor and aroma.

Description. Durians are large fruits weighing from 2 to 10 lb, with a thick, fibrous skin studded with short, sharp, pyramidal spines. The fruit is made up of three locules containing the pulp and seeds. The rich, creamy, highly aromatic pulp surrounding the seeds is the edible portion. The flavor and aroma are much liked by those who appreciate durians, and the price for a good durian, from about \$4 up to \$20 U.S. per fruit, speaks for itself.

Propagation and culture. Propagation is usually by patch budding or inarching. Durian trees grow up to 120 ft tall, so there is a danger from falling fruit when walking under large trees as the crop matures.

Harvest and yield. Fallen fruits sell for only about one fourth to one half as much as comparable mature fruits harvested from the tree. In Thailand a record of flowering time is kept so that fruits can be harvested when fully mature but before they fall. Mature durians picked from the tree can be kept in cool storage at 50° to 60°F for at least 10 days, and are sometimes shipped from Thailand to be marketed in Hong Kong, Singapore, Malaysia, and Japan. A recent development in durian marketing is the shipment by air of frozen durian segments from Thailand to the U.S. West Coast and Hawaii, where they command very high prices.

Use. Durians are consumed mainly as a fresh fruit, although durian-flavored candy is a fairly common item in several countries of Southeast Asia. Recently a dehydrated durian powder was developed in the MARDI food laboratory in Malaysia. It is an excellent product used in flavoring ice cream and various other food products.

Outlook. There is no good reason why durians could not be grown in humid tropical areas of the Americas. There are presently a few durian trees growing and producing in warm

humid parts of Honduras, Panama, and Hawaii. Like mangosteens, durians have not become a well-known or widely grown fruit in tropical America, although they probably could become popular in the future.

Pummelo (*Citrus grandis*)

Distribution. Pummelos are native to the Malay peninsula, probably Thailand and Malaysia, from where they spread north to China. Pummelos have their greatest development and importance in Southeast Asian countries, where they are highly regarded. Although well-grown fruits of the best cultivars have been considered the best of all citrus fruits for dessert purposes, pummelos are little known and seldom grown in the American tropics. They are the most tropical of all citrus species and develop their best quality in warm tropical areas where they are grown near sea level. Pummelos can tolerate brackish water and poor drainage where other citrus fruits usually fail.

A few good clonal pummelos can be found in the Yucatan peninsula in Mexico, as well as in Brazil, near Belem and in Amazonas, between Manaus and Itacoatiara. Good pummelos are occasionally found in Hawaii, but most of the pummelos grown in this state are seedlings, many of which produce extremely variable fruits of mediocre to poor quality. Air-layered trees of several good seedlings selected in Hawaii are grown in dooryard plantings as combination ornamental fruit trees. Three of the best of these are 'Leslie', 'Pauthel', and 'Haiku B'.

Countries where pummelos are grown as a commercial crop, usually from selected clonal cultivars, include China, Thailand, Malaysia, Indonesia, Taiwan, the Philippines, Kampuchea, and Vietnam. The best pummelos in the world are produced in Southeast Asia, especially South China, Thailand, Malaysia, and Taiwan, where they are highly prized and often expensive. During the Chinese New Year holiday it is not uncommon to pay several dollars for a good pummelo fruit.

Description. Pummelo fruits are large and usually, but not always, thick skinned. Pummelos vary in shape and may be round, oblate, or pyriform. They also vary in size. The largest fruits may weigh as much as 6 lb. Thin-skinned, juicy pummelo clones may be used in the same way as the grapefruit they resemble. The best pummelos are usually not as juicy as grapefruit, however, and can be peeled, separated into segments, the membrane surrounding the sections removed, and the sections eaten out of the hand. The quality and flavor of the best pummelo cultivars, such as 'Thong Dee', 'Kao Pan', and

'Kao Yai' from Thailand, are generally considered superior to all other citrus fruit by those who have had the good fortune to sample them.

Propagation and culture. Unlike limes, oranges, grapefruits, and tangerines, which have seeds with polyembryonic embryos, pummelo seeds are monoembryonic and have sexual embryos. This is why pummelos do not come true from seed. Each seedling is a new and often interspecific hybrid, depending upon the pollen source. Pummelos are also self-incompatible, so that solid block plantings of a single pummelo clone grown in isolation produce seedless fruits. Such fruits usually sell for premium prices. This simple, effective method of producing seedless pummelos is common in Thailand but not well known in other countries. In the United States, where pummelos are mostly grown in citrus collections or in orchards with other citrus species, it is not uncommon to find pummelo fruits with 100 or more seeds. To produce seedless pummelos, trees of a single clone must be planted well isolated from other citrus fruits. There is a great variation among pummelo seedlings, so it is natural to select the best seedlings and propagate them clonally. This has been done in most countries where pummelos are grown and is the method by which most cultivars have originated.

Trees of selected pummelo clones grown commercially in Southeast Asia are usually air-layers. They are also sometimes grafted or inarched on rough lemon or other citrus rootstocks, but marcotts or air-layers are usually preferred.

Very little organized breeding work has been done with pummelos, although a very good quality red-fleshed pummelo named 'Chandler' was bred and released by plant breeders at the University of California at Riverside. Cultivars used in Southeast Asia are outstanding seedlings, some of which were selected hundreds of years ago. There are at least 20 named varieties grown in Southeast Asia under local names. Because most pummelo cultivars are of ancient origin, many carry virus diseases, especially tristeza. Certain cultivars apparently have good tolerance to tristeza since they continue to thrive and produce good fruit in spite of the fact that they are known to carry the disease.

Harvest and yield. An outstanding feature of pummelo marketing and utilization is their unusually long shelf life. Pummelos can be stored two to three months without deterioration. No other citrus fruit has as good post-harvest characteristics and long storage life as pummelos. For example, if quarantine restrictions permitted, mature pummelos could be

shipped from Hawaii to the U.S. mainland by boat and arrive in good condition. In fact, it is generally conceded that the quality of pummelos is improved by storing them for a month or more before eating.

Nutritional value. Pummelos are a good source of vitamin C, and the best varieties have up to 15 percent soluble solids.

Use. Pummelos are primarily a high quality dessert fruit for fresh consumption.

Outlook. Pummelos are truly a neglected crop with a promising future in the Americas. Their outstanding flavor, quality, and excellent postharvest handling characteristics give them an excellent chance for future development. Furthermore, there are large areas of tropical America where good pummelos could be grown. These include the Amazon basin and Campeche, Quintana Roo, and Yucatan in Mexico. Improved clonal varieties of pummelo can produce good quality fruit in warm, sheltered areas of Hawaii below 1000 ft in elevation.

Rambutan (*Nephelium lappaceum*)

Distribution. Rambutans, which are native to the rain forests of Malaysia, are an important and well-accepted fruit of the family Sapindaceae. Rambutans are grown and consumed principally in Southeast Asian countries, including Malaysia, Indonesia, Thailand, Laos, Kampuchea, Vietnam, and the Philippines. They are also grown and marketed in Costa Rica. In Hawaii, rambutans have fruited in Lahaina, Hilo, and Kona.

Description. Individual fruits may be red, pink, or yellow and quite similar in form, shape, and flavor to lychee fruits. In fact, rambutans have been called "the lychee of the tropics." The fruits have a single large seed surrounded by the edible pulp, enclosed in a leathery skin covered with fleshy pliable spines. The flesh is sweet and juicy with a pleasant subacid flavor.

Propagation and culture. Rambutans are often propagated by seed, but selected clones propagated by patch budding, inarching, and air-layering are preferred. More than 20 clones have been selected and named in Thailand, Indonesia, and Malaysia. Improved clones are recognized by name and their fruit is usually sold at higher prices than that from seedling trees. Since many seedling trees are also grown, seedlings with outstanding production and high quality fruit have become well known and eventually established as clones. This has been the principal method of obtaining better cultivars. There has been little or no organized plant breeding with rambutan.

Harvest and yield. The fruit is borne in large terminal clusters, and fruiting is regular and heavy under favorable conditions. Rambutans are harvested by breaking off the terminal fruiting branches, which are then marketed with the fruits still attached. Mature rambutan trees often bear up to 450 lb of fruits per year. After harvest, shelf life is less than one week unless the fruit is refrigerated.

Use. Rambutans are usually consumed as fresh dessert fruits after removing the leathery outer membrane, or pericarp. In Thailand and Malaysia, the fleshy pulp is canned in sugar syrup after removing the seed and outer membrane.

Outlook. The resemblance of rambutans to lychees in flavor and color and their good quality and ease of culture under humid tropical conditions make them a promising fruit for expansion in Hawaii and areas of the tropics where they are not well known but could be grown. The excellence of canned rambutans is another desirable characteristic.

CONCLUSION

It is hoped that this modest attempt to sort out and characterize some of the important and potentially important fruits of the humid tropics will be of some interest and value to students of tropical fruits in Hawaii. It is a fascinating and sometimes frustrating group of plants to deal with, as there are more than 110 fruits in the Amazon basin alone (Cavalcante, 1972, 1974, 1979). Of the many interesting and varied native fruits of the tropics, relatively few are presently important on a worldwide basis. Peach palm is considered one of the most promising, but is presently only regionally important. Food habits and preferences are unpredictable, difficult to analyze, and slow to change. Who can predict, with much confidence, which of the various fruits discussed here will eventually become important in Hawaii or other tropical areas around the world with similar climates? Time will tell!

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