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# **GENETIC RESOURCES OF TROPICAL AND SUB-TROPICAL FRUITS AND NUTS**

**(Excluding *Musa*)**



**International Board for Plant Genetic Resources**

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INTERNATIONAL BOARD FOR PLANT GENETIC RESOURCES

GENETIC RESOURCES OF  
TROPICAL AND SUB-TROPICAL FRUITS AND NUTS  
(Excluding Rusa)

IBPGR Secretariat  
Rome, July 1986

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## INTRODUCTION

In 1980 the International Board for Plant Genetic Resources (IBPGR) commissioned the Royal Tropical Institute, Amsterdam, the Netherlands, to prepare reports concerning specific aspects relevant to the conservation of genetic resources of a number of - mainly tropical and sub-tropical - fruit and nut crops. Some major crops, such as banana and plantain, which have been covered in other recent IBPGR publications, were not included. Most of the work was carried out by Ir. F. Geurts, but the account for pejobaye was written by Ir. G. Blaak, and the date palm by Dr. T. El Baradi, all at the time staff of the Institute's Department of Agricultural Research.

The draft reports were completed between December 1980 and September 1982, and then sent by IBPGR for review to several external experts. In 1985 the reports were edited and condensed as chapters of the present publication. The comments of the crop experts, updated information on the current status of collections, and any new references were incorporated in the final draft.

The crops covered are a diverse group, ranging from those of major international importance supporting large industries to locally-important species grown only on a home-garden scale. They vary also in their contribution to diet. While the majority of them are high in carbohydrate and supply some vitamins (especially vitamin C) and minerals, but are of low nutritional value otherwise, some, like breadfruit, date, avocado or cashew nut, may make a significant contribution to protein, carbohydrate or fat intake in certain areas. Some of the crops may be only moderately interesting because of the fruit itself, but have a wide range of other actual or potential uses in medicine, industry or agriculture.

The current state of genetic erosion in fruit trees is influenced by many factors, including the origin and distribution of the crop, its breeding system, the propagation method used, whether improved cultivars are available, whether the crop is in decline or expanding, and whether the natural habitat of its wild ancestors and relatives is under threat. An attempt has been made to answer these questions, and in light of the answers come to conclusions regarding the need for genetic resources conservation measures. In each chapter dealing with a crop, or a few related crops, there is a table which summarizes the existing germplasm collections around the world. The data in the tables relate to another IBPGR publication <sup>1/</sup>, which gives further details on collections and addresses, and this document should be used in conjunction with the present work.

A few general points apply to most of the crops: i) conservation in field genebanks is rarely adequately representative of the variability; ii) where seed can be stored there is little evidence of it so far; and iii) in situ conservation will be important for the wider gene pool. Hitherto the wider gene pool has been barely exploited, except in cases where it has been necessary for rootstocks. Most fruits have numerous related wild species, which are imperfectly understood (Williams, 1976). Success in conservation will be determined by economics and by the degree of sophistication in breeding. In many tropical and sub-tropical fruits this is little understood.

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<sup>1/</sup> IBPGR. 1984. Directory of Germplasm Collections 6.1. Tropical and Sub-Tropical Fruits and Tree Nuts. P. Gulick and D.H. van Sloten. IBPGR, Rome.

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Table 1. The nutritional composition of tropical crops (mostly from Platt, 1975)

Crop/product	Representative values per 100g of edible portion													
	Water (g)	Calories (g)	Protein (g)	Fat (g)	Carbohydrate (g)	Fibre (g)	Calcium (mg)	Iron (mg)	Vitamin A potency (i.u.)	Thiamine (mg)	Riboflavin (mg)	Nicotinamide (mg)	Ascorbic acid (mg)	% waste
Cashew nut	5	590	20.0	45.0	26	1.3	50	5.0	0	0.60	0.20	2.1	0	-
Cashew apple	85	56	0.7	0.0	13	0.6	2	0.5	150	0.02	0.02	0.5	250	29
Mango	83	63	0.5	0.0	15	0.8	10	0.5	600	0.03	0.04	0.3	3	34
Pistachio nut	6	626	20.0	54.0	15	2.0	140	14.0	100	0.70	0.20	1.5	0	-
Amberella	75	95	1.0	0.0	23	0.6	20	1.2	50	0.10	0.04	1.0	40	31
Soursop	75	93	1.0	0.0	22	1.0	25	0.5	0	0.10	0.08	0.8	30	26
Durian	-	-	-	3.0	33	-	-	-	-	-	-	-	-	82
Pineapple	85	57	0.4	0.0	14	0.5	20	0.5	100	0.08	0.03	0.1	30	40
Papaya	89	39	0.6	0.0	9	0.7	20	0.5	1000	0.03	0.03	0.2	50	30
Kaki	80	73	0.5	0.0	18	1.2	10	0.4	2000	0.02	0.02	0.2	20	20
Emblic	80	65	0.5	0.2	15	3.4	20	0.5	0	0.03	0.05	0.2	500	-
Mangosteen	85	-	0.5	0.1	14	-	170	0.2	-	-	-	-	-	70
Avocado	75	165	1.5	15.0	6	1.5	10	1.0	200	0.07	0.15	1.0	15	30
Acerola	92	31	0.4	0.3	7	0.4	12	0.5	20	0.03	0.05	0.4	2000	17
Langsat	86	-	-	-	10	2.0	-	-	-	-	-	-	-	40
Breadfruit pulp	70	113	1.5	0.4	26	1.3	25	1.0	0	0.10	0.06	1.2	20	23
Jackfruit pulp	80	72	1.5	0.3	16	1.5	20	0.5	150	0.03	0.03	0.4	8	72
Fig, fresh	85	49	1.3	0.0	11	2.0	50	1.0	80	0.05	0.05	0.4	2	0
Fig, dried	20	269	4.0	0.0	63	11.0	200	4.0	100	0.10	0.08	1.7	0	0
Guava <sup>1/</sup>	80	58	1.0	0.4	13	5.5	15	1.0	200	0.05	0.04	1.0	200	20
Rose apple	85	56	0.6	0.0	13	0.7	10	0.5	0	0.03	0.03	0.3	15	23
Date (dried)	20	303	2.0	0.0	74	2.4	70	2.0	50	0.07	0.05	2.0	0	13
Pejlbaye (fruit)	50	209	2.5	3.5	42	1.1	20	1.5	500	0.04	0.10	1.5	25	-
Passiflora fruit <sup>1/</sup>	75	92	2.3	2.0 <sup>3/</sup>	16	3.5	10	1.0	20	0.00	0.10	1.5	20	43
Macadamia nut	3	-	8.0	71.0	16	2.5	-	-	-	-	-	-	-	-
Pomegranate	80	77	1.0	0.0	18	0.2	3	0.7	0	0.02	0.03	0.2	8	44
Indian Jujube	83	63	1.8	0.0	14	0.6	25	0.8	0	0.02	0.04	0.9	65	7
Orange & Tangerine	86	55	0.8	0.0	13	0.3	30	0.5	50	0.08	0.03	0.2	45 <sup>2/</sup>	25
Citrus (other) <sup>2/</sup>	90	37	0.6	0.0	9	0.4	21	0.5	0	0.05	0.01	0.2	40 <sup>2/</sup>	27
Litchi	82	71	0.9	0.5	16	0.3	5	0.5	-	0.04	0.04	0.3	50	40
Longan	82	-	1.4	0.4	8	0.6	-	-	-	-	-	-	-	68
Rambutan	82	-	-	-	16	-	-	-	-	-	-	-	-	61
Sapodilla	75	97	0.4	1.0	22	1.5	22	0.8	15	0.00	0.03	0.2	15	23
Canistel	57	-	2.5	0.6	39	7.5	40	1.1	2000	0.02	0.07	-	43	-
Lucmo	72	-	1.5	0.5	25	1.3	16	4.6	1500	0.11	0.14	-	5	-
Tree tomato	86	46	1.5	0.5	9	2.2	50	0.2	150	0.04	0.03	1.0	25	27

<sup>1/</sup> Flesh and seeds

<sup>2/</sup> Skin has a high value 90-150 mg.

<sup>3/</sup> Fat in seeds

<sup>4/</sup> Grapefruit, pumelo, lemon, lime

Other sources of data

Durian (Dohse and Bakhuizen van den Brink, 1931; Soegeng Raksodihardjo, 1962)

Mangosteen (Anon., 1956; Stanton, 1966)

Langsat (Singh *et al.*, 1967)

Smooth-shell Macadamia nut (Woodroof, 1967)

Longan (Anon., 1952)

Rambutan (Anon., 1966)

Canistel, Lucmo (Martin and Malo, 1978)



Table 2. FAO production statistics of the major tropical and sub-tropical fruit and nut crops <sup>1/</sup> <sub>2/</sub>

Crop	1973-75	1976-78	1979-81	1982-84
Bananas and Plantains	55,710 (98.8)	60,491 (98.9)	62,725 (98.7)	64,532 (98.7)
Citrus fruits	46,466 (43.6)	49,833 (46.6)	54,171 (50.3)	56,253 (55.9)
Pineapple	11,575 (99.9)	12,125 (99.9)	13,075 (99.9)	14,042 (99.9)
Mango	5,717 (81.8)	6,832 (86.1)	8,119 (87.7)	8,513 (88.6)
Date	2,299 (98.2)	2,458 (98.4)	2,576 (98.6)	2,567 (98.6)
Papaya	1,386 (97.2)	1,627 (99.9)	1,855 (97.2)	2,048 (97.4)
Avocado	1,139 (90.6)	1,290 (87.1)	1,403 (84.6)	1,595 (80.0)
Persimmon	794 (62.0)	811 (65.8)	897 (70.2)	1,084 (69.8)
Fig	972 (49.9)	904 (56.5)	916 (60.6)	941 (65.3)
Cashew nut	583 (100.0)	463 (100.0)	440 (100.0)	429 (100.0)
Pistachio nut	61 (94.9)	75 (95.7)	91 (86.0)	139 (83.1)

<sup>1/</sup> Average annual yields for three-year periods are in 1000 metric tonnes.

<sub>2/</sub> Figure in brackets after the yield figure is the percentage of the crop grown in the developing countries, as defined in the FAO Production Yearbooks.

ANACARDIUM OCCIDENTALE  
(Cashew)

1. INTRODUCTION

The cashew tree yields 3 products: an edible nut, an edible swollen pedicel, and a phenolic liquid with industrial uses. The principal product, the kernel or nut, varies considerably in composition, but is of high nutritional and calorific value. The nuts are a rich source of unsaturated fatty acids, calcium, iron, thiamine, riboflavin and nicotinamide. "Cashew Nut Shell Liquid" (CNSL) obtained from the shell, has numerous industrial uses, the main ones being for brake linings of motor vehicles, and in paints, chemicals and plastics. The shells contain 20-25% CNSL of which 7-12% is commonly recovered, but only a small proportion of all cashew shells are used. The cashew 'apple' is the fleshy stem below the fruit. It produces a gum used in varnishes (cashawa gum), and is used as a table fruit or processed into paste, jam, juice, beverages (e.g. Brazilian cajuardo), vinegar, candied fruit, etc. It is similar in composition to that of many other succulent fruits, with a low calorific value, low protein and fat content, but has a very high vitamin C content (Table 1).

Cashew ranks third after almonds and hazelnuts on the basis of total world production of tree nuts. Total world production fell between 1974 and 1983 (Table 2), and exports declined from 210,000 tons to 60-70,000 tons. During this period, production remained stable in India at 91,400 tons, dropped in Africa, especially in Mozambique (from 188,000 to 20,300 tons), and Tanzania (from 142,000 to 45,700 tons), and increased slightly in Brazil (from 61,000 to 66,000 tons) (Gill and Duffus Landauer Ltd., 1984). Countries currently developing a cashew industry include Benin, Colombia, Côte d'Ivoire, Indonesia, Malaysia, Nigeria, Peru, Togo, Uganda and Venezuela (Ohler, 1979).

2. TAXONOMY AND BOTANY

The genus Anacardium was established in 1753 by Linnaeus with the single species A. occidentale, the cashew. Subsequently at least 25 further species were described, the most recent being A. othonianum Rizzini. Some taxonomists placed some of the species in related genera, such as Semecarpus. Cavalcante (1972) listed the following species with edible pseudo-fruits/seeds, in addition to A. occidentale L.:

- (i) A. giganteum Hancock ex Engler, a majestic tree up to 40 m high and common in the Amazonian high forest, which is occasionally cultivated for its edible 'apple';
- (ii) A. microcarpum Duke, a tree, 4-6 m high of dry soils with an edible 'apple';
- (iii) A. negrense Pires et Froes, a tree up to 15 m high, one of 2 species without a swollen pedicel. The real fruits are roasted and can be stored for long periods, and the seeds are edible; and
- (iv) A. spruceanum Bentham, a tree of 20-25 m high in Amazonian forest with an edible, but rather sour 'apple'.

The cashew plant is an evergreen, woody, much-branched tree up to 15-20 m tall. Leaves alternate, simple, glabrous, thick and leathery, oblong to obovate, 10-20 cm x 5-10 cm. Inflorescence a panicle with numerous (up to 1000) hermaphrodite or staminate flowers; hermaphrodite flowers usually terminal on a short (2 mm) pedicel; usually with 5 petals, 5 sepals, 1-2 long stamens, 8-9 short stamens (staminodes), and a superior, reniform, monocarpellate ovary; staminate flowers similar in structure to the perfect ones, but smaller, and with a sterile, rudimentary pistil; after fertilization, the ovary develops into a one-seeded fruit, the receptacle swells and becomes a pseudo-fruit, the 'apple'. Fruit when mature a kidney- or heart-shaped achene, commonly, though incorrectly, called a nut; of average size 3 cm x 2 cm x 1.2 cm, and weight 5-6 g. but there may be great variation; pericarp comprises a coriaceous

epicarp, a spongy mesocarp containing alveoles with a sticky, resinous liquid, CNSL, and a hard endocarp. Seed slightly curved, 1.5 cm to 2 cm x 1 cm, consisting of a creamy white kernel covered by a thin, reddish-brown testa; pseudo-fruit when ripe ranging in colour from red to yellow, and of variable shape and size; larger diameter 5-11 cm, weight 20-100 g or more (Agnoloni and Giuliani, 1977; Ohler, 1979; Nair et al., 1979).

The ratio of male:hermaphrodite flowers in any panicle is about 1:6. The flowers are pollinated by wind and insects. Honey bees may be the most effective, collecting both nectar and pollen (Crane and Walker, 1984).

Stands of cashew trees, particularly in South America, often show significant tree-to-tree variation in such characters as habit, vigour, flowering date, and panicle, 'apple', and nut size and shape. By comparison, the variability, and presumably the genetic base, is more restricted in India. Trees which are similar, for instance in flowering time, nut size and red 'apple' colour, can be considered as cultivar groups, or loosely as cultivars (Agnoloni and Giuliani, 1977). Damodaran et al. (1979) presents a detailed description of 4 cultivars using a wide range of characteristics. The IBPGR is due to publish a descriptor list for cashew in 1986.

### 3. ORIGIN, DISTRIBUTION AND ECOLOGY

The cashew probably originated in the states of Maranhão or Ceara in northeastern Brazil. It spread in pre-Columbian times to large areas of South and Central America. The Portuguese and Spaniards took it to Africa and Asia in the 16th and 17th centuries, and later it reached northern Australia, Fiji, Hawaii and southern Florida.

Today cashew is naturalized and cultivated in many tropical countries. Most commercial production occurs at low altitudes between 30°N and 23°S. Cashew is sensitive to frost especially in its young stages, and growth stops below 7°C. Growth is most rapid at an optimum temperature, measured on a monthly average basis of 27°C (15°C minimum, 35°C maximum). Cashew needs a well-defined dry season of at least 4 months, the amount of rainfall required depending very much on distribution and soil type, but generally 1,000-2,000 mm per year over a 6 to 8 month period is suitable for commercial cultivation. Heavy rain during flowering is harmful. The cashew tree is regarded as very suitable for the re-forestation of poor, exhausted and eroded lands, although the best crops are produced on deep and fertile soils.

### 4. AGRONOMY, DISEASES AND PESTS

Cashew has hitherto mostly been propagated from seeds, which germinate within 15 to 25 days. The seedling populations are often highly heterogenous, and vegetative methods of propagation must be used to maintain the characteristics of selected trees. Various grafting and layering techniques can also be used to produce clonal populations, albeit at relatively high cost (Ohler, 1979). Trees begin to bear fruit after 3 years, and reach full production after 7 years.

Up to 28 fungus diseases affect cashew. Anthracnose (Colletotrichum gloeosporioides) is common and serious, usually being preceded by damage by Helopeltis species. Water-soaked lesions develop on affected shoots, inflorescences and fruits, resulting in die-back and finally death of the whole tree. Fungicidal sprays, preferably in combination with insecticides, may be used to control it. Powdery mildew (Oidium anacardii) is a recurrent disease in many cashew-growing areas of the New World. Leaves, shoots and inflorescences are covered with a floury whitish film, leading to discoloration of leaves and loss of flowers. Control is by fungicides (Ohler, 1979).

Of 100 insects and mites, the following are major pests of cashew: Mecocorytus loripes (Coleoptera), a weevil in East Africa the larvae of which make extensive tunnels in the trees; Plocaederus ferrugineus (Coleoptera), a weevil in India with wood-boring grubs; Anthistarcha binocularis (Lepidoptera), a butterfly in Brazil with larvae boring

into young twigs and inflorescences; Anarsia spotias (Lepidoptera), a shoot-borer in India; Paranaleptus reticulata (Coleoptera), a beetle in Kenya which girdles branches and causes them to break off; Crimissa cruralis (Coleoptera), a red beetle in Brazil, the adults and larvae of which are voracious leaf feeders; Acrocercops syngramma (Lepidoptera), a leaf miner, especially on the west coast of India; Several Helopeltis spp. (Heteroptera), bugs in Africa and India sucking on soft and young tissues, often causing die-back of twigs and inflorescences; and Ailurodicus cocois (Homoptera), a white fly in Brazil sucking the leaf sap and causing sooty mould. General control measures include plant and plantation sanitation, and the use of insect repellants and insecticides. There may also be scope for the use of biological control methods (Ohler, 1979).

#### 5. GENETICS AND IMPROVEMENT

The chromosome number of A. occidentale is  $2n=42$ . Khosla et al. (1973) reported it to be  $2n=24$  in a study of Himalayan Anacardiaceae, but the reason for the difference is not known. There have been no inheritance studies with cashew. In the past growers selected seeds for planting from trees with desirable characteristics, or on the basis of nut quality. Desirable provenances have been selected in India (Nair et al., 1979), Tanzania (Mutter and Bigger, 1962; Northwood, 1967), Kenya (van Eijnatten, 1979) and Brazil (Gondim et al., 1973). Rather few perfect flowers open on any one day, so bagging and hand-pollination is laborious.

The following criteria were used in India for selecting parent trees (Damodaran et al., 1979): dwarf, bushy, much-branched plant with many inflorescences; short flowering period (2-3 weeks); high percentage of perfect flowers; medium nut size; high shelling percentage; and quality of 'apple' if of interest. Promising results have been obtained in cashew breeding programmes in India (Anon., 1979a) and Kenya (van Eijnatten, 1979).

The yields of cashew can be significantly increased through breeding and selection. Crosses between local and exotic parental material in India exhibited hybrid vigour for yield, indicating the benefit of germplasm exchange. The generally poor quality of cashew nuts in Madagascar compared with Brazil could also be improved. Breeding work has hitherto been confined to A. occidentale parental material, and has not involved interspecific crosses. A dwarf tree is being studied in Brazil (Ohler, 1979).

#### 6. GERMPLASM CONSERVATION

Wild Anacardium species, including cashew, occur mainly in the Amazon basin. More information is needed on their frequency, distribution, and possible uses in breeding, and on genetic erosion.

Material in existing collections, which are mostly of selected trees, should be properly evaluated and described. The seeds are orthodox (Ellis, 1984), but only retain their viability for about a year, and long-term storage is not feasible. Collections need to be augmented with representative samples of wild species. The cashew deserves high priority for germplasm conservation because of its edible and industrial products, and its ability to grow under marginal conditions, and the industry should take a larger responsibility.

Table 3. Collections of cashew

Country	Location	Number of accessions	
		<u>Anacardium occidentale</u> <sup>1/</sup>	Other <u>Anacardium</u> species
Australia	Darwin	23	
Brazil	Pacajus, Ceara	127	<u>A. humile</u> (1) <u>A. othonianum</u> (1) <u>A. microcarpum</u> (1)
China	Hainan	?	<sup>2/</sup>
India	Kerala	880	
Kenya	Kikambala	10	
Mozambique	Maputo	530	
Nigeria	Ibadan	10	
Philippines	Los Baños	1,302	
Thailand	Chantaburi	744	
USA	Miami, Florida	16	

<sup>1/</sup> Largely seedling progenies and not fully representative of the diversity available.

<sup>2/</sup> Hainan Botanical Garden of Tropical Economic Plants, Academy of Tropical Crops of South China, Ministry of Agriculture, Hainan Island, Guangdong Province, China.

A collection is likely to exist in Tanzania (Nachingwea), but no details were available. There are also some trees at the Grand'Anse Experimental Centre, Mahé Island, Seychelles.

IBPGR (1984) also lists small collections of cashew, but these can probably not be regarded as genetic resources collections, at: Palmira Valle, Colombia; Tananarive, Madagascar; Cozolepa, Oaxaca, Mexico; Karavat, Papua New Guinea.

Anacardiaceae

MANGIFERA INDICA  
(Mango)

1. INTRODUCTION

Mangoes are usually eaten fresh, few being either cooked or processed into preserves and pickles. They vary considerably in composition, are of relatively low calorific and nutritional value, but are high in carotene and vitamin C (Table 1). Mango seed kernels are a possible source of starch, and the skin could be used for animal feed.

World production has increased over the last decade (Table 2). The major producer in 1984 was India, accounting for 62% of the world crop, followed in descending order of production by Pakistan, Mexico, the Philippines, Brazil, Indonesia, Haiti and Bangladesh. International trade of mangoes is relatively insignificant, but Mexico and Haiti export to USA, and India, Kenya and Mali to Europe.

2. TAXONOMY AND BOTANY

Mangifera indica L. is the principal cultivated species in the genus Mangifera, family Anacardiaceae. The monograph of Mukherji (1949) listed 41 Mangifera species. Ding Hou (1978) reduced 14 of the species listed by Mukherji to synonymy and added 4 more in the Malesian region. Tardieu (1962) added another 4 species for the Indo-China region and in China, Ling (1993) added a new species. Kochummen (1983) reduced 1 more species to synonymy (M. longipes Griff. as part of M. indica L.), but this would extend the distribution range of M. indica with doubtful phytogeographic validity. Kochummen created 2 new species in the Malayan region. Based on the taxonomic treatments provided above, Mukherjee (1985) recognized 39 species.

Plant a large, spreading evergreen tree, 20-45 m high. Leaves alternate, broadly lanceolate, up to 30 cm long, dark green. Inflorescence a terminal panicle 7-50 cm long, with 200-4,000 (or more) flowers. Flowers 5-8 mm in diameter, perfect or male, usually 1-35% perfect, determined genetically and environmentally; petals (4-)5(-7), twice as long as calyx, mainly cream becoming pinkish; calyx (4-)5(-7) free, concave, yellowish-green, hirsute; annular, fleshy 5-lobed disc between corolla and androecium; stamens (3-)5(-7) inserted on outer margin of disc, pollen abundant; ovary small, oblique with a single ovule. Fruit a large ovoid asymmetrical drupe, yellow, green or red; mesocarp fleshy, usually bright orange but some are light yellow or golden yellow in colour, sometimes fibrous; endocarp hard and fibrous, enclosing single seed with one or several embryos (Singh, 1969; Purseglove, 1968).

Pollination is mainly by insects, and only about 30% of the perfect flowers are ever fertilized. The fruits of some cultivars apparently develop parthenogenetically (Crane and Walker, 1984). Since mango is self-incompatible, cultivars should be planted close to pollinator trees, with the inflorescences of the two bagged together, and using the housefly as a pollinator. The two parents could also be brought together by grafting them on the same rootstock (Oppenheimer, 1972).

There are only a few, mainly polyembryonic cultivars in the Philippines, which give rise to fairly uniform seedling populations. Most of the cultivars in India, except for a few grown on the Malabar coast, are monoembryonic and sexual, and do not breed true from seed (Singh et al., 1967). The embryo in monoembryonic seeds may occasionally be asexually produced. Polyembryony is much more common in the moist tropical areas of Southeast Asia, such as Malaysia, the Philippines and Indonesia, but why this should be so is not clear. In a study of foreign cultivars examined in India, the numbers of embryos per seed ranged from 2-5 to 2-11, giving rise on average to 3.1 seedlings (Prasad and Prasad, 1972). There are many thousands of mango cultivars in the world, many of which have been multiplied true to type, named and described (Gangolly et

al., 1957; de Laroussilh, 1980; Mukherjee, 1948; Naik and Gangolly, 1950; Popenoe, 1941; Singh, 1960; Singh and Singh, 1956; Surachmat Kusomo et al., 1975). The IBPGR is due to publish a descriptor list for mango in 1986.

### 3. ORIGIN, DISTRIBUTION AND ECOLOGY

The natural distribution of the genus Mangifera extends from India and Sri Lanka in the west to the Philippines and the Solomon Islands in the east, and from Yunnan in the Chinese Himalayas and Indo-China in the north to the arc of islands comprising the Sunda and Sulu archipelago in the south. The greatest diversity of species is in the Malay Peninsula, which is assumed to be the centre of origin of the genus, followed by Sumatra and Kalimantan (Indonesia). Mukherjee (1972) considers that the centre of origin includes the Thailand/Indo-China area.

The cultivated mango probably originated in Indo-Burma, notably the Assam-Chittagong hills area, where many wild mango trees still grow, but its progenitors are not known. Primary centres of diversity of other less common cultivated Mangifera species are: Indonesia (M. caesia Jack.), Indo-China and Malaysia (M. foetida Jack.), the bachang mango, and Malaysia (M. odorata Grif.), the kurazini mango. The mango has been cultivated in India for several millennia; it spread to other parts of Southeast Asia about 1,500 years ago, and to the east coast of Africa about 1,000 years ago. Further spread to Australia, West Africa and the Americas has been within the last few hundred years.

The mango is limited to tropical or near tropical climates. Young trees in a growth flush are damaged at  $-1^{\circ}\text{C}$  to  $-2^{\circ}\text{C}$ , and less severe frosts may still kill the flowers. Growth and fruit ripening are retarded at temperatures below  $18^{\circ}\text{C}$ . Mango production therefore is confined to the area between the  $15^{\circ}\text{C}$  isotherms (average monthly temperature) north and south of the equator. About 750 mm rainfall is the minimum required per year, and distribution is critical. A dry period of about 3 months is needed for flower induction and successful pollination. Mango trees thrive on a variety of soils from sands to loamy clays, and grow quite well in shallow, impervious soils which are unsuitable for most tree species.

### 4. AGRONOMY, DISEASES AND PESTS

Mango trees are highly heterozygous, and sexually-produced seedlings are therefore very variable. They may be propagated true-to-type either by growing the asexual (nucellar) seedlings from polyembryonic seeds to produce a seedling race, or vegetatively to produce a clone. Seeds with the endocarp removed germinate after 2-3 weeks, and crop after 4-6 years. Monoembryonic cultivars have to be propagated vegetatively. Inarching was the method commonly used for centuries with ordinary seedlings as the rootstock, but is laborious and costly. Several other grafting, budding and layering techniques have been developed within the last 50 years. Rootstocks should also be propagated vegetatively by stooling and using rooting hormones with cuttings, for uniform plantations (de Laroussilh, 1980). One of the principal factors limiting the production of many mango cultivars is the tendency for alternate bearing, sometimes with virtually no crop for two or more years.

They are also affected by around 25 fungal pathogens, the most serious and widespread being anthracnose (Colletotrichum gloeosporioides). Five bacterial diseases have also been recorded. A trunk-cracking in South Africa, and a condition known as "malformation" which affects inflorescences resulting in fruit loss, in India, Pakistan and Bangladesh, may both be caused by viruses. Malformation is associated with mites and the fungus Fusarium moniliforme, and can only be controlled by removal and destruction of affected branches, and chemical control of mites.

Among many insect pests the following are important: scale insects, white flies, gall midges, leaf hoppers, thrips, fruit flies, fruit piercing moths and wood borers. Most can be controlled chemically, although there has been some success in the biological control of white flies. The use of sex attractants is being tested in fruit fly control.

## 5. GENETICS AND IMPROVEMENT

Mukherjee (1972) suggested that *M. indica* (2n=40) is an allotetraploid, but its ancestors are not known. Little genetical information is available on mango, clear-cut dominance having been observed in only a few characters, such as new leaf and panicle colour in the cultivar 'Totapari Red Small' (Majumder et al., 1972).

The following list of breeding aims combines some suggested by Singh (1972) for India (a-e), and others by Purseglove (1968) (f-i):

- a) dwarf tree;
- b) desirable eating qualities;
- c) regular cropping;
- d) tolerance of malformation disease;
- e) good keeping qualities;
- f) good cropping in the wet tropics;
- g) resistance to diseases, especially anthracnose, and pests, especially fruit flies;
- h) bearing at an early age; and
- i) early or late season cropping.

Improvements in mango production have mostly resulted from selection within populations of spontaneous seedlings (Mukherjee et al., 1968; Singh, 1969). This process has continued for many years in India, where there are now large numbers of locally-adapted cultivars. Dwarfness can be sought both through the scion and the rootstock. Programmes based on hybridization date back to 1912 in the West Indies and 1920 in India (Krishnamurthi and Madhava Rao, 1964). A few promising hybrids were obtained in India at Yodur and Sabour (1940), Saharanpur (1951) and Hyderabad and New Delhi (1961).

Common mango cultivars have usually been used as parents in crosses. Crosses have also been made using *M. odorata* and *M. zeylanica* Hook. in India. Large numbers of inflorescences have to be pollinated in order to get a few viable seeds, as there may be a high rate (96-100%) of premature fruit drop (Singh, 1960; Mukherjee et al., 1961). Iyer and Subramanyam (1972) suggested that embryos might be grown from hanging or recently fallen fruit using a culture medium.

Many commercial cultivars of mango are based on Indian germplasm. Some have been selected in Florida as first or second generation seedlings from a known mother tree, or as chance seedlings of unknown origin. Specific improvements in mango include: in Hawaii and Florida, increased resistance to blossom and fruit anthracnose found in crosses in which one of the parents originated from a humid area where the disease was endemic (Hamilton, 1975); and in India a combination of good fruit quality and regular bearing (Abdul Khader et al., 1977; Singh et al., 1977). As a result of recent hybridization work at IARI, New Delhi, a dwarf regular-bearing hybrid 'Amrapali' has been released which is amenable to high-density planting at up to 1,600 plants/ha (Mukherjee, 1982 pers. comm.).

## 6. GERMPLASM CONSERVATION

The greatest diversity of mango cultivars is in India, with at least 1,000 unique and several widely-grown cultivars. Other countries with many old cultivars are Pakistan, Bangladesh and Indonesia. Genetic erosion of these cultivars is serious in India (Mukherjee, 1982 pers. comm.). Sastrapradja (1975) found that the collections in Southeast Asia mostly contained cultivars which had been distributed to farmers as grafted seedlings, leading to the disappearance of less desirable, usually seed-propagated cultivars.

Wild mangoes (*M. indica*) have been reported from the forests bordering India and Burma in the states of Assam, Tripura, North East Frontiers area and Nagaland, in the



vegetation in the eastern hill ranges in Orissa state and on the Andaman Islands, but little is known about the size and genetic variability of those populations. Sharma (1976) reported trees which were not affected by malformation disease, but information on wild species other than M. indica is scant (Mukherji, 1949). Mukherjee (1985) is a study on the gene pool in the genus Mangifera, which should be consulted for detailed information.

A rare mango known as 'Bingloo' which was last recorded by Indonesian forest officials at the turn of the century, has recently been found on Java, and may also be present in Borneo (Anon., 1985). The fruits are less fibrous than those of M. kamanagat, which is widely sold in Borneo, but they are deliciously sweet, and at least twice as large as those of M. indica. They may be better adapted to continuously wet tropical conditions than M. indica. Very little use has been made of available mango germplasm by plant breeders, and there is insufficient information on its potential contribution. There are many collections, but few accessions are of species other than M. indica. Conservation of seed is not feasible as they are recalcitrant (Ellis, 1984).

Mango has been assigned high priority by IBPGR. It is an important crop, and is especially valuable because it grows on marginal soils, and much potential remains for development of trade and exports. Existing collections should be augmented with more species and primitive accessions. Ultimately successful conservation will probably depend upon in vitro genebanks and in situ reserves. IUCN/WWF and IBPGR are currently conducting a survey of sites for the latter.

Table 4. Collections of mango

Country	Location	Number of accessions	
		<u>Mangifera Indica</u>	Other <u>Mangifera</u> spp.
Australia	Darwin	63	
Australia	Alstonville	20	
Australia	Nambour	25	
Australia	Ormiston	30	
Bangladesh	Rajshahi	107	
Brazil	Cruz das Almas	100	
Brazil	Manaus	14	
Brazil	Planaltina	35	
Brazil	Jeboticabal	45	
Brazil	Piracicaba	53	
China	Taiwan	60	
China <sup>4/</sup>	Hainan	7	
Colombia	Palmira Valle	59	<u>M. odorata</u> (1)
Côte d'Ivoire	Abidjan	30	
Cuba	Habana	350	
Fiji	Nausori	100	
Fiji	Sigatoka	43	
India <sup>1/</sup>	Bangalore	998	<u>M. cambodiensis</u> (1) <u>M. cochinchinensis</u> (1) <u>M. odorata</u> (1) <u>M. zeylanica</u> (1) 9 <u>Mangifera</u> spp.
Indonesia	Bogor	53	
Indonesia	Malang	239	
Jamaica	Kingston	63	
Madagascar	Tananarive	42	
Malawi	Limbe	32	
Malaysia	Kuala Lumpur	222	
Mauritius <sup>2/</sup>	Barkly	7	
Mexico	Sinaloa	78	
Mexico	Celaya	40	
Mexico	Cotaxtla	27	
Nicaragua	Unos	40	
Nigeria	Ibadan	47	
Peru	Plura	36	
Philippines	Los Baños	343	<u>M. altissima</u> (2) <u>M. caesia</u> (2) <u>M. foetida</u> (1) <u>M. odorata</u> (4)
Portugal	Oeiras	100	
Seychelles <sup>3/</sup>	Mahé	308	<u>M. odorata</u> (1)
South Africa	Nelspruit	85	
Sudan	Wed Mwanl	30	
Thailand	Bangkok	94	11 <u>Mangifera</u> spp. (34)
Thailand	Chantaburi	80	
Thailand	Nakhon Rachasima	120	
USA	Florida	194	<u>M. odorata</u> (1)
USA	Hawaii	109	<u>M. odorata</u> (1)
USA	Puerto Rico	106	
Venezuela	Maracay	103	

<sup>1/</sup> This collection is distributed among 25 Indian Institutes.

<sup>2/</sup> Department of Horticulture, Barkly Experiment Station, Mauritius.

<sup>3/</sup> Grand'Anse Experimental Centre, Mahé Island, Seychelles.

<sup>4/</sup> Hainan Botanical Garden of Tropical Economic Plants, Academy of Tropical Crops of South China, Ministry of Agriculture, Hainan Island, Guangdong Province, China.

Anacardiaceae

PISTACIA VERA  
(Pistachio Nut)

1. INTRODUCTION

Pistachio nuts, or green almonds, are harvested from wild or cultivated trees mainly for their edible seed kernels. They may be bought roasted and salted, shelled or unshelled, and are used in ice creams, sweets, cakes and meat dishes. The kernels are nutritious (Table 1), with a fat component including 68% oleic acid and 17% linoleic acid. 0.54% of the oil is unsaponifiable, and contains about 93% sterols, chiefly B-sitosterol (Danehrad, 1974). Other products from pistachio are: resin, tannin and dye from galls developing on the leaves; aromatic resin used in paints and varnishes from the bark; pistachio nut oil, a non-drying oil used medicinally in India; and fertilizer from the hulls.

World production of pistachios is currently increasing (Table 2). Although normally regarded as a temperate crop, it assumes importance in the sub-tropics. The crop is important in relatively few areas, mostly in the eastern Mediterranean and central and western Asia, but also in California and New South Wales.

2. TAXONOMY AND BOTANY

According to the key of Zohary (1952), the genus Pistacia, family Anacardiaceae, comprises 4 sections, 11 species and 13 botanical varieties. Some of the species have in the past been placed in the genus Rhus. Leaf characteristics have often been more useful than floral ones for identification.

Pistacia vera L., the common pistachio, is a dioecious and resinous tree, 3-8(-10) m tall. Leaves alternate, deciduous, leathery, imparipinnate, 10-20 cm long, with 5-10 cm long petiole; leaflets petiolate or sessile, 1-2(-3) paired, rarely solitary, glabrous or sparsely puberulent at midrib, shining at upper, pale at lower surface, broadly lanceolate to ovate or orbicular, often abruptly short acuminate, acute, rarely obtuse or retuse, mucronate, rarely mucicous, 5-10(-12) cm long, 3-6 (or more) cm broad, terminal leaflet as large as or larger than lateral ones; rachis not winged, crisp-puberulent. Flowers minute, unisexual, in axillary panicles. Male panicles compact, 3-5(-6), almost alike, linear-lanceolate, whitish or scarious, margin ciliolate, especially at tip, 2.0-3.5 mm long. Male flowers stamens 5-6, 2.5-3.0 mm long, inserted on disc of flower; anthers ovate apiculate, longitudinally dehiscent, 3-4 times as long as the filament, rudimentary pistil absent. Female panicles looser and generally longer and broader than male, crisp pubescent at tip, 1.0-2.5 mm long. Female flowers pistil 3 mm long; ovary superior, ovoid, 1-celled; style short; stigmas 3, obovate, retuse, or 2-lobed; rudimentary stamens 0; ovules pendulous with superior micropyle and accumbent radicle. Fruit 1-seeded drupe, long-pedicelled, oblong-linear to ovate or almost obovoid globular, laterally compressed, 10-20 mm long, 6-12 mm broad; mesocarp fleshy, variously coloured, readily separating from dehiscent or indehiscent bony endocarp. Seeds laterally compressed with membranous testa, exalbuminous, with flat-convex, fleshy cotyledons and notorhizos radicle (Zohary, 1952).

Stands of wild pistachio trees in central Asia are typically highly heterogeneous, and individual trees do not breed true. Pollination is predominately anemophilous. Although pollen is collected by honey bees, which may assist in its dispersal, the bees do not visit the female flowers. Trees are planted at a ratio of 1 male: 8 female in modern orchards (Crane and Walker, 1984).

There are probably less than 50 clonally-propagated named cultivars in the area of ancient cultivation in Asia and the Mediterranean, and only a few more elsewhere. Some cultivars are actually cultivar groups with similar nut characteristics, which are often sold under a single geographical name, e.g. Aleppo, Tunis, Sicily etc. Larue

(1960) states that there are 3 groups of cultivars in Iran, viz. elongated, round and small. Many cultivars have been described, but often in insufficient detail, and ignoring the differences between male and female trees (eggs, 1973). Popov (1977) discusses the pistachio cultivars of central Asia. Species other than P. vera are of interest for the production of resins, turpentine, mastic (P. lentiscus L.) and medicines.

### 3. ORIGIN, DISTRIBUTION AND ECOLOGY

According to Zohary (1952), the genus Pistacia evolved in the upper Cretaceous period in southwest and central Asia, from sea level to about 2,500 m. Nuts were probably first collected from wild trees and only later planted. The multiplication of selected trees depended upon the development of grafting techniques, which also allowed cultivation to extend towards the semi-arid areas of Turkey, Iran, Syria and Lebanon (Zohary, 1973). Further spread was to Cyprus and Greece. It reached Italy in the first century A.D., and later Sicily (Maugeri, 1975). Early this century it was introduced to California and in 1930 to New South Wales (Maggs, 1972), and to Mexico about 10 years ago (Lagarda, 1977).

Both cultivated and wild pistachios are now mainly found in semi-arid areas between 28°N and 42°N, and from 70°E to the Mediterranean. The distribution within this areas is patchy. The climatic requirements for good nut production include: a cold winter with an average temperature of less than 7-8°C for vernalization of dormant buds; no further frosts after flowering has started; dry and windy conditions during pollination; hot and dry summer weather; and 500-600 mm rainfall during autumn, winter and early spring. Irrigation may be necessary in areas with insufficient rainfall. The pistachio grows well on sloping, stony and well-drained soils, areas often of marginal use for agriculture.

### 4. AGRONOMY, DISEASES AND PESTS

The pistachio is usually propagated vegetatively by budding or grafting on to one year-old seedling rootstocks of such species as Pistacia atlantica, P. khinjuk Stocks., used for fodder and tanning, and P. palaestina Boiss. P. atlantica Desf., the Mount Atlas pistachio used for wood, thrives under semi-arid conditions, allowing cultivation in such areas. The use of P. terebinthus is recommended as a rootstock in shallow soils. Male and female trees with similar flowering periods are planted together in orchards. Grafted seedling trees begin to fruit at about 7 years old, and are in full production when about 20 years old. The nuts are picked from the trees when the green or reddish husk becomes translucent and separates from the shell, and are dried, usually in the sun, before or after hulling. Like other crops in the family Anacardiaceae, pistachios tend to alternate bearing.

At least 25 fungal diseases attack pistachio (Lemaistre, 1959; Spina and Pennisi, 1957), of which the most serious are:

- Verticillium albo-atrum - a soil-borne disease which causes die-back of some of the branches, and eventually death of the tree. Soils on which cotton, melon, vegetables or strawberries have been grown should be avoided (Opitz, 1975), and control can also be achieved by soil fumigation;
- Phytophthora parasitica - causes foot rot in young trees under conditions of poor drainage;
- Septoria pistaciarum and S. pistacina - easily controlled by copper sprays or zineb;
- Nematospora coryli - "Manju" disease, discoloration and lesions on kernel;
- Camarsporium pistaciae - affects leaves and fruit clusters, causing losses of yield of up to 50% in Greece, especially at high humidity. Preventive sprays with copper fungicide; and
- Aspergillus flavus - occurs worldwide. Insect-damaged or split nuts are infected, especially at high humidity.

Pistachio may also possibly be infected by Agrobacterium tumefaciens (Evrainoff, 1948a), and 2 diseases probably caused by viruses have also been reported from USSR and adjacent areas (Whitehouse, 1957; Lemaistre, 1959).

About 40 species of insects and 3 mites have been reported as damaging to pistachio (Whitehouse, 1957; Lemaistre, 1959), of which the following are significant:

- Forda linonta - attacks leaves and young shoots causing gall formation (Evrainoff, 1948a);
- Slavum lentis - similar to Forda linonta;
- Tropocarpus ballasteri - a fruit parasite. Burn empty fruit containing larvae, and prevent larvae entering stores using screens;
- Capnodis cariosa - a beetle laying eggs under bark of young trees. Larvae tunnel in cambium;
- Thrips iranicus and T. pistacia - which destroy pollen in male flowers;
- Centorrhynchus spp. - a pollen-destroying beetle; and
- Ceroplastes ruzesi and other species of scale insect.

A nematode, which has not yet been identified, causes collar gummosis in Iran (Larue, 1960), and root knot nematode (Meloidogyne spp.) has been reported from California (Whitehouse, 1957). P. terebinthus has some resistance.

#### 5. GENETICS AND IMPROVEMENT

According to Zohary (1952), the chromosome number of P. vera is  $2n=2x=30$ ; Jones found it to be  $2n=2x=32$  (Whitehouse, 1957). Two other Pistacia species have lower chromosome numbers: P. lentiscus,  $2n=24$ , and P. atlantica,  $2n=28$ . Most pistachio improvement is based on selection amongst existing local or introduced cultivars, or selection amongst the seedlings from open-pollinated trees. Controlled hybridization has not yet been practised. Because pistachio is dioecious, it is not possible to simply combine the best characteristics of 2 cultivars, both of which are female, by hybridization.

Breeding aims for pistachio may include one or more of the following: (in female cultivars) resistance to low winter temperatures; even bud break despite high winter temperatures; resistance of flowers to frost; flowering after frosts; early bearing; high yield; high nut/fruit weight ratio; low percentage blanks (poorly-filled or empty shells); high percentage split kernels; large kernels; high protein content; high oil content; intensive green colour; freedom from "kerman blotch" or "canker"; and monoecious habit. The aims in male trees include: abundant pollen production, timing well with flowering of female trees; a favourable effect of pollen on fruit maturity and nut and kernel quality; and good pollen longevity in storage. In rootstocks, the aims include: resistance to nematodes, and to Verticillium albo-atrum wilt (found in P. integerrima); favourable effect on scion growth and development, including fruiting and fruit characteristics; induction of more regular bearing in the scion; and ease of vegetative propagation.

There are pistachio research programmes in Australia, Cyprus, Iran, Israel, Tunisia, Turkey, USA and USSR. The cultivar 'Sirora' which was released in 1981 in Australia originated as a seedling from open-pollinated 'Red Aleppo', a cultivar introduced as budwood from USA. Work with the crop has continued in Cyprus since 1895 (Türel and Ayfer, 1959). In Iran work is coordinated by the Seed and Plant Introduction Institute in Karaj (FAO, 1978). A programme was started in Israel about 33 years ago to select cultivars with a low chilling requirement. Two female cultivars, 'Nazareth 4' and 'Eilon 209' and 3 males were of interest (Spiegel-Roy et al., 1972). Varietal and agronomic research with rainfed and irrigated crops has been carried out in Tunisia (Dumont et al., 1972). A selection programme was started in California in 1929, and the female cultivars 'Kerman' and 'Lassen', and the males 'Chico 23' and 'Peters' have been released (Brooks and Olmo, 1972). The major commercial cultivar in California in 1979 was 'Kerman', while 'Peters' was the principal pollinator (Crane and Takoda, 1979). Local farmers in the USSR probably made the early pistachio selections (Evrainoff,

1948a; En'kova and Beskaravainyl, 1974), some of which are very interesting. Trosko (1938) reported cultivars in the Baba-Dag mountains with large nuts and a high fat content. Kerimov (1934) reported a high oil content in cultivars from Aspheron, while Popov (1979) discussed the selection of large-fruited cultivars for dryland cultivation.

#### 6. GERMPLASM CONSERVATION

Genetic erosion of wild stands of P. vera in West Asia and the Mediterranean countries has occurred because of land clearance, charcoal burning, and over-grazing by goats. Wild trees were often only kept as rootstocks for top-working with selected cultivars. The number of commercially-grown cultivars is likely to be reduced in the future. Several wild Pistacia species are used as rootstocks or pollinators, while others may have a role in future improvement work.

The existing collections contain a few only of the wild species, and it is unlikely that seeds can be effectively stored. The areas of greatest priority for germplasm conservation are in central and West Asia. The genetic diversity of stands of wild Pistacia trees should be surveyed, and steps should be taken to protect and conserve them where they are endangered, largely in situ with representative samples of diversity ex situ in field genebanks. A complete list and description of all cultivars should be made, based on an agreed descriptor list.

Table 5. Collections of pistachio nut

Country	Location	Number of accessions	
		<u>Pistacia vera</u>	Other <u>Pistacia</u> spp.
Australia	Merbein, Victoria	30	<u>P. atlantica</u> (3) <u>P. euinensis</u> (2) <u>P. khinjuk</u> (3) <u>P. mutica</u> (6) <u>P. terebinthus</u> (3) <u>Pistacia</u> spp. (5)
Chile	Santiago		
Cyprus	Nicosia	8	
Italy	Rome	13	
Syria	Damascus	125 <sup>1/</sup>	<u>P. atlantica</u> (7) <u>P. khinjuk</u> (7) <u>P. lentiscus</u> (7) <u>P. palaestina</u> (7) <u>P. terebinthus</u> (7)
Turkey	Izmir	19	
USA Davis		25-30	<u>Pistacia</u> spp. (6-8)

<sup>1/</sup> Pistacia spp., a total of 125 accessions, mainly P. vera, but also some accessions of the 5 related species as shown above.

Collections are likely to exist in Iran, Israel and Tunisia, but no details were available.

SPONDIAS CYTHEREA  
(Ambarella)

1. INTRODUCTION

The ambarella tree is principally cultivated for its edible fruits, which are usually consumed in the form of juice, sauce, jam or preserves. Its flavour is like that of mango or pineapple. The flesh of the unripe fruit is crisp, juicy and somewhat acidic, but as it ripens it becomes fibrous with a musky aroma and flavour. Sometimes the leaves are eaten as a vegetable (Anon., 1976). Data on the nutritional composition of the ambarella, which is unexceptional, are in Table 1.

The ambarella is of minor economic importance, and production statistics are not compiled by FAO. It is cultivated on a small scale in many tropical countries, including Burma, Cuba, India, Indonesia, Jamaica, Malaysia, the Philippines, Sri Lanka and the USA (Puerto Rico).

2. TAXONOMY AND BOTANY

The genus Spondias L. contains 10 species in the Indo-Malesian and African tropics. For keys to the genus, see Ding Hou (1978) and Airy Shaw (1967). Several species have edible fruits, of which at least 2 are cultivated for fruits (others are used for gum production): S. cytherea Sonner, the ambarella; and S. purpurea L., the red mombin, Spanish plum, ciruela (Spanish) or xocotl (Aztec language), which is extensively grown in tropical America. The fruits of S. tuberosa Arruda, the imbu, are picked from wild trees and eaten in northeastern Brazil.

Spondias cytherea has also been classified as: Condonum malaccense Rumphius, Spondias dulcis Solar. der, Poupartia dulcis Blume, Evia dulcis Commelin, Evia amara var. tuberculosa Blume and Spondias mangifera var. tuberculosa Engler. There are also many names, including: great hog plum and Otaheite apple, pomme cythère (French), ciruela judía and jobo de la India (Spanish), cajá-manga, tapiribá do Sertão and cajarana (Brazil), kedongdong (Malaysia), Jew plum (Jamaica) and vi or evi (Polynesia).

The ambarella is a tree 10-25 m tall. Leaves alternate, crowded at the ends of the branchlets, pinnate, usually with a terminal leaflet and 4-12 pairs of lateral leaflets; rachis 15-55 cm long; leaflets oblong 5-13 cm long and 2-5 cm broad. Inflorescence a terminal panicle, up to 50 cm long, widely branched, many-flowered. Flowers small, hermaphrodite, pedicelled, clustered; calyx small, ca. 2.5 cm diameter, halfway 5-cleft; petals 5, reflexed, yellowish-white, 0.3 cm long; stamens 10, shorter than the petals; disc thick, yellow; ovary sessile, 5-celled; styles 5, erect, initially close to each other, later spreading. Fruit an ellipsoid, glabrous drupe, yellow or orange when ripe, 5-10 cm long and 4-8 cm wide; pulp thick, fleshy, white; stone comparatively thin, consisting of one layer, with prominent ridges from which long tough fibres radiate in all directions, 5-celled (Ochse and Bakhuizen van den Brink, 1931).

Ambarella flowers are cross-pollinated by insects (Ding Hou, 1978). There are no named cultivars although there are relatively improved forms with a thick mesocarp, and a sweet, refreshing acid taste, and unimproved forms with long spines on the woody endocarp, and resinous or pungent taste (Ochse and Bakhuizen van den Brink, 1931; Anon., 1976).

3. ORIGIN, DISTRIBUTION AND ECOLOGY

The origin of ambarella is unknown, but it is now widely distributed throughout the tropics. It grows between about 23°N and 23°S at low and medium altitudes. In Indonesia it is planted up to 700 m high, and in climates ranging from continuously wet to seasonal, with 6 wet months (over 100 mm rainfall per month) and 6 dry months (under

60 mm rainfall per month) (Terra, 1948). The tree does not have exacting soil requirements, and in Florida, USA, grows equally well on rocky limestone soils or acid sands, but responds well to application of fertilizer (Popenos, 1979).

#### 4. AGRONOMY, DISEASES AND PESTS

Propagation can be by seed or vegetatively using hardwood cuttings, air-layering, or budding of non-petioled wood on stocks of the same species or on S. mangifera Willd. (Ochse and Bakhuizen van den Brink, 1931; Anon., 1974). Seedlings fruit at about 4 years old, and flowering and fruiting are seasonal. In Java, trees flower during the dry season, and fruits are ripe 6-7 months later. Tohir (1970) states that 800-900 fruits per tree may be an average yield.

The ambarella has few pathogens. Cook (1975) mentions only scab and Sphaceloma spondiadii, a fungus which causes round spots on leaves and fruit. The disease occurs in Florida and Brazil, but is not serious. Leather (1967) reported a sooty mould disease, caused by the fungus Tripospermum spp. in Jamaica, and it is also affected by gummosis, the cause of which is unknown (Morton, 1961). Tohir (1970) reported a disease in Indonesia known as "penyakit blendok", but gave no details.

Two beetles, Podontia 14-punctata and P. affinis cause considerable damage to leaves in Malaysia and Indonesia (Ochse and Bakhuizen van den Brink, 1931). In Jamaica, the West Indian fruit fly (Anastrepha mombin-prooptans) attacks the fruits. Diseases and pests appear to be of small economic consequence and little attention is paid to control.

#### 5. GENETICS AND IMPROVEMENT

The chromosome number of Spondias cytheraea is  $2n=32$ . There is no genetic inheritance data on ambarella, and there has been no systematic selection, although occasionally seedlings have been propagated vegetatively.

#### 6. GERMPLASM CONSERVATION

Cultivated ambarellas are under little threat of genetic erosion while they are mainly propagated by seed. The threat to the wild species is difficult to assess, and a study needs to be made on the origins of the cultivated forms.

All of the collections which contain ambarella are too small to be regarded as being genetic resources collections. IBPGR (1984) mentions the following: Manaus and São Paulo, Brazil; Njombe, Cameroon; Turrialba, Costa Rica; Habana, Cuba; Guliacan, Sinaloa, Mexico; Los Baños, Philippines, and there are 12 accessions at Miami, Florida. There is also 1 accession of S. dulcis at Grand'Anse Experimental Centre, Mahé Island, Seychelles. The seeds are recalcitrant (Ellis, 1984).



ANNONA spp.  
(Annona Fruits)

1. INTRODUCTION

Four species of Annona are commonly cultivated for their edible fruits: A. muricata (soursop), A. squamosa (sweetsop), and A. reticulata (bullock's heart) in tropical lowlands; and A. cherimola (cherimoya) at higher altitudes in the tropics or sub-tropics. The fruits of these species differ in size, shape, taste and surface features. They are usually eaten fresh or used in desserts, ice-creams or sherberts, and are juicy but not particularly nutritious (Table 1). Many other Annona species are gathered from the wild.

Annona fruits are of minor economic significance. Many of them grow throughout the tropics, and are almost always consumed locally, and rarely traded internationally. Soursop is grown in Venezuela, Surinam and Hawaii; sweetsop in Brazil and India; and cherimoya in Colombia, Argentina and New South Wales.

2. TAXONOMY AND BOTANY

The genus Annona is characterized by a fleshy syncarp, or 'apple', formed by the fusion of numerous pistils on an elongated receptacle. Of 119 species in the genus, 108 are tropical American, 10 are tropical African, but A. glabra L. is found in both continents (Fries, 1959). The principal characteristics of the major cultivated species are:

- (i) A. muricata L. (soursop, guanabana, corossol, sirsak - Indonesia). A small, slender tree, rarely over 6 m high, with a large fruit, often over 2 kg in weight. The fruit is ovoid, heart-shaped or conical with many short fleshy spines. The flesh is like that of the cherimoya, but tastes more like pineapple.
- (ii) A. squamosa L. (sweetsop, sugar apple, custard apple, fruta de conde, ata, pinha - Brazil, srikaja - Indonesia). A small tree, reaching only 5 m high. The fruit is round, heart-shaped, ovoid or conical, 5.0-7.5 cm in diameter, and yellowish-green. The surface is tuberculate and covered in a whitish bloom. The white custard-like pulp has a pleasant acidic taste with good dessert qualities.
- (iii) A. reticulata L. (bullock's heart, common custard apple, corazon, bush nona - Indonesia). Tree is 6.0-7.5 m high. The fruit is commonly heart-shaped, but may be conical, oval or irregular and weighs 0.1-1.0 kg. The surface is smooth, reddish-yellow when ripe, and divided by impressed lines into 5- or 6-angled areas. The flesh is milk white with a sweet, somewhat insipid flavour. The species is vigorous, but produces the least tasty fruits.
- (iv) A. cherimola Mill. (cherimoya) is a small, erect or somewhat spreading tree, rarely over 7.5 m high. The fruit is heart-shaped, conical, oval or somewhat irregular in form, and weighs 0.1-2.0 kg. The fruit skin is thin, delicate, light green and either smooth, or covered with small conical lumps. The white, slightly acid flesh has a delicate flavour of pineapple and banana, and contains numerous brown seeds.

In addition, the following species are sometimes cultivated for their edible fruits: A. diversifolia Safford (llama) in Central America, A. montana Macf. (mountain soursop, guanabana, cimarrona) in Venezuela and the West Indies, A. purpurea Noc. and Sessé (soncoya) in Central America, A. scleroderma Safford (posh té) in southern Mexico to Guatemala, and A. glabra L. (pond apple) in Venezuela and the West Indies. About 13 species of Annona have edible fruits.

Seedling populations of Annona species are very heterogeneous, although the flowers appear to have a mechanism preventing out-crossing. In A. muricata and related

species, the inner group of petals forms a cap covering the stigma and anthers during flowering. The dehiscent anthers are shed after flowering, and slide along the stigma, so that pollen is passed to it (Fries, 1959).

Despite this, insect pollination has also been reported. Venkataratnam (1959) reported proterogyny, which favours out-crossing, in which the anthers dehisce for a period of about 4 hours, mostly after a 2-3 hour period of stigma receptivity. Deficient pollination may result in misshapen fruits, and low yields, and it is sometimes useful to pollinate flowers by hand (Cañizares Zayas, 1966). There are named cultivars of the widely grown Annona species, but they have not been properly described.

### 3. ORIGIN, DISTRIBUTION AND ECOLOGY

Most cultivated annonans originated in Central America, either on the mainland or on islands of the Caribbean.

A. cherimola is typically found in tropical highland or sub-tropical lowlands. A. squamosa, which is mentioned in Sanskrit literature, was introduced to India at an early date (Singh et al., 1967). The spread of the other species was probably much later, but they are now cultivated in many tropical countries. The different Annona species differ somewhat in climatic and edaphic requirements, and in their adaptation to drought and sensitivity to frost. Many of them, possibly except A. cherimola, could be much more widely grown.

### 4. AGRONOMY, DISEASES AND PESTS

The Annona species can either be grown from seed or vegetatively propagated. Seeds from freshly harvested fruits should be sown. Campbell and Popenoe (1966) reported that seeds of A. diversifolia imported into Florida were dormant, but gibberellic acid stimulated germination. Pittman (1956) advocated submerging cherimoya seeds under water for 3-4 days before sowing. Germination occurred after 4-5 weeks in warm soil. Trees grown from seed are heterogeneous, but methods of vegetative propagation are recommended in several countries by which cultivar characteristics may be perpetuated (Bourke, 1976).

Annona trees start flowering 4-5 years after sowing. In India they lose their leaves between November and December. Some species flower twice a year, although the summer flowers may fail to set fruit (Venkataratnam, 1959). Inadequate pollination is a common cause of low yields, which are typically below 5 tonnes/ha.

Anthracoze (Colletotrichum gloeosporioides) is the principal disease of annonans (Alvarez Garcia, 1963). Fungicide sprays can be used to control it. Six other fungal diseases may be locally serious (Cook, 1975). About 20 insect species may be damaging, probably the most serious being fruit and seed borers, but control measures are not usually practised.

### 5. GENETICS AND IMPROVEMENT

Most species of Annona have  $2n=14$  or  $2n=16$  chromosomes.

There has been a little breeding work with annonans this century, vegetative propagation facilitating multiplication of selections or hybrids. Crosses were made in Florida and the Philippines between several Annona species (Wester, 1913). One result was the 'atemoya', a cross between A. squamosa x A. cherimola. Two local atemoya selections, 'Bradley' and 'Page' have been grown in Florida for many years, and there is also a South African atemoya cultivar 'African Pride' (Campbell, 1970). Some promising atemoyas have been produced in India, where they also grow 'Israel Hybrid', an interspecific hybrid, and 'cutomoya' (atemoya x A. cherimola). In Egypt there is a hybrid known as 'cherimata' (A. squamosa x A. cherimola) (Ezzat et al., 1974). Apart from hybridization, plant breeders have experimented with colchicine-induced tetraploids of A. squamosa, but they were unproductive (Islam, 1953, 1960).

6. GERMPLASM CONSERVATION

The amount of genetic erosion in cultivated annonas is slight, although A. diversifolia, one of the minor cultivated species, is considered to be at considerable risk as a result of agricultural expansion in the area from southern Mexico to El Salvador.

Table 6 lists collections of trees. Although the seeds of A. muricata and A. squamosa have orthodox storage behaviour (Ellis, 1984), there are currently no seeds in genebanks.

Table 6. Collections of Annona spp.

Country	Location	Number of accessions				
		<u>A. cherimola</u>	<u>A. muricata</u>	<u>A. reticulata</u>	<u>A. squamosa</u>	Other <u>Annona</u> spp. 'atamoya'
Australia	Nambour, Queensland	8	11		5	<u>A. glabra</u> (1) 20
Brazil	Bahia Manaus, Amazonas		14		2	<u>A. glabra</u> (1) 1 <u>A. montana</u> (3) <u>Annona</u> spp. (5)
Chile	Santiago					<u>Annona</u> spp. (5)
Costa Rica	Turrialba	38	41	40	7	<u>A. diversifolia</u> (25) 1 <u>A. purpurea</u> (6)
Cyprus	Nicosia	2				
Ecuador	Quito	12				
India	Bangalore					<u>Annona</u> spp. (10)
Indonesia	Bogor					<u>Annona</u> spp. (7)
Jamaica	Kingston					<u>Annona</u> spp. (9)
Malawi	Lilimbe					<u>Annona</u> spp. (3)
Mexico	Veracruz		15			
Papua						
New Guinea	Keravat					<u>Annona</u> spp. (4)
Peru	Lima	49	6			
Philippines	Los Baños		7	11	43	<u>Annona</u> spp. 8 (5 accessions of 3 species)
Seychelles <sup>1/</sup>	Mahé	1		1	34	
Sudan	Wed Medeni				7	
Thailand	Bangkok				7	
USA	Miami, Florida	6	13	17	13	<u>A. bullata</u> (2) 21 <u>A. diversifolia</u> (3) <u>A. glabra</u> (2) <u>A. montana</u> (5) <u>Annona</u> spp. (14)
USA	Mayaguez, Puerto Rico		250			
USA	Hilo, Hawaii	11	2			<u>A. glabra</u> (2) 5 <u>Annona</u> spp. (2)

<sup>1/</sup> Grand'Anse Experimental Centre, Mahé Island, Seychelles.

IBPGR (1984) also lists small collections of Annona fruits at Darwin and New South Wales, Australia; Alstonville, Njombe, Cameroon; and Habana, Cuba.

DURIO ZIBETHINUS  
(Durian)

1. INTRODUCTION

The durian is a large fruit, of which 14-22% is typically aril, 18-22% is seeds, and the rest is waste. The pulpy aril has an acquired taste, a pungent smell, and is relatively nutritious being rich in carbohydrates and fat (Table 1). It is usually consumed fresh, but may be boiled as a vegetable, and made into jams or desiccated products or fermented. The seeds are edible when fried in oil, roasted or boiled, but are rarely eaten. They are high in carbohydrates, mostly starch, oil (10-45%) and protein (Stanton, 1966).

Durians do not store and travel well, so most are sold locally, and insignificant amounts are exported. It is Malaysia's third most widely-grown fruit crop after banana and rambutan. It is also grown in Indonesia, Thailand, Viet Nam, southern Kampuchea, and Mindanao and Sulu islands in the Philippines, but rarely outside Southeast Asia (Malo and Martin, 1979).

2. TAXONOMY AND BOTANY

The genus Durio contains about 27 species in Southeast Asia and Sri Lanka (Kostermans, 1958), at least 6 of which have edible fruits, including Durio zibethinus Murr., the cultivated durian; D. kutejensis (Hassk.) Beccari, the lai or kerantongan, which is cultivated in Borneo; D. oxleyanus Griffith, which is also cultivated; D. graveolens Beccari - not cultivated; and D. grandiflorus (Mast.) Kostermans and Soegeng - not cultivated.

D. zibethinus is a large buttressed tree. Leaves alternate, elliptical or lanceolate-elliptical, ca. 10-15 cm long and 3.0-4.5 cm wide. Inflorescences on older branches, forming bundles of corymbs of 3-30 flowers (up to 15 cm long) with a main pedicel (5-7 cm long), branching 1-3 times. Flowers 5-6 cm long, ca. 2 cm in diameter, white or greenish-white; flower buds globose-ovoid, ca. 2 cm in diameter; apicalyx splitting into 2-3 ovate deciduous lobes; stamens in 5 free phalanges, each filament with up to 12 anthers; ovary ovoid, 5-ribbed, 5-celled, covered with scales; stigma capitate. Fruit a capsule green to yellow, globose, ovoid or ellipsoid, up to 25 cm long and 20 cm in diameter, weight 1.5-2.5(-8.0) kg; spines broadly pyramidal, sharp, 4-6 gonous, up to 1 cm long; valves usually 5, thick, fibrous, inside white, smooth. Seeds 1-6 per cell, up to 4 cm long, completely covered by a white or yellowish, soft, very sweet aril (Kostermans, 1958).

Moths and bats usually pollinate durians. Some of the trees in the Philippines are self-incompatible (Valmayor and Espino, 1975), but even in self-compatible trees in Malaysia, cross-pollination may result in higher yields (Soepadmo and Eow, 1977).

The seedlings of durians vary widely in fruit, aril and seed characters. In Malaysia, Indonesia and elsewhere where durians are common, a rough distinction is made between groups of cultivars sharing particular characteristics (Soegeng-Reksodihardjo, 1962).

3. ORIGIN, DISTRIBUTION AND ECOLOGY

The centre of diversity of the genus Durio is Southeast Asia. A total of 19 species, 14 of which are endemic, are found on Kalimantan. The Malaysian peninsula has 11 species, of which 5 are endemic, and Sumatra has 7 species, none of which are endemic. The durian is naturalized over a much wider area extending from Sri Lanka and southern Burma through Java and Irian Jaya to the southern Philippines (Kostermans, 1958). There are concentrations of semi-wild durian trees in the forests of the Batak

region of northeastern Sumatra, in parts of Sulawesi, and in Ambon-Ceram (Moluccas), which probably grew from seed discarded after wild fruits were collected and eaten.

The ancestry, domestication and spread of the durian is not clear. Its progenitor might either have been a wild form of the same species (Soegeng-Reksodihardjo, 1962), or a related species, *D. wyatt-smithii* Kostermans, from Malaya (Kostermans, 1955). The durian has been introduced within the last century to many other tropical areas, including India, Africa and the West Indies.

As a species of the humid tropics, durians grow best where the annual rainfall is 2,000 mm or more, and evenly distributed. Excessive rain during flowering seriously reduces yields, but dry periods of over 3 months are damaging to the trees. In Malaysia and Thailand the trees are not usually grown at over 300 m in altitude, whereas they were frequent at 800 m in Java (Ochse and Bakhuizen van den Brink, 1931). Well-drained, sandy or loamy soils are best.

#### 4. AGRONOMY, DISEASES AND PESTS

Durians have traditionally been seed-propagated. They germinate and grow rapidly, flowering and fruiting after about 7 years. Vegetative methods of propagation were developed in the 1920's. A commonly-used method is the modified Forkert method of patch budding, in which a bud from a relatively young branch is grafted on to a 2-month old seedling rootstock (Tidbury, 1976). The scions flower and fruit when about 4 years old. Fruit production in durian is seasonal, and they are also prone to alternate bearing.

At least 30 fungal diseases of durians have been recorded in Malaysia alone, 2 of which may be serious. Root rot or patch canker (*Phytophthora palmivora*), can quickly kill trees shortly after the first symptoms appear. Usually older trees are affected and young seedlings, which are somewhat tolerant of the fungus, may be used as rootstocks to inarch older, diseased trees. *D. malaccensis* and *D. mansonii* might be used as rootstocks for the durian in infected soils (Malo and Martin, 1979), laboratory experiments having shown that they do not attract zoospores of the fungus. *Pythium complementens* also causes a patch canker and root rot in Malaysia. These diseases are most serious in poorly drained soils (Singh, 1973; Williams and Liu, 1976).

At least 14 insect species attack durians in Indonesia, including 3 scale insects, several leaf-eating caterpillars and beetles, 2 trunk and branch borers, and 3 fruit borers (Lepidoptera). None are very damaging, and control is not usually practised (Kalshoven and van der Vecht, 1950). Additionally, 2 nematode pests *Helicotylenchus* spp. and *Radopholus* spp. have been reported from the Malay peninsula (Singh, 1973).

#### 5. GENETICS AND IMPROVEMENT

The chromosome number of durian is  $2n=2x=56$  as reported in Zeven and de Wet (1982). Soepadmo (1979) found the somatic chromosome numbers of 4 *Durio* species to be between 54 and 69. No genetic inheritance studies have been made in durian.

Durian fruits were presumably collected from the wild, but by the 19th century, cultivars with desirable characteristics began to be recognized. In 1948, 13 clonally produced cultivars were compared in a trial at Serdang, and the best ones were distributed for cultivation. In West Java, 86 accessions collected in Indonesia in 1978 have been assembled as the basis for a selection programme. Some inter-cultivar crosses were made in 1962 in Malaysia, but no results have been reported.

#### 6. GERMPLASM CONSERVATION

Sastrapradja (1975) concluded that genetic erosion in the cultivated durian was extensive in Indonesia, Malaysia and Thailand, moderate in southern Viet Nam, and slight

in the Philippines. The distribution of relatively few clonally-propagated cultivars to farmers was the major cause. Some loss of germplasm of D. dulciss, D. grandiflorus, D. graveolens, D. kutejensis and D. oxleyanus, which have edible fruits, has also occurred in Indonesia and Malaysia. Tropical rainforest, which is the habitat of wild Durio species, has been extensively cut down for agriculture, roads and towns. In the Malayan uniform system of forest regeneration, native fruit trees, including Durio species, are selectively removed to allow the growth of trees of higher timber value (Choke, 1973).

The IBPGR has supported a number of collecting projects in Indonesia, Malaysia and Thailand. Several sizeable collections are now in existence, but they largely contain cultivated durian and not wild species except in Thailand. Storage of seed, which usually contain one zygotic embryo, is not possible as they are recalcitrant (Chin and Roberts, 1980; Hanson, 1984). Some effort has been made to conserve Durio species in situ in areas of Malaysian forest designated as Virgin Jungle Reserves (Choke, 1973). D. cinnatus was noted in one of them (Putz, 1978). In situ conservation will be the major method of preserving the diversity of the gene pool.

Table 7. Collections of durian

Country	Location	Number of accessions	
		<u>Durio zibethinus</u>	Other <u>Durio</u> spp.
Australia	Darwin, N.T.	10	
Indonesia	Bogor (IPB)	86	
Indonesia	Bogor (LBN)	?	?
Indonesia	Lembang	20	
Malaysia	Kuala Lumpur	-----310-----	
Philippines	Los Baños	97	
Thailand	Bangkok	68	
Thailand	Chantaburi	504	<u>D. graveolens</u> (102) <u>D. kutejensis</u> (14) <u>D. malaccensis</u> (5) <u>D. mansonii</u> (158) <u>D. oxleyanus</u> (8) <u>Durio</u> spp. (36)
USA	Miami, Florida	16	
USA	Hilo, Hawaii	6	

IBPGR (1984) also lists the following small collections of durian, but these can probably not be regarded as genetic resources collections: Manaus, Amazonas, Brazil; Keravat, Papua New Guinea.

ANANAS COMOSUS  
(Pineapple)

1. INTRODUCTION

Pineapples are a sweet, succulent and tasty but not particularly nutritious fruit, supplying a modest amount of carotene, riboflavin and vitamin C (Table 1). They may be eaten fresh, and are frequently canned in pieces or as juice. The fibrous waste can be fed to livestock, while the mill juice can be used for the production of organic acid and alcohol. A textile fibre can be produced from the leaves where labour costs are low. All parts of the plant are a potential, though currently unexploited, source of the protease enzyme bromelain, which has uses in food processing and medicine (Dupaigne, 1975; Heinicke and Gortner, 1957).

Pineapples are grown for domestic consumption, or for export, either fresh or processed. They are now a major fruit crop (Table 2), being grown in about 66 countries. The largest producers in 1984 were Thailand, Brazil, India, Hawaii, Mexico, Indonesia and China. Detailed statistics based on geographical areas of production are given in Py *et al.* (1984).

2. TAXONOMY AND BOTANY

Ananas comosus L. (Merr.) is the cultivated pineapple. Two closely-related genera produce pineapples, a 'false' or syncarpous fruit comprising swollen fused carpels, calyx segments and bracts on an inflorescence axis.

Smith (1939, 1955) recognized 5 species of Ananas, some of them with subspecies, and one species of Pseudananas, P. sargenarius L.B. Smith. A key to the genera and species, with detailed botanical descriptions is given in Collins (1960). A new key was recently proposed in which 8 species of Ananas are recognized (Smith, 1979). The two genera differ in the form of the bracts covering the syncarp, which are reduced and squamiform in Pseudananas, and conspicuous and foliaceous in Ananas. There are also differences in the production of 'slips' and stolons, and in the appendages borne on the petals, which are in the form of lateral folds in Pseudananas, but like delicate fimbriated funnel-shaped scales in Ananas.

A. comosus is a perennial herb, 90-100 cm high. Leaves in a bushy rosette crowded on stem with right- or left-handed spiral and 5/13 phyllotaxy, up to 1 m long and 6.5 cm broad, sessile with clasping base, margin spiny, tip pointed. Inflorescence compact with 100-200 flowers borne spirally. Flowers hermaphrodite, trimerous, with floral bract; sepals 3 short fleshy; petals 3, free, connivent with small opening at tip; ovary inferior 3-locular with thick, fleshy septa; ovules 14-20 per loculus in 2 rows, usually aborted. Fruit parthenocarpic syncarp formed by almost complete fusion of all the berry-like fruitlets, and leafy bracts on the inflorescence peduncle (Purseglove, 1972).

A. comosus is known only in cultivation, and is almost always propagated clonally. Occasional chance hybridization and seed set in normally seedless fruits, and mutation, may have played a part in the development of a few cultivars. The ancestry of other cultivars may be traceable to plants selected by South American Indians. Many cultivars have been named and described (Py and Tisseau, 1965), usually classified in 3-5 groups, but few are commercially grown. Collins (1960) lists 7 widely-grown cultivars: Cayenne, Singapore Spanish, Red Spanish, Pernambuco, Ananas amarillo, Vermelho and Monte Lirio. Different cultivars may be suited for growth in different climatic zones.

3. ORIGIN, DISTRIBUTION AND ECOLOGY

There is little evidence on the origin of pineapple. It was probably

domesticated in the Paraná-Paraguay river drainage area by the Tupi-Guarani Indians, where the related seedy species occur. It may possibly also come from the highlands of Guyana alongside rivers (Zeven and de Wet, 1982).

The crop was widely grown in Central America, the Caribbean, and northern South America before the discovery of the New World by Europeans, who introduced it in the 16th and 17th centuries to many other tropical countries. Early this century, pineapples were still a minor crop, supplying domestic needs and a small European market. Production expanded 5-fold between 1950 and 1984, particularly in developing countries.

The pineapple is mostly cultivated within the tropics, but is occasionally grown at latitudes up to about 34°. Continuously warm conditions favour rapid growth and development. The fruit takes longer to grow at both higher altitudes and latitudes, but fruit colour and quality is often better at lower temperatures. The crop is frost-sensitive, but able to withstand considerable drought, albeit at the expense of growth and yield. Pineapples grow best in well cultivated and fertile soils.

#### 4. AGRONOMY, DISEASES AND PESTS

Vegetative shoots from various positions on the plant are used for propagation: 'suckers' are from buds just below ground level; 'shoots' are from buds in leaf axils; 'slips' are those just below the base of the fruit; 'hapas' are from the base of the pedicel; 'crowns' are from the top of the fruit; and 'butts' are virtually what remains of an entire plant after harvesting the fruit. The various types of shoots differ in size, weight and speed of growth. There are techniques also of rapid multiplication, which involve the stimulation of dormant buds in leaf axils.

The number of shoots needed to establish a new plantation depends on cultivar, climate and agronomic factors; commonly 45-65,000 are planted per hectare. In many countries the soil is mulched with polyethylene or paper to conserve moisture. Chemical and mechanical weed control measures are also standard practice, the weed problem being considerable because of the slow growth of pineapple plants. Growth regulators may be applied in some countries to ensure synchronous flowering and fruit production.

In the tropics a crop may be produced from newly-planted shoots in less than 18 months, while it may take more than 18 months in the sub-tropics. In some countries like Côte d'Ivoire, only one fruit crop is normally taken when they are grown for export, whereas 2 or 3 further crops may be allowed to develop from suckers, depending also on the cultivar grown and the nematode problem, if fruit quality is not a major criterion. After a full cropping cycle, new planting material is removed from the old plants, and the remaining stumps are cut up and ploughed in. A green manure crop may be grown between successive pineapple crops to help control nematodes, or other fruit crops may be grown in rotation. Yields vary from an average of 25 tons to up to 100 tons/ha, ratoon crops usually producing less, and especially so in the case of 'Cayenne Lisée' (Py et al., 1984).

About 12 fungal diseases affect pineapple. Several Phytophthora species are widespread, causing root, heart or top-rot, especially when drainage is poor. Nematodes and other animal parasites may facilitate entry of the fungus. Planting in the dry season, and other cultural methods help to keep the disease in check, while chemical control of the fungus is also possible. Butt and fruit rots can be caused by Ceratocystis paradoxa. Drying or aeration of plant materials and preplanting fungicide dips help to control it. The fungus Fusarium moniliforme penetrates the fruit through small wounds, often caused by mites, and may cause fruitloft core rot (black spot). No means of control has yet been developed, although it is fairly common. Other fungal diseases are not severe and not controlled.

Several species of bacteria, such as Erwinia carotovora and E. chrysanthemi, which cause fruit collapse in Malaysia, may have very damaging effects. The disease is



probably transmitted by insects visiting the flowers. Spraying with ethephon, which reduces anthosis, also reduced disease incidence (Lim and Lowings, 1979). The "pink disease", reported from several countries, is caused by one or more species of bacteria. This also is transmitted by insects or mites, and can be reduced by insecticide sprays (Kontaxis, 1978).

In Hawaii, the yellow spot virus causes leaf spots, and necrotic areas and rotting of affected fruits. Control is by removing infected plants and the alternate weed host, Emilia sonchifolia, and by routine insecticide sprays to control the thrip vectors. The causes of pineapple wilt disease, which is widespread and results in serious losses if unchecked, and the "terminal mottle" disease in Hawaii and Mexico, are not fully understood (Cook, 1975).

At least 30 insect pests, including a few mite species, cause economic damage to pineapples. Several species of mealybug are associated with wilts, which may be caused by a toxic material introduced when they feed. Ants may help in dispersing the mealybugs. Routine measures to control both ants and mealybugs, using insecticides and plantation hygiene, are applied in many countries. Several insects and mites are vectors of Fusarium. The larvae of Thecla basilides (Lepidoptera) may cause large crop losses in Brazil, by tunnelling into the fruit, and causing the exudation of a gum-like substance. Again control is usually chemical. Fruit flies are of little importance in pineapples. There are differences between cultivars in susceptibility to some insects.

At least 11 species of nematodes attack pineapple roots, causing growth reduction. Nematicides are used in some countries to control them, and crop rotation may also help.

#### 5. GENETICS AND IMPROVEMENT

Commercial cultivars of pineapple may be diploid, triploid or tetraploid, with  $2n=50$ , 75 or 100 chromosomes respectively. Diploids and tetraploids are fertile but self-incompatible, while triploids, whether naturally or artificially produced, are sterile. Higher ploidy results in larger cells and fewer stomata per  $\text{mm}^2$  of leaf surface, but is not clearly related to fruit production or quality. Pseudananas is a tetraploid with  $2n=100$  chromosomes.

A few plant characters have been the subject of inheritance studies. Leaf spinness, a barrier to easy cultivation, is determined by the alleles S-s; S for spiny tips, and s for spiny leaves. The cultivar 'Cayenne', which is spiny-tipped is S/s. Another character of known inheritance is the so-called "piping leaf", a completely spineless form with a silvery band on the upper leaf surface. The gene P (piping) is epistatic to S or s. The homozygous P/P genotype produces a more pronounced piping than the P/p genotype, while the p/p genotype has no obvious phenotype in the presence of S or s genes. Mutations of S to s are fairly frequent, and should be rogued, but the reverse mutation is rare. Many other mutations, such as "collar-of-slips", characterized by an excessive number of 'slips' attached to or massed around the fruit base, are known. The fruits of this mutant are smaller than normal, and should be rogued (Collins, 1960).

Most pineapple breeding has been based on mass selection or individual plant selection, followed by clonal multiplication. The use of induced mutations, and/or intervarietal or interspecific hybridization has only rarely been reported. Large collections of cultivars form the basis of many successful selection programmes in Côte d'Ivoire, Hawaii, the Philippines and elsewhere.

Artificial cross-pollination is quite simple, and the seeds can be removed from the fruit without difficulty. Seed germination is slow and irregular without treatment with concentrated sulphuric acid to soften the tough seed coat (Iyer et al., 1978). The seedlings are grown in a nursery for about 18 months, and in the field for 16-30 months before they produce fruit. Selected plants are cloned and then tested in replicated

trials. The possible use of callus cultures for producing new cultivars has also been suggested (Pannetier and Lanaud, 1976).

Pineapple breeding has mostly been aimed at improving fruit quality for canning. Collins (1960) lists 9 desirable changes in 'Smooth Cayenne', which is widely grown in Hawaii for canning: yellower fruit colour, higher sugar content, lower acid content, more cylindrical fruit shape, more uniform ripening, higher vitamin C content, absence of seeds, larger and more vigorous root system, and improved disease resistance. Breeding aims in Côte d'Ivoire have included: short cropping cycle, mealybug, nematode and symphilit resistance, large fruit, short and stout pedicel, small crown and quick production of 1-2 suckers and 1-2 slips at least 2 cm below the fruit base (IRFA, 1977). Resistance to Fusarium is an important breeding aim in Brazil.

Breeding programmes in the Philippines (Capinpin, 1939), Hawaii (Collins, 1960), Puerto Rico (Ramirez et al., 1970), Malaysia (Lee, 1977), Brazil (Gadilha, 1978), Queensland (Leverington, 1969), Malaysia (Wee and Tay, 1974), and Guinea (Py and Tisseau, 1965) and other countries have produced improved cultivars. Systems of clonal selection operating in many countries may be reaching the limits of their productivity, to be replaced by programmes based on hybridization. Such programmes, however, are slow, as  $F_1$  seed takes 4 years to fruit, and 4 generations of back-crossing to an inter-specific cross may be required before a commercially-acceptable cultivar is produced. The whole process may take 25 years to be followed by several years of multiplication before sufficient planting material is available, although the use of in vitro methods may speed up the process considerably.

#### 6. GERMPLASM CONSERVATION

It is difficult to assess the danger of disappearance of wild Ananas and Pseudananas species, because the precise ranges of many of them are unknown, and some of the wild relatives of pineapple grow in inaccessible areas which have been inadequately explored (Pickersgill, 1976). Information is generally available from easily accessible areas, such as along the Paraguay and Paraná rivers (Argentina, Paraguay, Bolivia and Brazil), and in the states of São Paulo and Minas Gerais in northeastern Brazil, where genetic erosion may have been most serious. IBPGR has recently funded a collecting mission in the Orinoco basin.

Several wild species of Ananas and Pseudananas are now being used in breeding programmes in Hawaii. Collins (1960) has listed the desirable and undesirable characteristics of A. ananassoides (Bak.) L.B. Smith, A. bracteatus (Lindl.) Schultes, A. erectifolius L.B. Smith, and P. segenarius, and 5 important cultivars of A. comosus. A. ananassoides has contributed a distinctive flavour, an ability to grow in cool moist conditions, and some disease resistance. Possibly other wild Ananas species may contribute useful genes, as crossing barriers are usually slight.

There are relatively few extensive collections of pineapple cultivars and wild relatives, most of which are of clonally-maintained cultivars grown in the field. Several collections are maintained by private companies, and may therefore not be available for general use. A well-drained site is essential in order to avoid Phytophthora and other diseases. Some individual plants may occasionally undergo genetic change through mutation, but this is unlikely to happen with more than a few of the plants of a clone. Pineapple seeds are orthodox (Ellis, 1984), but they are not known to have been stored for germplasm conservation. Commercial cultivars are seedless, but seeds may result from cross-pollination. New pineapple plants have been raised in vitro from various types of explant (Hathews, 1979), the maintenance of which under minimal growth conditions will be useful both for the international exchange of disease-free material and for medium-term germplasm conservation.

Table 8. Collections of pineapple

Country	Location	Number of accessions	
		<u>Ananas comosus</u>	Other species/ hybrids/genera
Australia	Queensland	40	
Brazil	Bahia	83	<u>A. ananassoides</u> (18) <u>A. bracteatus</u> (10) <u>A. erectifolius</u> (3) <u>A. paraguayensis</u> (1) <u>Ananas</u> spp. (39) <u>Bilbergia</u> spp. (2) <u>Bromelia</u> spp. (36) <u>Tillandsia</u> sp. (1) hybrids (21)
Brazil	Rio de Janeiro	43	
Brazil	Pernambuco	31	
Cameron (IRFA)	Njombe	14	
China	Taiwan	45	
Colombia	Palмира Valle	29	<u>Bromelia chrysacantha</u> (1)
Côte d'Ivoire (IRFA)	Abidjan	107	12 wild relatives
France (IRFA)	Martinique	29	<u>Ananas</u> spp. (6)
France (IRFA)	la Réunion	15	
India	Bangalore	36	
Indonesia	Lembang	48	
Japan	Okinawa	48	<u>A. ananassoides</u> (2) <u>A. bracteatus</u> (3) <u>A. erectifolius</u> (1) <u>A. lucidus</u> (1) <u>Ananas</u> spp. (2) <u>Pseudananas sapenarius</u> (2)
Malaysia	Kuala Lumpur	54	
Mexico	Veracruz	11	<u>Ananas</u> spp. (2)
Mexico	Celaya	20	
Mozambique	Maputo	20+	
Nigeria	Ibadan	106	
Philippines	Los Baños	10	
Seychelles 1/	Mahé	?	<u>Ananas marron</u> (1)
South Africa	Nelspruit	11	
Thailand	Bangkok	12	<u>A. bracteatus</u> (3) <u>Ananas</u> sp. (1)
USA	Miami, Florida	25	<u>Aschmea</u> spp. (1) <u>Bromelia pinguin</u> (1) <u>Tillandsia</u> spp. (6)
USA	Puerto Rico	58	

1/ Grand'Anse Experimental Centre, Mahé Island, Seychelles.

CARICA PAPAYA

(Papaya)

1. INTRODUCTION

The papaya is principally a dessert fruit, but when green can be cooked as a vegetable. Ripe papaya flesh is rich in vitamin A, relatively high in riboflavin, and average in vitamin C (Singh et al., 1967 and Table 1), but is of poor food value otherwise. It can be used in pickles, jelly, jam, candy, canned pieces, nectar or pulp and in pies and sherberts (Bhutiani et al., 1963). The enzyme papain, which consists of 2 high molecular-weight components, can be extracted from latex tapped from green fruits, after which the fruit, heal and can be eaten, and leaves are also used for this purpose (Bocker, 1958). Papain has a variety of industrial and medicinal uses, mainly in the chill-proofing of beer, and also in meat tenderization (Lassoudière, 1969e).

According to FAO statistics, papaya is grown in 32 countries. This is probably an under-estimate, as it is produced in many countries on a small scale and for local consumption only. World production of fruit (Table 2) has increased over the last decade, the largest producers in 1984, in descending order, being Brazil, Mexico, India, Indonesia and Zaire. Papain production is very labour intensive, and was restricted to Zaire, Tanzania, Uganda and Sri Lanka in 1970 (Flynn, 1975). Many aspects of papaya production are covered in Lassoudière (1969 a,b,c,d and f).

2. TAXONOMY AND BOTANY

Carica papaya L. is the the papaya, melon tree or pawpaw. Badillo (1967) revised the family, recognizing 21 of 57 named Carica species.

Some other Carica species, besides C. papaya, have edible fruits. C. candamarcensis Hook. f., mountain papaya, a frost-resistant species is grown in the mountains of Colombia between 1,500 and 2,700 m. Its small and tart fruits have to be cooked. C. monoica Desf. is a native of the Amazonian forests, which fruits only 4 months after the seeds are sown. Both fruits and leaves may be eaten when boiled. The fruits of C. pentagona Heilb., a native of the Andean highlands of Ecuador and adjacent territory, may be used for making sweets. C. chrysopetala Heilborn also has edible fruits.

The papaya plant is herbaceous in structure, 2-10 m in height, usually unbranched, and rapidly-growing. Latex vessels producing papain are found in all parts of the plant. Leaves large, deeply-lobed with a long petiole, leaving a large scar. Plants are male, female, or andromonoecious; female form is stable; male and andromonoecious may be stable or not, with varying proportions of male, female and perfect flowers at different times of year, depending on weather and photoperiod. Inflorescence<sup>1/</sup> of female plants is short, compact and few-flowered, that of other types long and pendulous, with many sessile flowers. Flowers of 3 types: male flowers with sympetalous corolla forming a slender tube about 2.5 cm long, surmounted by a 5-parted limb of about the same length, with 10 stamens inserted in 2 rows at throat of the tube, gynoecium absent except for a pistillode; hermaphrodite flowers larger than males, with 5-carpellate ovary with parietal placentation, and usually producing long cylindrical, obovoid or pyriform fruits, depending on cultivar; female flowers with large functional pistil, but no stamens, ovoid-shaped ovary developing into oblate, spheroidal to oval fruits. Fruits vary in size and shape according to cultivar and plant sex type. Ripe fruits usually have a smooth, orange skin enclosing a thick layer of yellow-orange pulp in which the numerous small, black and round seeds are embedded,

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<sup>1/</sup> 'inflorescence' a raceme according to Cobley (1956), a cyme according to Storey (1969).

each surrounded by a mucilaginous mass derived from the aril. Many intermediate flower forms can occur, leading to over 30 different tree types.

Pollination of papaya is by wind and insects. Because their unusual breeding system favours cross-pollination, cultivar characteristics can only be maintained by selfing, and few are recognized. 'Solo' was developed in Hawaii from seeds imported from Barbados in 1910. It is hermaphrodite, with fruits of an acceptable weight for the USA market, and does not lose vigour on inbreeding. Several strains of 'Solo' exist (Hamilton and Ito, 1968). Other recognized cultivars are: 'Hortus Gold' from South Africa, 'Co 1' and 'Co 2' from Coimbatore, India, and 'Maradol' a hermaphrodite from Cuba (Rodriguez Nodals and Ricardo Corrales, 1967). The IBPGR is due to publish a descriptor list for papaya in 1986.

### 3. ORIGIN, DISTRIBUTION AND ECOLOGY

Papaya is generally assumed to have originated in the lowlands of Central America somewhere between southern Mexico and Nicaragua. The history of its domestication is not known, but by the time European botanists discovered it, there were already a large range of types in cultivation (Zeven and de Wet, 1982). C. pelta Hook and Arn., a close relative of the papaya, originated in the same region. C. candamarcensis originated in the Andes of Colombia and Ecuador, and C. chrysopetala and C. pentagona are from Ecuador. The cultivated papaya is now ubiquitous throughout much of the tropics and sub-tropics.

Papaya is not frost-hardy, although slight frost sometimes only damages the leaves. Growth is most rapid at 22-26°C, and for high quality fruit full sunlight is required. 1,000-1,500 mm. of rainfall evenly distributed throughout the year, is ideal. For papain production, conditions somewhat cooler than typical in tropical lowland areas, seem to be favourable (French, 1972). Papaya grows well in many soils, provided they are well-drained and free from root knot nematodes. An ideal pH is 6-7 but they grow quite well at pH 5-6. In areas only marginally suitable for papaya production, i.e. at higher altitudes and latitudes, cool weather may result in poor pollen production and/or the formation of abnormal flowers leading to deformed and non-marketable fruits, which may also have a lower sugar content and poorer taste. Pollination may be inadequate in wet weather, while extended dry periods reduce apical growth and new leaf and inflorescence development.

### 4. AGRONOMY, DISEASES AND PESTS

Papayas are usually grown from seeds, which germinate in 2-4 weeks under tropical conditions. Often seedlings are raised in nurseries, and transplanted 6-8 weeks later at a density of about 1,100 plants/ha. Initially only leaves are produced, but after 4-8 months, inflorescences are initiated in the leaf axils. The fruit takes about 5 months to develop in the tropics but longer under cooler conditions. Vegetative propagation is possible, but rarely practised because of the scarcity of scion material from the mother plant, which makes it expensive.

Orchards have to be replanted every 3-4 years, but need little maintenance: some weed control and no pruning. The first fruits are formed low on the plant, but they are borne progressively higher up, so that after a few years they are too high for economic harvesting. Fruit production can be continuous, but is likely to be seasonal in climates with cool or dry periods.

About 50 fungal diseases affect papaya, and are a major factor limiting yields, especially in plantations. Anthracnose (Colletotrichum gloeosporioides and other Colletotrichum spp.) spoils ripening or stored fruits, but can be effectively reduced by a post-harvest hot water treatment. Different Pythium and Phytophthora species cause a number of root, foot and trunk rots. Other disease symptoms include seed rot, damping-off of seedlings, powdery mildew, premature leaf shed, flower and young fruit drop, and fruit spotting and rots. Control measures in nurseries and plantations,

though costly, are often essential. They include soil sterilization in nurseries, the introduction of disease-free soil in older plantation sites, regular chemical spraying programmes, plantation hygiene, and crop rotation (Frossard, 1969a).

About 20 virus and virus-like diseases affecting papaya have been reported, but up to half of them may be synonyms (Frossard, 1969b; Cook, 1972, 1975). Many occur in restricted areas, and they vary greatly in severity. Virus diseases virtually destroyed a flourishing industry in Cuba (Roig and Mesa, 1962). Control measures include chemical control of insect vectors, removal of weed hosts, and roguing of infected plants. Three bacterial diseases of minor importance only have been reported (Cook, 1975).

Up to 70 species of insects and mites, almost half of them Homoptera, attack papaya. The mites, Hemitarsonemus latus and several Tetranychus species, cause yellowing and shedding of leaves, and also damage fruits. The Homoptera group includes at least 14 species which are vectors of virus diseases, 6 jassids, 14 scale insects and 8 aphids. The larvae of at least 11 species of fruit flies (Diptera), which lay their eggs in the fruit, are very damaging. Among the group of Coleoptera, some species seriously damage leaves or fruits. The group of Coleoptera comprises mainly trunk-boring beetles. The Orthoptera includes a polyphagous grasshopper, and a mole cricket which cuts young seedlings off at ground level. Reasonably effective insect control can be achieved with pesticides (Guérout, 1969).

Five root knot nematode (Meloidogyne spp.) and one reniform nematode (Rotylenchulus reniformis) may be serious pests. Chemical soil treatments and crop rotation are appropriate control measures (Guérout, 1969).

## 5. GENETICS AND IMPROVEMENT

All Carica species examined are diploid with  $2n=18$  (Chandler, 1958). Tetraploid papayas have been produced artificially (Lassoudiere, 1968). Three alleles determine the inheritance of sex (Storey, 1969): M for male,  $M^H$  for hermaphrodite and m for female. Combinations of dominants, i.e. MM,  $MM^H$  and  $M^HM^H$  are lethal to the zygotes receiving them. Hermaphrodites are  $M^Hm$ , males Mm and females mm. Selfing of hermaphrodites leads to 25% females, 50% hermaphrodites, but no males, and 25% of the zygotes are non-viable. Males only occur in the offspring when one of the parents is male. The inheritance of fruit shape, fruit size, muskiness of flesh flavour, flesh colour, earliness of fruiting, and height at first fruiting are also more or less well understood.

The genetic improvement of papaya has continued for centuries, by raising seedlings from selected fruits and eliminating unwanted male plants. Breeding programmes based on artificial hybridization were started in Hawaii in 1915 (Storey, 1969), in South Africa in 1931 (Hofmeyr, 1933), in Colombia in 1963 (Torres and Rios Castano, 1967), in Peru in 1964 (Caldaza, 1967), and in Côte d'Ivoire in 1977 (Anon., 1978c).

Breeding goals depend, among other things, on the market requirements of different countries. In Hawaii export to mainland USA requires small fruits (450-700 g), while local canneries demand large fruits (900-1,350 g). Traits common to both markets are: high yield, uniformity of fruit size and shape, thick and firm fruit flesh, attractive flesh and skin colour, small cavity, high sugar content, absence of unpleasant odours, absence of carpelloidyl<sup>1/</sup> and sterility, and resistance to diseases.

In general, papaya breeding seems to be relatively problem-free. A wide range of

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<sup>1/</sup> The abnormal development of stamens into fleshy structures which spoil the shape of the fruit - "cat-face" fruits.

variability exists in C. papaya and closely related species. The fruit produces many (300-700) seeds which germinate rapidly, and the plant has a short breeding cycle. Despite their breeding system, yield is not depressed on inbreeding. The successful hermaphrodite cultivar 'Solo' and strains developed from it (Yee, 1970; Nakasone et al., 1974) have resulted in improved crops in Hawaii and elsewhere, but resistance to papaya mosaic and other virus diseases, and a juvenile sex-linked character allowing the early elimination of superfluous male seedlings, are still required.

Several Carica species are potentially useful sources of disease resistance, but the cross-compatibility of different species has been insufficiently studied (Sawant, 1958; Horovitz and Jiménez, 1972; Mekako and Nakasone, 1975). The study of graft-compatibility between different species could be valuable in the search for a rootstock resistant to soil-borne diseases, notably Phytophthora spp.

#### 6. GERMPLASM CONSERVATION

The risk of genetic erosion in wild Carica species may be low because the plants grow and fruit rapidly, often in disturbed habitats, produce numerous seeds, and have a breeding system favouring out-crossing and occasional interspecific crossing.

Collections currently contain a range of both cultivated and wild accessions of several Carica species. Most are maintained as living plants, but several also contain seeds. The seeds are orthodox (Ellis, 1984), and remain viable for about a year if dried and kept at 12°C in a tightly-capped jar, or longer under IBPGR preferred conditions.

Table 9. Collections of papaya

Country	Location	Number of accessions	
		<u>Carica papaya</u>	Other <u>Carica</u> spp.
Brazil	Bahia	42	<u>C. cauliflora</u> (1) <u>C. goudotiana</u> (1) <u>C. pubescens</u> (1) <u>C. quercifolia</u> (1) <u>Carica</u> spp. (3)
Colombia	Palмира Valle	70	<u>C. cauliflora</u> (5) <u>C. goudotiana</u> (5)
Colombia	Tibatata	18	
Costa Rica	Turrialba	15	
Cuba	Habana	20	
Equador	Quito	10	<u>C. pentagona</u> (50)
India <sup>1/</sup>	Coimbatore	104	
India <sup>1/</sup>	New Delhi	90	<u>C. candamarcensis</u> (1) <u>C. cauliflora</u> (1) <u>C. chilensis</u> (1) <u>C. chrysopetala</u> (1) <u>C. goudotiana</u> (1) <u>C. microcarpa</u> (1) <u>C. monoica</u> (1) <u>C. pentagona</u> (1)
Malaysia	Kuala Lumpur	35	
Mexico <sup>1/</sup>	Veracruz	54	<u>Carica</u> spp. (6)
Nigeria <sup>1/</sup>	Ibadan	249	
Peru	Lima	39	<u>C. monoica</u> (2) <u>C. pubescens</u> (1)
Peru	Iquitos	10	
Philippines <sup>1/</sup>	Los Baños	301	<u>C. x hallbornii</u> (1) <u>Carica</u> spp. (24 of 7 species)
Seychelles <sup>1/ 2/</sup>	Mahé	37	
USA	Florida	13	<u>C. chrysopetala</u> (1) <u>C. goudotiana</u> (3) <u>Jacaratia spinosa</u> (1)
USA <sup>1/</sup>	Hawaii	29	<u>C. cauliflora</u> (1) <u>C. goudotiana</u> (1) <u>C. microcarpa</u> (1) <u>C. monoica</u> (1) <u>C. peltata</u> (1) <u>C. pubescens</u> (1)
USA	Puerto Rico	10	
Venezuela <sup>1/</sup>	Maracay		<u>Carica</u> species

<sup>1/</sup> Plants and seeds

<sup>2/</sup> Grand'Anse Experimental Centre, Mahé Island, Seychelles.

IBPGR (1984) also lists the following small collections of papaya, but these can probably not be regarded as genetic resources collections, at: Queensland, Australia; Santiago, Chile; Keravat, Papua New Guinea; Nelspruit, South Africa; Wad Medani, Sudan.



Ebenaceae

DIOSPYROS KAKI

(Kaki)

1. INTRODUCTION

The kaki or Japanese persimmon is one of 5 species of Diospyros with edible fruits, which are mainly eaten fresh, but can be frozen, canned or dried, and are sometimes used in oriental cooking. They can be stored for up to 6 months. Kaki is high in vitamin A (from its red to yellowish-orange carotenoid pigments), and is also a moderate source of ascorbic acid (Table 1). Some cultivars are astringent when not fully ripe, containing an average of 1.4% of soluble tannins in special cells. There are old reports from Japan (Trabut, 1925) and India (Anon., 1952) on the use of kaki fruit tannins. Kaki wood is dense, moderately hard, heavy and marbled, and is used for ornamental work in boxes, desks and mosaics, and in Japan for golf-club heads.

FAO statistics of world production (Table 2) are from 5 countries only, with China (Taiwan) producing 61% and Japan 29% of the crop in 1984, and the remainder from the Republic of Korea, Brazil and Israel. Persimmons are relatively minor crops of warm temperate areas rather than the tropics or sub-tropics.

2. TAXONOMY AND BOTANY

Diospyros Kaki L.f. (syn D. chinensis Blume), the oriental or Japanese persimmon, date plum, keg fig or kaki, belongs to the family Ebenaceae. Heywood (1978) considers that the genus Diospyros should contain 400-500 species which were previously distributed among 5 genera. The only other genus Euclea has 14 species. A number of Diospyros species produce ebony wood, and several have edible fruits, the main ones, apart from kaki being, D. discolor Willd., the mabolo (cultivated in Southeast Asia and occasionally elsewhere), D. lotus L., the date plum or Central Asian persimmon (widely distributed from West Asia to China), and D. virginiana L., the American or common persimmon. The latter species is dioecious, though monoecious trees are sometimes also found (Darrow, 1975).

The kaki is a deciduous tree up to 12 m high, rounded or pyramidal in shape. Leaves alternate, entire, dark green, shortly-petioled, and varying in form according to cultivar, 5-15 cm long. Flowers male and hermaphrodite in varying proportions on one tree; male flowers in 3-flowered cymes in leaf axils; calyx and corolla 4-lobed, 16-24 stamens in 2 rows on the petals; sometimes central flower of cyme is hermaphrodite; female flowers also in leaf axils, but singly; calyx leafy with 4 lobes; corolla light yellow, tubular at base, higher up divided in 4 lobes; 8 abortive stamens; ovary globular, more or less flattened with 4 cells each divided in 2 giving 8 compartments each with a single ovule. Fruit a large berry of variable shape with a fine, membranous skin of variable colour; fruit flesh orange-yellow, more or less soft and almost fluid when fully ripe; fruit consistency is influenced by pollination. Seeds up to 8 per fruit, flattened, dark brown; many cultivars have 4 seeds or less, or are completely seedless (Poponoe, 1920).

In areas where kaki has been traditionally cultivated, there were large numbers of cultivars: 800-1,000 in Japan, 2,000 in China (Itou, 1980; Evreinoff, 1948b). A few of these were introduced into other countries, including the USA in the 1860's and 1870's, Brazil and France (Poponoe, 1920; Simão, 1971; Trabut, 1924, 1925), and formed the basis of new national cultivars. Very few cultivars are currently grown on a large scale, 'Fuyu' for instance occupying half the area under kaki cultivation in Japan.

Cultivars can be classified as follows:

GROUP A: Trees with female flowers only

- (i) Ovaries develop asexually and fruit is seedless;
- (ii) Ovaries develop either with or without pollination; and
- (iii) Ovaries develop only if pollinated.

GROUP B: Trees with male flowers only.

GROUP C: Trees with both female and male flowers

- (i) Male flowers produced regularly and abundantly; and
- (ii) Male flowers produced inconsistently.

A further division may be made according to the astringency of the fruits into:

- a) Fruits are non-astringent when mature, and independent of pollination (PCNA cultivars: Pollination Constant Non-Astringent);
- b) Fruits are astringent when mature, independent of pollination (PCA cultivars); and
- c) Fruits are astringent at maturity when not pollinated, and not or only partly astringent when pollinated (PVA and PVNA cultivars: Pollination Variant Astringent or Non-Astringent).

Factors such as fruit size, shape and colour, leaf size and shape, flowering and fruiting period, and others may also be used in classification. A catalogue describing 277 cultivars has recently been published in Japanese by the Akitau Branch of the Fruit Tree Research Station. Cho and Cho (1965) identified 186 cultivars (including those of D. lotus) in the Republic of Korea.

### 3. ORIGIN, DISTRIBUTION AND ECOLOGY

According to Smith (1976), kaki originated from D. roxburghii, a wild species found in forests from Assam to Indo-China. Kaki has been cultivated in northern China for about 2,000 years (Evreinoff, 1948b), and was probably domesticated there; it was introduced into Japan during the 8th Century A.D. (Itou, 1980).

Kaki was introduced into Europe in the early 1700's, but only cultivated from about 1850. It was grown in Italy from 1876, and in Algeria from 1898. The USA imported seeds from Japan in 1856, and grafted cultivars in 1870, and it is now widely grown there. Introduction to Australia took place in about 1880 (Bois, 1928), and to the USSR, notably the Caucasus, in 1888. Japanese immigrants took kaki to Brazil.

The area devoted to the kaki crop in Japan has declined steadily since 1900, and it is now restricted mostly to the central Kanto-Tosan region spreading into the southern Tohoku and Kinki regions (Kajiura, 1980). Other countries which grow kaki include Afghanistan, Brazil, China, Egypt, Indonesia, Israel, Italy, Philippines, Republic of Korea, USA (Florida, California) and the USSR. Some may also be grown in Algeria, Iran, South Africa, Spain, Sri Lanka and Tunisia.

The American persimmon is native to southern USA up to 38°N, from Connecticut to Florida and west to Kansas and Texas, where it used to be abundant in forests of the middle zone on a variety of soils (Trabut, 1925). D. lotus is native to a large area stretching from the Black Sea through central Asia to Japan, and has been grown from historical times (Trabut, 1926). In Japan it occurs mainly in wooded mountain areas. It was found in the northwestern Himalayas of India at 600-1,800 m, but was not abundant (Anon., 1952). In the USSR it grew wild in Tadzikistan (Softalij, 1952) and in eastern and western Georgia (Citavilli, 1953). The present status of these species in the wild is not known.

The kaki tree grows best in mild climates, but is dormant in winter and can withstand mild frost. Some winter chilling is required for uniform bud break and shoot growth. In experiments in Japan with one year old plants, 5-10 days at 0°C to -1°C was sufficient vernalization, and chilling at -7°C for 30 days killed buds (Yoshimura, 1961). Growth is retarded and fruit production is poor in tropical conditions (Singh et al., 1967; Terra, 1936). Kaki requires a good water supply, but with irrigation can be grown in semi-arid areas like California. A deep, heavy and well-drained soil is ideal; the range of suitable soils can be increased by fertilization, liming and cultivation.

#### 4. AGRONOMY, DISEASES AND PESTS

The kaki is may be propagated vegetatively, or from seed, but seedlings may be variable, and are slow to crop. The methods most usually applied are budding and grafting (Kvreinoff, 1948b; Opitz and La Rue, 1975; Simão, 1971). The rootstocks used are kaki itself, the American persimmon, and the Central Asian persimmon.

Cook (1975) lists 10 fungal diseases, many from only one country. Anthracnose (Colletotrichum gloeosporioides) is sometimes serious in Brazil, Italy and Japan. Small spots develop on fruits, later coalescing to form lesions 1 cm or more in diameter, and severely affected fruits drop prematurely. High humidity and moderately hot weather favour spore germination and disease development. Control is by the pruning of affected branches during tree dormancy, and by regular chemical sprays. Astringent cultivars usually have most resistance. Black fruit spot (Phoma kaki-vora) causes dark spots 1-15 cm in diameter on the fruit surface in Japan. Bitter rot (Gloeosporium kaki) is an important disease of kaki cultivars like 'Fuyu' and 'Hiratanenashi', affecting fruits and shoots (Kajiura, 1980). Kajiura mentions 5 other fungal diseases, and a further 7 are known.

Crown gall, (Agrobacterium tumefaciens), causes yellowing and eventually death of kaki trees (Kvreinoff, 1948b; Opitz and La Rue, 1975). Infection may be avoided by using disease-free nursery stock, by preventing injury to the trunk or crown roots, and by protective copper sprays. Blast disease, caused by Pseudomonas syringae, has been reported from New Zealand (Cook, 1975). Symptoms are dark discoloration of leaf bases, petioles and small branches. It can be controlled chemically.

A virus disease, kaki mosaic, has been reported from Brazil. It may have the same cause as a yellowing or premature leaf fall which has been observed in Italy since 1947. Symptoms include leaf mottling and premature leaf drop, necrosis and flower fall, necrotic spots on fruits, and die-back of shoots, twigs and branches. The virus is transmitted mechanically, and may infect a whole range of host plants (Herbas, 1969).

Kaki has few serious pests. 17 species of insect and mite pests were listed in Japan, 6 in Brazil (Simão, 1971), and 4 in California (Opitz and La Rue, 1975). An estimated 50 species are mentioned in the literature. Many belong to the Homoptera, especially the mealybugs, scale insects and armoured scale insects. There are also several Coleoptera (beetles), Lepidoptera (fruit and leaf-eating caterpillars), Diptera (especially fruit flies) and Acarina (mites). In most cases control is by insecticide spraying.

The root-knot nematode (Meloidogyne spp.) and the citrus nematode (Tylenchulus semipalmicranus) occur on kaki in California, but are not serious (Opitz and La Rue, 1975). The latter species also occurred in Israel on D. virginiana used as rootstocks for kaki (Cohn and Minz, 1961).

#### 5. GENETICS AND IMPROVEMENT

The basic chromosome number of the genus Diospyros is  $x=15$ . D. discolor, D. lotus, and D. texana are diploids ( $2n=30$ ), and D. kaki is a hexaploid ( $2n=90$ ). D. virginiana has both tetraploid and hexaploid forms, each within well-defined geographical areas, the best cultivars being hexaploid (Darrow, 1975). It is possible to cross D. virginiana and D. kaki, but good seed is only formed with D. virginiana as the female parent. Little is known about the genetic inheritance of characters in kaki (Oohata et al., 1964; Ikeda et al., 1975).

Systematic selection of kaki has been carried out since 1938 in Japan, the aims being: a cultivar earlier than 'Fuyu' and 'Jiro'; large fruit; good quality, i.e. non-astringent, independent of pollination (PCNA type), and of good taste; and resistance to anthracnose. Cross-pollination is easy because flowers are unisexual.  $F_1$  seedlings take 5-6 years before producing fruit, although the juvenile period can

be shortened to 3 years by budding the seedlings on to an adult tree. In Japan they are budded on to 'Fuyu', 7-8 seedlings per tree. The cultivars 'Fuyu' and 'Jirc', which are of excellent quality but not sufficiently early, are used as female parents, while an early and non-astringent type, which also produces male flowers, is used as a male parent.

The cultivar 'Izu' was selected from the cross 'Fuyu' x 'A4' in 1960. 'Izu' is very early, and of similar quality to 'Fuyu' but is prone to alternate bearing. The cultivar 'Suruga', from the cross 'Hanagoshu' x 'Okugoshu' has non-astringent high-quality fruits. Occasionally cultivars have been developed through mutation, like 'Matsumoto-wase Fuyu', a bud mutation which is two weeks earlier than 'Fuyu'.

#### 6. GERMPLASM CONSERVATION

There is evidence that there has been serious genetic erosion in both the Japanese and American persimmons. The number of commercial cultivars grown in Japan has declined from about 50 to 10-15 in a few decades. Many of the 1,000 or so previously known non-commercial cultivars have also been lost (Kajiura, 1980). About 50 years ago, over 60 cultivars were grown in USA (Smith, 1970); now 5 only are recommended in California, while another 6 are under trial (Opitz and La Rue, 1975). Many cultivars were lost from the collection at Okitsu, Japan, early this century.

The wild kaki, occasionally known as *D. kaki* var. *sylvestris* Makino, has been reported from Japan and the Republic of Korea. *D. oleifera* Cheng, which may be synonymous with wild kaki, has been reported to grow wild in China. No information is currently available on genetic erosion in wild kaki, or on *D. virginiana* or *D. lotus*. *Diospyros* seeds are recalcitrant (Ellis, 1984), and therefore collections are currently only maintained in field genebanks.

Table 10. Collections of persimmons

Country	Location	Number of accessions	
		<u>Diospyros kaki</u>	Other <u>Diospyros</u> spp.
Australia	Nambour, Queensland	20	
China	Shensi	185	
China	Taiwan		<u>D. discolor</u> (2) <u>D. ebenaster</u> (10) <u>Diospyros</u> sp. (1)
Costa Rica	Turrialba		
Israel	Beit-Dagan	12	
Japan	Hiroshima	338	<u>D. lotus</u> (2) <u>D. virginiana</u> (2) <u>Diospyros</u> sp. (1) <u>D. discolor</u> (1)
Papua New Guinea	Keravat		<u>D. blaccol</u> (5) <u>Diospyros</u> spp. (2)
Philippines	Los Baños		
Thailand	Bangkok	41	
Turkey	Izmir	10	
USSR	Leningrad		<u>Diospyros</u> spp. (7)
USA	Davis, California	70	
USA	Urbana, Illinois	46	
USA	Miami, Florida		37 accessions of 12 species
USA	Hilo, Hawai	8	

IBPGR (1984) also lists the following small collections of persimmons, but these can probably not be regarded as genetic resources collections, at: Habana, Cuba; Nicosia, Cyprus.

There is also reported to be a collection of 186 accessions, including both D. kaki and D. lotus, at Kimhae Branch Station, which is a part of the Horticultural Experiment Station, 475 Imog Dong, Suweon SI - Gyeonggi Do, Postal code: 170, Suweon 42857, Republic of Korea. There are reported to be some accessions of D. kaki at the Provincial Academy of Agricultural Sciences, Shaanxi, China.

Euphorbiaceae

PHYLLANTHUS EMBLICA  
(Emblie)

1. INTRODUCTION

The fruits of emblic are small, round, sour and astringent, and more suitable for use in cooking, pickles, jams etc. than for fresh consumption. They are notable for their very high vitamin C content. Morton (1960) lists the following uses of the whole plant: fruit powder for treating vitamin C deficiency (scurvy); fermented juice for treating coughs, jaundice and dyspepsia; leaves for diarrhoea and indigestion; seeds for asthma and bronchitis; bark, which is strongly astringent, for treating diarrhoea and for tanning leather; leaves and fruit for dyes; foliage and fruits as fodder for cattle; and the hard and flexible red wood for construction, furniture and implements.

The emblic is a minor crop, which is mainly grown in home-gardens in India, and no quantitative data on its economic value are available.

2. TAXONOMY AND BOTANY

Phyllanthus emblica L. (syn. Emblie officinalis Gaertn.), the emblic or myrobalan, and P. acidus (L.) Skeels (syn. P. distichus (L.) Muell.-Arg.), the Otaheite gooseberry, which is native to Madagascar and India, both have edible fruits.

The emblic plant is a much-branched shrub or tree, 9-18(-30) m high. Leaves entire, linear oblong, 1.2-1.9 cm long, 0.3 cm wide, obtuse, nearly sessile, distichously arranged on very slender branchlets, giving an impression of finely pinnate foliage. Flowers inconspicuous, yellow to greenish-yellow, in compact clusters in axils of lower leaves, apetalous; male flowers usually at the lower end of branchlets with female flowers above them, but trees occasionally dioecious; sepals 5-6, imbricated, intrastaminal disc present; stamens 3, with connate filaments; ovary 3-4 celled with 2 ovules per cell, each of the 2 styles usually 2-cleft. Fruit a berry, nearly stemless, round, indented at base, and smooth to obscurely 6-lobed, initially light green, becoming a dull greenish-yellow or more rarely brick red as it matures, hard 2-3(-5) cm in diameter; skin thin, translucent; flesh very crisp, juicy; stone containing 6 small seeds (Bailey 1949; Morton, 1960).

The breeding system of emblic favours out-crossing, so seedlings are very variable. Flowering lasts about a month, and pollination is by wind, honey bees and gravity. Fruit set may be increased by introducing hives into orchards. Some Indian cultivars with superior fruits, which have been rather poorly described, are recommended for vegetative propagation (Singh et al., 1967; Ram, 1974).

3. ORIGIN, DISTRIBUTION AND ECOLOGY

The origin and domestication of the emblic is not clear. The wild tree is widely distributed in tropical Asia based on: Pax (1896) (Mascarene islands, India, Burma, Bangladesh, Sunda islands, China, Japan); Anon. (1952) (India, Malaya, Sri Lanka, China); Ram (1974) (wild in forests of India to 1,800 m); and Whitmore (1973), according to whom, emblic is found throughout Malaya in lowland forests (but not the hills of northeastern Kelantan), and in the area from India to southern China and Malasia eastward to Borneo and the lesser Sunda islands. It is not cultivated to any extent outside this area.

The emblic does not have particularly specific climatic requirements, and grows in a fairly wide area of the tropics and sub-tropics. It is considered to be ideal for dry regions (Singh, 1974).

4. AGRONOMY, DISEASES AND PESTS

The emblic tree was grown from seeds for many years, but recently methods of

vegetative propagation have been developed in India, such as inarching, budding and top-working (Singh et al., 1967; Ram, 1974). Seedlings start bearing after about 8 years; budded trees take about 6 years. Flower induction may be affected by day length, with only one flowering period in northern India, and two in southern India. The emblic is often grown at a spacing of 9-12 m. An average 15-year old tree may yield 200 kg of fruit, or 20 tons/ha. Yields may be less than average if trees have a high proportion of male flowers (Dhar, 1979).

The following fungal diseases are of minor importance in India: Phakopsora phyllanthi (leaf rust); Ravenelia emblicae (ring rust); Aspergillus niger (fruit rot); Phoma emblicae (dry fruit rot, post-harvest) (Anon., 1950a; Jamaluddin et al., 1975a, 1975b). An internal fruit necrosis of unknown cause occurs in India, affecting cultivar 'Francis' seriously, but not 'Chakaiya' (Ram, 1974; Ram et al., 1976), but could be controlled with foliar sprays of borax.

In India, Betonsa stylophora causes the formation of shoot galls, which check growth if near the growing tip. It can be controlled by regular pruning of affected wood, followed by chemical spraying (Ram, 1974). Emblic is the preferred host of bark-eating caterpillars (Indarbela spp.) in Haryana State, India. In Indonesia, the leaves of emblic are sometimes damaged by the caterpillars of Parallelia joviana (Kalshoven and van der Vecht, 1950).

#### 5. GENETICS AND IMPROVEMENT

Margenot et al. (1977) considers that the basic chromosome number of P. emblic is  $x=13$ , although  $2n$  values of 26, 90, 98-104, and 104 have been found. The chromosomes are very small. No other genetic data exists on emblic, and no improvement other than the selection of a few cultivars for clonal propagation, has been attempted.

#### 6. GERMPLASM CONSERVATION

There are currently large numbers of seedling trees of cultivated emblic, which are genetically heterogeneous. The status of wild emblic is not known. There are a few collections containing emblic trees. Its seed storage characteristics are not known.

There are really no proper genetic resources collections of emblic, but IBPGR (1984) lists some accessions in the following places: Havana, Cuba; Uttar Pradesh, India; Udaipur, India; Bangkok, Thailand; Miami, Florida, USA.

Guttiferae

GARCINIA MANGOSTANA  
(Mangosteen)

1. INTRODUCTION

The mangosteen is one of the most delicious tropical fruits. Most mangosteens are consumed fresh, but the edible segments can also be canned, cooked or made into squash or syrup. The fruit flesh has a similar nutritional composition to that of many other juicy fruits (Table 1). The rind is relatively rich in protein and can be made into jelly. It can also be used for tanning by virtue of its high tannin content (7-14%), and has several medicinal uses. The wood, which is heavy, dark brown, hard and durable, is suitable for cabinet work, building purposes and rice pounders.

Mangosteen is only grown to any extent in Southeast Asia, often as a minor component in mixed fruit holdings, but extends westwards to Burma and east India. Production data are not published by FAO. The main producing countries, in descending order of yield, are Thailand (59,200 tons in 1978), peninsular Malaysia (1,640 ha in 1972, which is assumed to yield about 16,000 tons), Indonesia-East Java (2,500 tons in 1972), and a group of countries including Côte d'Ivoire, India, Honduras, Panama, Sri Lanka and the Philippines (Lum, 1975; Vangnai, 1980).

2. TAXONOMY AND BOTANY

The mangosteen (Garcinia mangostana L.), dodol, mang-khut (Thai) or manggis (Malay, Indonesian, Philippines), belongs to the Guttiferae. The genus Garcinia L. has at least 400 species, mostly in Asia. Characteristics of the genus include: habit - usually small or medium trees, occasionally shrubs, rarely over 30 m in height; crown - monopodial, dense; inner bark with a sticky exudate; leaves with bases clasping the twigs, the uppermost pair concealing the terminal bud; flowering habit - mostly dioecious; stigma usually conspicuous; fruit - a fleshy to woody, non-dehiscent berry (Whitmore, 1973).

Many Garcinia spp. yield useful products, such as timber (not very valuable), dyes (yellow pigment from the latex of G. hanburyi Hook f. in Indonesia, Malaysia, Thailand and Indo-China), vegetables (leaves of G. lanceaefolia Roxb. in Assam, India), medicines and fruits (Heyne, 1950; Burkill, 1966; Anon., 1956; Brown, 1954). G. dulcis (Roxb.) Kurz, is the gurka, or ma-phut (Thai), mundu (Malay, Indonesian), or baniti (Philippines), which is cultivated for its edible fruits in Malasia and India (IBPGR, 1980). Pijnaert listed 44 species with edible fruits (Bourdeaut and Moreuil, 1970).

Mangosteen is a dioecious tree of 10-25 m high and 25-35 cm trunk diameter. Leaves opposite, shortly-stalked, ovate-elliptic-oblong, entire, thickly coriaceous, 12-23 cm x 4.5-10.0 cm; petiole 1.5-2.0 cm. Male flowers<sup>1/</sup> in fascicles of 2-9 at the ends of branches, rather long-stalked; sepals 4, erect; petals 4 yellowish-red inside, greenish-red outside; stamens numerous, inserted on a disc under rudimentary ovary. Female flowers terminal at tips of young branchlets, solitary, ca. 5.5 cm in diameter; pedicel short and thick; sepals 4, biseriolate; outer sepals 2 cm long, yellowish-green; inner sepals somewhat smaller than outer ones, bordered with red; petals 4, thick fleshy, yellowish green, bordered with red or almost entirely red, 2.5 cm x 3.0 cm; staminodes more or less arranged in groups of 1-3, ca. 0.5 cm long; ovary sessile, sub-globose, 4-8 celled; stigma sessile. Fruit a berry, sessile on the persistent

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<sup>1/</sup> According to other sources, male flowers are never found on fruit-bearing mangosteens (Bourdeaut and Moreuil, 1970).



calyx, crowned by stigma, 3.5-7.0 cm diameter, black or dark violet; pericarp ca. 0.9 cm thick, purplish-violet, containing very bitter yellow juice. Seeds usually 0-3 well-developed, ovoid-oblong, laterally compressed; the other ones minute or abortive; all surrounded by a white, fleshy juicy aril (Ochse and Bakhuizen van den Brink, 1931).

Virtually all of the mangosteens in the world are more or less uniform, and could be considered as a single cultivar. They are mostly grown from seeds but these develop from the nucellus without pollination, and so in effect reproduce them clonally. There are a few, older reports of mangosteens which differ from the usual type, but whether they originated from different ancestors or through mutation is not clear.

### 3. ORIGIN, DISTRIBUTION AND ECOLOGY

The origin of the mangosteen is a matter of some controversy. While Zeven and de Wet (1982) consider it to be derived from wild C. silvestris Boerl., a species found in both Malaysia and India, Whitmore (1973) states that the true wild home of the mangosteen is not known. Indeed, Whitmore does not mention C. silvestris as part of the tree flora of Malaya, but notes that the vegetative characteristics of mangosteen resemble those of other species in Malaya, C. hombroniana Pierre, also indigenous in the Nicobar islands, and C. malaccensis Hooker f. Almeyda and Martin (1976) state that wild mangosteen grows in the Malay peninsula, Burma, Thailand, Kampuchea, Viet Nam, the Sunda islands and the Moluccas. Both Zeven and de Wet, and Almeyda and Martin were quoting other published sources, while Whitmore's statements are based on recent field work. The mangosteen spread to tropical countries outside Southeast Asia only within the last few centuries (Bourdeaut and Moreuil, 1970; Cox, 1976).

As a tropical tree adapted to regions of heavy and well-distributed rainfall, the mangosteen requires a minimum of about 1,250 mm of rainfall per annum without irrigation. The optimum temperature range is 25°C-35°C and the optimum humidity is over 80%. The preferred soils are deep and rich in organic matter, and do not drain too rapidly. Many other types of soil are also suitable, but the tree grows slowly and may die prematurely on poor and alkaline soils.

### 4. AGRONOMY, DISEASES AND PESTS

The mangosteen is usually propagated from seeds, which germinate in 10 days to 9 weeks, depending on seed age and other factors. The seedlings may reach 25-35 cm after a year, but are not vigorous or easy to transplant, and may not produce fruit for 10-15 years. Vegetative methods of propagation have been developed in which mangosteen is grafted or budded on to related species, which are easier to establish as seedlings and grow more rapidly, but such propagation can prove to be difficult. Some wild Garcinia species, such as C. speciosa, which has some drought resistance, are graft-compatible with the mangosteen. Hitherto the method has not been commercially adopted, and seed propagation remains the method commonly used (Bourdeaut and Moreuil, 1970; Cox, 1976; Almeyda and Martin, 1976). Yields, which may not start until about 15 years, increase rapidly until trees are about 50 years old, but older trees may produce smaller fruits. Average yields over a period of 18 years were about 360 fruits/tree/year (Krishnamurthi and Madhava Rao, 1965), but may be as high as 500. Mangosteen is rather prone to irregular bearing, but without a consistent year-to-year rhythm; the causes of these fluctuations are not clear.

Though mangosteen is fairly exacting in its climatic and soil requirements, it has been grown successfully on a small scale outside Southeast Asia in such countries as Costa Rica, Côte d'Ivoire, Ecuador, India, Madagascar and Panama.

Seven fungal diseases have been reported from peninsular Malaysia, of which only brown root (Phellinus noxius) and red root (Ganoderma pseudoferrugineum) are serious and economically important (Singh, 1973). Fruit rot (Botryodiplodia theobromae) is common in Sabah, and two other fungal pathogens occur rarely (Williams and Liu, 1976). Thread

blight (Pellicularia kaleroga) has been seen frequently in Puerto Rico, affecting leaves, young branches and young fruits (Almeyda and Martin, 1976). Bourdeaut and Moreuil (1970) reported anthracnose from Côte d'Ivoire, a scab from Nicaragua, and a sooty mould from Madagascar. Chemical control measures have been recommended for many of the diseases.

Mangosteens in Malabar, India are affected by 2 physiological conditions: "gamboge canker", which may occur if there is heavy rainfall during the period 2-8 weeks before fruit maturity, and in which gum exudes on to the pericarp; and fruit-cracking in the rainy season due to absorption of moisture through the placenta - affected fruits develop swollen arils and the pulp becomes mushy. A condition known as little leaf has been reported from India (Singh et al., 1967).

Mangosteen is attacked by up to 12 insects and mites including: leaf-eating caterpillars in Indonesia and Malaysia, especially Stictoptera spp. (Lepidoptera); a trunk and branch-boring ant in Puerto Rico; fruit surface capsids in Indonesia and Côte d'Ivoire; and mites damaging the fruit surface in Puerto Rico. Control measures recommended are mainly plantation and plant hygiene and chemical methods (Kalshoven and van der Vecht, 1950; Anon., 1956; Bourdeaut and Moreuil, 1970; Almeyda and Martin, 1976).

#### 5. GENETICS AND IMPROVEMENT

The chromosome number of mangosteen can not be unequivocally stated. Counts of about  $2n=76$  and  $2n=96$  have been published, while  $2n=120$  to  $130$  were also recorded in some unpublished work. The very high figures may indicate that the mangosteen is a high-level polyploid (Jong et al., 1973). Polyploid series of  $2n=44$ ,  $60$ ,  $64$ ,  $68$ ,  $88$ , and  $90$  have been observed in the genus Garcinia (Soepadmo, 1979). There has been no breeding work.

#### 6. GERMPLASM CONSERVATION

Mangosteen is an unusual case in which there is narrow diversity in the cultivated species. Nevertheless, Sastrapradja (1975) considered that there has been severe genetic erosion of mangosteen in Southeast Asia. There are no truly wild populations of mangosteen, either of male or female trees. Many other Garcinia species may be useful either for their fruits, or as rootstocks for the mangosteen. They are typically trees of Southeast Asian rainforests, and are likely to be under considerable threat as this habitat continues to be destroyed.

Mangosteen seeds are recalcitrant, and lose their viability rather quickly, especially when the thin membrane around the seed is damaged, or when seed is placed in a dry or cool atmosphere (Chin and Roberts, 1980; Hanson, 1984). Viability is best maintained by keeping the seeds in moist charcoal or moss at room temperature, but even so the storage period was not more than a few months (Cox, 1976). Clearly seed storage is quite impracticable, and all of the field genebanks contain trees.

Table II. Collections of mangosteen

Country	Location	Number of accessions	
		<u>Garcinia mangostana</u>	Other <u>Garcinia</u> spp.
Indonesia	Bogor		<u>Garcinia</u> spp. (7)
Philippines	Los Baños		10 accessions of 8 species
Thailand	Chantaburi	440	
Thailand	Songkla	59	<u>G. atroviridis</u> (3) <u>G. dulcis</u> (2) <u>G. prainiana</u> (4) <u>G. speciosa</u> (1) <u>G. xanthochymus</u> (1) <u>Garcinia</u> spp. (2)
USA	Miami, Florida		25 accessions of 11 species

IBPGR (1984) also lists the following small collections of mangosteen, but these can probably not be regarded as genetic resources collections, at: Njombe, Cameroon; Cozolapa, Oaxaca, Mexico; Keravat, Papua New Guinea; Hilo, Hawaii, USA.

There are also reported to be some accessions at Hainan Botanical Garden of Tropical Economic Plants, Academy of Tropical Crops of South China, Ministry of Agriculture, Hainan Island, Guangdong Province, China.

Lauraceae

PERSEA AMERICANA  
(Avocado)

1. INTRODUCTION

Avocados are mostly consumed fresh as a salad fruit. They constitute a staple ingredient of the diet in many Latin American countries, being unusually high in oil and low in sugar (Table 1). The oil content varies with genetic and environmental factors, fruit age and ripeness from (3)-5-26-(40)% of pulp weight (Chandler, 1958; Bergh, 1983 pers. comm.). The main components of the oil, which is very digestible, are the unsaturated fatty acids, oleic and linoleic, and palmitic acid, which is saturated. The amino acid balance of the protein is well-suited for human requirements. They are a good source of vitamins A, B (thiamine), C and G. Avocado oil extracted from the seeds commands a high price, and is used in cosmetics, high quality soaps, pharmaceutical products, and as a high grade salad oil.

On a world scale, avocados are not a major crop (Table 2). An increase in production has occurred over the last decade, concomitant with a slight decrease in the proportion grown in developing countries. The leading producers in 1984 were Mexico, USA (Florida and California), Dominican Republic, Brazil, Indonesia, Peru and Haiti. Most of the crop is grown for home consumption, but a few countries, notably South Africa, Israel and Kenya, export fresh fruit to Europe. Crops are not usually grown solely for oil extraction.

2. TAXONOMY AND BOTANY

Williams (1977) considered that there are 2 species of cultivated avocados, Persea americana Mill. (syn. P. gratissima Gaertn.) and P. nubigena L. Williams. Earlier botanists usually treated them as one species, P. americana, but recognized 3 races (groups of cultivars with many characteristics in common): a Mexican, Guatemalan and West Indian race; plus a hybrid group (P. americana x P. drymifolia Cham. and Schlecht.), according to their probable origin. Williams put the West Indian race in P. nubigena, and the other 2 in P. americana. P. drymifolia is an old name for the Mexican group of cultivars. Bergh (1983 pers. comm.) considers that there is only one valid species, namely P. americana, with 3 botanical varieties, which are equivalent to the races recognized earlier. This is the system which is used here.

The avocado is an evergreen tree up to 20 m high. Leaves, simple, elliptic, ovate-oblong or obovate-oblong, 5-30 cm x 3-15 cm, spirally-arranged. Inflorescence a compact axillary panicle crowded at the ends of branches. Flowers numerous greenish-yellow with 6 perianth segments; stamens 9 perfect arranged in 3 series, innermost whorl of androecium is of 3 staminodes surrounding a one-celled superior ovary with a single ovule. Fruit a large fleshy berry, pyriform or globose, 7-20 cm long; mesocarp yellow or yellowish-green of a butter-like consistency. Seed single, large, globose, with 2 seed coats and 2 large fleshy cotyledons enclosing a small embryo.

The avocado exhibits protogynous, diurnally-synchronized dichogamy. The flowers open twice, firstly when the stigma is receptive, but the stamens not yet mature; secondly when the pollen is ready but the stigma is no longer receptive. Avocado trees may be grouped into 2 classes: the flowers of class A open first in the morning, and for the second time on the following afternoon; class B flowers open first in the afternoon and again the next morning. The flowering mechanism is partly controlled by weather conditions, and ensures cross-pollination unless the two stages overlap, as sometimes happens. Pollination is by insects, often bees.

There are several hundred named avocado cultivars, but most of the crop is

produced from only a few of them. Cultivars are classified primarily on the basis of the 3 botanical varieties, but there may also be natural or man-made hybrids between them. Many cultivars have been described (Bergh, 1975; Morin, 1967; Simão, 1971; Meulen, van der, 1970). The cultivars 'Duke' and 'C6' are moderately resistant to blight (Gaillard, 1982 pers. comm.).

### 3. ORIGIN, DISTRIBUTION AND ECOLOGY

The wild ancestors of present-day cultivated avocado are assumed to have been indigenous in Central America, where their fruits were probably picked for many centuries. Possibly South American Indians carried out some selection, as when the Spanish arrived in the 15th century, the 3 races were already known. The Mexican, which probably originated in highland Mexico, is the oldest selection; the West Indian one may have been developed from it also in Mexico; and the Guatemalan one which may have been selected in the high interior valleys of Guatemala is more recent.

The transfer of races outside their area of origin resulted in the development of hybrids, like 'Fuerte' (Guatemala x Mexico). At the time of the Spanish conquest, avocados were already well-known in Central America, Colombia, Venezuela, Peru and Ecuador. Their spread to the West Indies and the lower Amazon basin was probably post-conquest (Patiño, 1963). Avocados are now widely grown throughout the tropics and sub-tropics.

The ecological requirements of avocado vary somewhat with races. They are sensitive to frost, especially the West Indian one, being particularly susceptible during flowering. Mexican cultivars are rather less susceptible to cold than Guatemalan cultivars (Gaillard, 1982 pers. comm.). Using the best sources of cold resistance, it has been possible to extend the range of commercial production up to 43°N (Corsica). Their usual range, depending upon other climatic factors as well, is between 36°N and 36°S. In some areas, such as Florida, high winds may cause considerable damage to trees. Avocados grow well of a wide range of soil type from sandy to clayey, but the roots must not be waterlogged. High pH and salinity may be a problem in some areas.

### 4. AGRONOMY, DISEASES AND PESTS

Propagation of avocado has traditionally been from seeds, which have to be sown very soon after removing them from the fruits. Modern plantations are usually established by budding or grafting selected cultivars on to seedling rootstocks.

The most severe fungal disease is probably root rot, caused by Phytophthora cinnamomi, which results in tree decline and death. The disease is particularly serious on poorly-drained soils. Care should be taken to use disease-free planting material, raised in a nursery in sterilized soil. Chemical soil treatments in plantations have been only partially successful and are costly. A new systemic fungicide which is sprayed on to foliage has also been tested. The best solution to the root rot problem would seem to be either resistant cultivars or tolerant rootstocks. The cultivar 'Duke' is moderately resistant. Several wild species, such as P. borbonia, P. caerulea, and P. veraguasensis, are completely resistant, but are graft-incompatible with P. americana.

Other important diseases include anthracnose (Colletotrichum gloeosporioides), cercospora spot blotch (Cercospora purpurea) and scab (Sphaceloma perseae), all diseases of leaves and fruits. They may be controlled by using chemical sprays. Cercospora spot blotch is particularly severe in hot tropical climates. The rest of the 26 fungal diseases recorded on avocado are generally of minor importance and not controlled.

The bacterial disease blast (Pseudomonas syringae) has been recorded on avocado but is of little significance. A viroid disease, known as "sun blotch", has been found in several countries. It affects tree growth, and results in reduced fruit set and small misshapen fruits, but is not a major problem. The disease is transmitted through infected budwood and seed, and no insect vector is known. Virus-free propagating material can only be obtained by indexing seedlings, which takes from 3 to 24 months (Cook, 1975).

Several dozens of insect and mite species attack avocado, but the pest problem is much less serious than that of citrus. Chemical control methods are generally used. There may be varietal differences in susceptibility to insect damage; fruit flies (Dacus tryoni) in Queensland, for instance, prefer the thin-skinned, early and mid-season cultivars (Smith, 1973).

#### 5. GENETICS AND IMPROVEMENT

All Persea species examined have  $2n=2x=24$  chromosomes. There is virtually no other genetic data on the crop. Desirable fruit types were presumably selected by South American Indians, and their seeds, resulting from uncontrolled pollination, were planted. Genetic improvement based on controlled pollination and selection has only been practised in a few countries, notably Australia, Israel and USA (California), but progress so far has been slight (Bergh, 1969).

Major aims in the breeding of rootstocks include: resistance to root rot; tolerance to salinity; tolerance to high pH; tolerance to low soil temperatures at higher latitudes and altitudes; and a limiting effect on growth of the scion for more easily managed trees. The aims with respect to the scion include: spreading habit; cold hardiness; heat tolerance; early, heavy and consistent yield; and fruits of the required weight, shape, skin and flesh colour, flavour, storage and ripening behaviour, and oil content.

Selection within open-pollinated seedlings has resulted in many valuable avocado cultivars, and much has been achieved in the selection of rootstocks. The rootstock selections 'G.A.-13' and 'Maos' from Israel exhibit a high tolerance to saline and high lime conditions (Kadman and Ben-Ya'acov, 1980). Several sources of resistance to Phytophthora cinnamomi derived from P. americana in addition to 'Duke' are known ('Huntalis', G6, G22). Possibly half of the commercial avocados planted in California are on Phytophthora-resistant clonal rootstocks, chiefly 'Duke 7' (Bergh, 1983 pers. comm.).

#### 6. GERMPLASM CONSERVATION

Deforestation in Central America, where wild Persea trees grow, is doubtless leading to loss of genetic resources. P. theobromifolia, a native of lowland wet forest, but now only found in the Rio Palenque Biological Center in Ecuador, is listed in the Red Data Book as being in the 'endangered' category. It is potentially important as a blight-resistant rootstock for the cultivated avocado (IUCN, 1978). Avocado seeds are recalcitrant (Ellis, 1984), so the collections listed are all of trees.

Table 12. Collections of avocado

Country	Location	Number of accessions	
		<u>Persea americana</u>	Other <u>Persea</u> spp.
Australia	Merbeln, Victoria	294	<u>P. indica</u> (1) <u>P. schiedeana</u> (1)
Australia	Alstonville, N.S.W.	18	
Australia	Darwin, N.T.	26	
Australia	Nambour, Queensland	23	
Brazil	Itajai, Santa Catarina	32	
Brazil	Jaboticabal, São Paulo	343	<u>P. indica</u> (1)
Brazil	Planaltina	24	
Brazil	Londrina, Parana	20	
Chile	Santiago		<u>Persea</u> spp. (10)
China	Taiwan	20	<u>P. drymifolia</u> (2)
China <sup>1/</sup>	Hainan	7	
Colombia	Tolima	20	
Côte d'Ivoire	Abidjan	42	
Cuba	Habana	280	
Cuba	Villa Clara	47	
Cyprus	Nicosia	20	
Ecuador	Quito (INIAP)	36	
Ecuador	Quito (Universidad Central)	6	
France (INRA)	San Nicolo, Corsica	75	
France (IRFA)	La Réunion	40	
Greece	Crete	24	
Indonesia	Malang	21	
Indonesia	Lembang	21	
Israel	Bet-Dagan	211	<u>Persea</u> spp. (7)
Jamaica	Kingston	108	
Madagascar	Tananarive	27	
Mexico	Celaya, Guanajuato	164	<u>P. cinerascen.</u> (1) <u>P. indica</u> (1) <u>P. schiedeana</u> (1)
Mexico	Guliacán, Sinaloa	28	
Nicaragua	Departamento de Masaya	40	
Papua New Guinea	Keravat	26	
Philippines	Los Baños	246	
Seychelles <sup>2/</sup>	Mahé	50	
South Africa	Nelspruit	25	
Spain	La Laguna, Canary Islands	20	

<sup>1/</sup> Hainan Botanical Garden of Tropical Economic Plants, Academy of Tropical Crops of South China, Ministry of Agriculture, Hainan Island, Guangdong Province, China.

<sup>2/</sup> Grand'Anse Experimental Centre, Mahé Island, Seychelles.

NOTE: IRFA also maintains small collections in Cameroon and Togo, but further details are lacking.

Table 12. Collections of avocado (Continued)

Country	Location	Number of accessions	
		<u>Persea americana</u>	Other <u>Persea</u> spp.
Thailand	Chantaburi	136	
Thailand	Tak Province	227	
USA	Riverside, California	70	20 accessions including: <u>P. ficocosa</u> , <u>P. gigantea</u> , <u>P. nubilana</u> , <u>P. subg.</u> <u>Persea cinerascens</u> , <u>P. subg. Persea schiedeana</u> , <u>P. subg. Persea steyermarkii</u> , <u>P. subg. Eriodaphne borbonia</u> , <u>P. subg. Eriodaphne caerulea</u> , <u>P. subg. Eriodaphne</u> <u>donnell-smithii</u> , <u>P. subg. Eriodaphne indica</u> , <u>P. subg. Eriodaphne lingua</u> , <u>P. subg. Eriodaphne longipes</u> , <u>P. subg. Eriodaphne pachypoda</u> , <u>P. subg. Eriodaphne varaguasensis</u> , <u>P. subg. Eriodaphne vesticula</u>
USA	Miami, Florida	408	
USA	Hilo, Hawaii	107	
USA	Mayaguez, Puerto Rico	112	<u>P. schiedeana</u> (1)
Venezuela	Meracay, Estado Aragua	74	



MALPIGHIA EMARGINATA  
(Acerola)

1. INTRODUCTION

Acerola fruits, which taste somewhat like European cherries, are best made into juice, sauce or jelly, relatively few being eaten raw because of their large stones. Their vitamin C content is exceptionally high (Table 1), and about 88% of it can be recovered from the juice (Santini and Nevarez, 1955). The tree also produces a gum which was used in folk medicine. The bark has been sold for its tannin content, and the wood can also be used (Ostendorf, 1963).

The acerola is currently of minor importance in the West Indies, Florida, Hawaii and parts of northern South America. Between 1945 and 1965 a significant increase in production occurred in Puerto Rico, and to a smaller extent in Florida and Hawaii, for processing fruits into powders and juices high in vitamin C. The crop also became more widely grown in orchards and gardens elsewhere. About 200 ha of acerola trees were planted in Puerto Rico, some of which are still harvested, frozen fruits being exported to the USA for use in health foods (Asenjo, 1980).

2. TAXONOMY AND BOTANY

The genus Malpighia L. contains about 40 species (Bailey, 1949). Vivaldi (1979) has recently reviewed the genus. The acerola or Barbados cherry, which is native to Mexico, is M. emarginata DC (Asenjo, 1980). The following species also have edible fruits: M. urubus L. (Puerto Rico), M. coccigera L. (Antilles), and M. setosifolia Spreng. (northern Antilles, Puerto Rico, Cuba, Hispaniola). None of these are cultivated, but M. mexicana A. Juss is grown in Mexico for its fruits (Fouqué, 1973). M. glabra L. (syn M. puniceifolia L.), which has small insipid fruits, and grows from southern USA to South America, may be known by the name semarugo in Venezuela. Both Latin names are sometimes incorrectly used as synonyms for M. emarginata, but M. emarginata and M. glabra have very different gynoecia (Vivaldi, 1979).

Acerola is a glabrous shrub to 8 m high. Leaves opposite, almost sessile, entire, (1.0)-2.0-2.5-(8.5) cm long, (0.7)-1.5-2.5-(5.0) cm wide, sub-chartaceous to chartaceous, variously obovate, in some cultivars almost ovate, the apex obtuse and usually emarginate, very rarely somewhat acute in some cultivars, the base acute to cuneate. Inflorescence a (1-)-2-4(-6) flowered, umbel-like raceme 1.5-2.0(-2.5) cm long. Flowers bisexual regular, ca. 1.3 cm across; sepals 5 persistent, some or all bearing large sessile glands, up to a total of 6-10 in the calyx; petals erose or fringed, at anthesis (10-)-13-17(-20) mm in diameter; stamens 10, all anther-bearing, the filaments united below, glabrous; ovary styles truncate or obtuse at the apex, but rarely somewhat uncinatate, the lateral styles thick, somewhat curved, (2.5-)-3.0-3.5(-4.0) mm long, the anterior style thin, straight 0.5-1.0 mm shorter than the lateral styles. Fruit 3-pyrenous drupe, red or scarlet, depressed-ovoid, 1-3 cm in diameter, acid, with thin skin; epicarp thin and delicate; mesocarp of large juice-filled cells; endocarp of 3 hard stones, each formed by the lignified, elongated cells of vascular strands and adjoining cells. The development of the stones depends upon the degree of seed development in each carpel (Bailey, 1949; Vivaldi, 1983 pers. comm.).

Some Malpighia species, including M. emarginata, have to be pollinated by bees for a high rate of fruit set. Centris dirrhoda performs this role in Jamaica, but poor fruit yields in Hawaii were not improved when honey bees were introduced into orchards (Raw, 1979). There may be self-incompatibility in addition; both self-compatible and self-incompatible cultivars occur (Parthasarathy and Kalyanasundaram, 1979). Occasional cases of parthenocarpy have been found (Miyashita et al., 1964). The seedling progeny of open-pollinated acerola trees are very variable. A number of selected seedlings have been cloned in Florida, Puerto Rico and Hawaii, and have cultivar status.

### 3. ORIGIN, DISTRIBUTION AND ECOLOGY

The cultivated acerola originated somewhere in the area extending from southern USA through Mexico and Central America to northern South America and the Caribbean islands, and now only grows wild in the Yucatan area of Mexico. Domestication must have taken place before 1492; its distribution to countries outside tropical America has been since that date, and in many cases only since the beginning of this century. The crop is rarely cultivated outside of these areas.

The acerola is a tropical tree, but is quite drought-resistant. In areas of low rainfall it may be deciduous and only green in the rainy season, as in the Guajira peninsula of Colombia (Rieger, 1976). More rain is required for good fruit production. In Puerto Rico the best crops are grown where there is over 1,800 mm of rainfall/year, but too much rain may result in tender fruits of low quality. The acerola is not very exacting as to soil quality, but the heavier soils of Puerto Rico are preferred since they are usually less infested with nematodes (Py and Fouqué, 1963; Marty and Pennock, 1965).

### 4. AGRONOMY, DISEASES AND PESTS

The acerola can easily be grown from seed, despite the stony endocarp, but many seeds contain non-viable embryos, and germination may be poor (Argles, 1976). Methods of vegetative propagation, most commonly using hardwood cuttings, but also by air and ground layering and several grafting techniques, can be employed successfully. Seedlings are ready for grafting at 10-12 months after sowing (Holmquist, 1967).

Seedlings commence flowering when only 6 months old, and depending on climatic conditions, continue to bloom the whole year round or with seasonal peaks. A single plant may carry flowers and fruits at the same time. Yields vary with cultivar and growing conditions, but may vary from 20-50 kg per tree, which is equivalent to 8 to 20 tons/ha when plants are at a 5 m x 5 m spacing. The main factor limiting production of acerola is the availability of bee pollinators of the genus Centris.

Fungus diseases do not seem to be a great problem (Cook, 1975). Anthracnose (Colletotrichum spp.) may be important in India. Cercospora leaf spot (Cercospora bunchosia) occurs in Florida and Hawaii, especially in conditions of high humidity. Cultivars '269-2' and 'Florida Sweet' have some resistance. Cercospora leaf spot may also occur in Puerto Rico (Meléndez, 1963).

Insect pests, including scale insects, aphids, mealy bugs, mites, leaf-eating caterpillars and soil-borne insects, do not often cause excessive damage and may be controlled with insecticides. Nematodes are probably the most serious pests of acerola (Ostendorf, 1963). There has been some research in Florida on resistant rootstocks (Argles, 1976).

### 5. GENETICS AND IMPROVEMENT

Until about 35 years ago seed propagation was usually practised and little selection had been attempted. Since then, selection for desirable characteristics, including high vitamin C content and flavour has been carried out in Florida, Puerto Rico and Hawaii (Miyashita et al., 1964; Knight, 1980), some of the work in Florida being based on hybridization (Singh, 1961). Considerable improvements in the yield and quality of acerola have been achieved.

Some work has been done on the use of species related to acerola, such as M. puberosa, M. urens and M. cubensis, as rootstocks in order to obtain nematode resistance (Argles, 1976).

### 6. GENETIC CONSERVATION

There is little evidence of genetic erosion in either wild or cultivated

acerola. A few collections contain acerola trees, and although the seeds are orthodox, it is not known that they are stored in any genebanks. IBPGR (1984) 1/ lists the following, which are too minor to be regarded as genetic resources collections: Manaus, Amazonas, Brazil; Habana, Cuba; Cozolapa, Oaxaca, Mexico.

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1/ M. glabra is used instead of M. emarginata in IBPGR (1984).

Table 13. Collections of acerola

Country	Location	Number of accessions	
		<u>Malpighia emarginata</u>	Other <u>Malpighia</u> spp.
USA	Miami, Florida	10	<u>Malpighia</u> spp. (3)
USA	Mayaguez, Puerto Rico	6	
USA	Hilo, Hawaii	6	

LANSIUM DOMESTICUM  
(Langsat)

1. INTRODUCTION

The edible arils of the langsat fruit are usually eaten fresh, but can be preserved in syrup or candied. Its white flesh is sweet to slightly acid, fairly juicy, free from fibres, easy to peel and to separate from the few seeds. It is low in protein and fats and moderate in carbohydrates (Table 1). The peel emits an aromatic odour like burning incense and may be used as a mosquito repellent. Peel, seeds and bark have medicinal uses and the wood is suitable for tool handles and house posts (Anon., 1962a).

The langsat is cultivated as a garden crop in Southeast Asia, but is almost unknown outside this area. Production figures from various sources suggest the following approximate areas may be grown: Philippines (1979) 7,710 ha, Thailand (1978) 7,000 ha, Peninsular Malaysia (1972) 1,700 ha; the crop is also grown in Indonesia. Most fruit is consumed locally, as it does not store well.

2. TAXONOMY AND BOTANY

The genus Lansium Correa comprises 7-10 species, distributed in India, Malaysia, the Philippines, Indo-China and Indonesia. Species in Indonesia include L. pedicellatum Kosterm., a shrub 4 m tall in southern Sumatra, L. sepalinum Kosterm., a small tree 4 m tall in central Sumatra (Kostermans, 1960), and L. kostermansii B. Prijanto found on Sumbawa island (Prijanto, 1965). Besides the cultivated langsat (L. domesticum Jack.), the following have edible fruits, but are not cultivated:

- (i) L. anamallayanum Bedd., a tree up to 15 m high in evergreen forests of the Western Ghats in Kanara, Wijnad, Anaimalai hills, Travancore and Tinnevely in India at between 450-900 m (Anon., 1962a).
- (ii) L. dubium Merr., a tree up to 15 m high, which occurs in primary forests at low and medium altitudes in the Philippines from central Luzon to southern Mindanao (Brown, 1954).

The langsat is a slender but fairly tall tree (15-20 m) with fluted trunk and green bark. Leaves alternate and pinnately compound, 30-50 cm long, with 5-7 alternate leaflets, 12-35 cm x 7-12 cm. Inflorescences solitary or in fascicles of 2-10 on the trunk or on the oldest branches, many-flowered. Flowers bisexual, sessile or very shortly stalked, solitary, small; ovary fleshy, cupular, 5-lobed, small; lobes yellowish green to light yellow; petals erect, fleshy, white or pale yellow, 2-3 mm long and 4-5 mm wide; ovary globose, 4-5-celled. Fruit a berry, ovoid-oblong or ovoid-globular, pubescent, 2-4 cm long; pericarp sordidly light yellow, rather thin, lactiferous. Seeds usually 2, often with 2 embryos, very bitter; aril thick fleshy, white, somewhat transparent; other cells of the fruit contain only an aril without a seed or with an abortive one (Ochse and Bakhuizen van den Brink, 1931).

Three main groups have been recognized in Indonesia (Ochse and Bakhuizen van den Brink, 1931; Heyne, 1950):

- (a) duku - fruits oblong-globose, relatively large; rind thin, at maturity pale yellow with a little latex; aril thick and very sweet; seeds few, often only 1, and large or small.
- (b) langsat - fruits smaller; rind thicker, pale yellow at maturity and with more latex than a); aril less sweet and seed larger.

- (c) kokosan - small, round fruits; rind dark yellow at maturity; aril sour to very sour.

Many cultivars within the duku group are named after their place of origin, e.g. Menteng, Depok, Rejoso, and Karangajen. The duku, and the langsats and kokosans together, were given botanical variety status as var. typica Backer, and var. pubescens Koorders et Valston, respectively (Ochse and Bakhuizen van den Brink, 1931). Later the kokosan was given species rank with the name L. squameum (Jack.) Kosterm. (Kostermans, 1965).

In Malaysia, 2 groups have been distinguished (Burkill, 1966; Milsum, 1919):

- (a) duku - a very variable group of cultivars from Java with rounded fruits and a thick skin free of latex. Fruit 3.5-5.0 cm in diameter  
(b) langsats - includes wild trees and some cultivars

In Thailand, at least 3 groups are distinguished (Vangnai, 1980):

- (a) duku  
(b) langsats  
(c) long kong

In the Philippines, 2 groups are recognized (Valmayor and Espino, 1975):

- (a) duku - local cultivars with thick rind and sweet arils  
(b) common - local cultivars with thin rind and sub-acid to sweet arils

There is clearly a need for a thorough revision and comparative description of cultivar groups of langsats.

### 3. ORIGIN, DISTRIBUTION AND ECOLOGY

According to Zaven and de Wet (1982), the langsats is native to the Malaysian archipelago and Indo-China. Brown (1954) and Burkill (1966) reported wild trees in the southern islands of the Philippines and in Peninsular Malaysia, respectively. The existence of cultivar groups in the langsats suggests that it may have been domesticated in several different areas more or less simultaneously. The langsats has spread very little outside Southeast Asia and is virtually known only in experimental stations in Africa and the New World.

The langsats is a tree of tropical lowland rainforest and is damaged by frost. Suitable areas have an average yearly temperature of 27°C, with only slight monthly variation. In Java the tree grows in areas with from 6 to 12 wet months in which there is over 100 mm rainfall monthly. Though not exacting about soil conditions, loamy well-drained soils are ideal. The crop could doubtless be grown much more widely.

### 4. AGRONOMY, DISEASES AND PESTS

Seed propagation is usually practised. Seeds should be sown soon after removal from the fruit, and germinate in 1-3 weeks. When seedlings are 15 cm high, with at least 2 pairs of leaves, they are transferred to a nursery bed for 18-30 months before being planted in the field. Vegetative propagation, by budding or grafting on to seedling rootstocks, and by cuttings, is possible, but not yet commercially practised. A seedling tree may produce its first crop after 10 years; grafted trees crop several years earlier. The fruit takes about 3 months to mature. Yields increase with tree age and about 1,000 fruits per tree is normal (Almeyda and Martin, 1977). In the Philippines, trees yielded from about 10-100 kg/tree or about 7 tons/ha (Anon., 1980).

The langsats has few fungal diseases. Anthracnose (Colletotrichum gloeosporioides) may cause fruit spotting and premature drop, but can be controlled

using a copper fungicide (Almeyda and Martin, 1977). Other fungal diseases are not economically important. There are no records of bacterial or virus diseases.

There are also few records of insect pests. In Indonesia a weevil (Curculio spp. - Coleoptera) attacks the ripening fruits; a scale insect (Asterolecanium spp. - Homoptera) causes malformation and die-back of the tips of twigs; and several caterpillars (Lepidoptera) eat the leaves (Kalshoven and van der Vecht, 1950). In Puerto Rico, much damage can be done to young trees by the sugarcane root borer (Diaprepes abbreviatus - Coleoptera); two species of scale insect; and the red spider mite Tetranychus bimaculatus may be troublesome. Recommendations for control are mostly based on pesticides (Almeyda and Martin, 1977).

5. GENETICS AND IMPROVEMENT

The langsat is considered to be an octoploid with  $2n=8x=72$  chromosomes (Bernardo and Ramirez, 1959), but little else is known about its genetics, nor has there been any systematic selection, or work on rootstocks.

6. GERMPLASM CONSERVATION

Sastrapradja (1975) concluded that there was extensive genetic erosion of cultivated langsat in Indonesia, Malaysia, southern Viet Nam and Thailand, and moderate erosion in the Philippines, resulting from the replacement of traditional cultivars with a limited number of selected clones. Some loss of wild langsat has also occurred due to destruction of rainforests. There are 296 accessions of langsat at Chantaburi, and 22 at Songkla, Thailand, and also a few plants at: Bogor, Indonesia; Keravat, Papua New Guinea; Los Baños, Philippines; Miami, Florida and Hawaii, USA (IBPGR, 1984).

Hitherto it has not been possible to use any of the related species as rootstocks for the cultivated langsat, so the need for conserving them is difficult to assess.

ARTOCARPUS ALTILIS AND A. HETEROPHYLLUS  
(Breadfruit and Jackfruit)

1. INTRODUCTION

(a) There are seeded and seedless forms of the breadfruit, the pulp of which may be boiled, roasted or steamed, and used in various main and side dishes. It has a high nutritional value (Table 1), between that of rice and potatoes. The seeds can also be eaten after cooking.

The breadfruit is a minor crop on a world scale, but is quite important in Polynesia, where it may supply a large proportion of the daily food requirements.

(b) The jackfruit, a large fruit, also contains edible pulp and seeds. Young immature fruits are cooked as a vegetable, and the pulp of ripe fruits may be eaten fresh, cooked, or preserved in syrup. Seeds can be boiled or roasted. The rind can be used as a fodder for livestock; the wood for timber; the latex as an adhesive and for medicinal purposes; and the leaves as fodder and for medicinal purposes (Morton, 1965). The fruit of the champedan is used much as is the jackfruit.

The jackfruit is of some significance in southern India, Sri Lanka, Malaysia and Indonesia. The champedan is grown throughout the Malaysian archipelago. All of these crops are usually cultivated in gardens or small-holdings and used locally, as they do not store or travel well.

2. TAXONOMY AND BOTANY

The genus Artocarpus was revised by Jarrett (1959). About 50 species are indigenous in Asia and Polynesia, including 3 which are commonly cultivated for their edible fruits: A. altilis (breadfruit), A. heterophyllus (jackfruit) and A. champedan (champedan). A number of other wild and sometimes cultivated species also have edible fruits, including A. elasticus Reinw. (both pulp and seeds edible) and A. odoratissimus Blanco (edible pulp of very delicate flavour and edible seeds), both reported from the Philippines (Brown, 1951).

(a) The breadfruit tree is large and up to 15 m and more broad, with heavy foliage. Leaves 45-60 cm long, ovate, pinnately-lobed with large deciduous stipules. Inflorescences male and female: male inflorescences - 15-30 cm long, club-shaped, yellow, drooping or downward curving; female inflorescences - globular to oblong spikes, ripening into syncarp. Fruits weigh 800-1,200 g on average and up to 5 kg.

Two main groups of cultivars of breadfruit are distinguished: seeded and seedless. The seedless ones contain about 70% edible pulp; the seeded one 30% pulp and 5% edible seeds. They are very similar morphologically, but the seeded forms are taller and more vigorous (Léon, 1968). The number of seeds in the seeded forms varies; some intermediate types have only 10-15 seeds. Sometimes the seeds are not viable and the tree is propagated vegetatively. In the seedless forms, which have to be propagated vegetatively, a number of clonal cultivars are distinguished (Jarrett, 1959; Murai et al., 1958; Coenen and Barrau, 1961).

(b) The jackfruit differs from the breadfruit notably in its entire leaves, the female inflorescence which develops on short stalks on the trunk and thicker branches and the much larger size (up to 30 kg) and less globular shape of the fully mature syncarp or pseudo-fruit. Pollination is probably by small flies and beetles.

As the jackfruit is usually propagated by seed, the seedlings may be very

variable. Nevertheless, two main types can be distinguished: with soft or firm (crisp) pulp (Singh et al., 1967), which can apparently be maintained by seed propagation. There are also small-fruited forms, known as 'rudrakshi', which are widely grown in India but considered to be inferior. A few cultivars have been described and named in India, Sri Lanka, Thailand and the West Indies (Morton, 1965).

### 3. ORIGIN, DISTRIBUTION AND ECOLOGY

(a) The centre of origin of the breadfruit probably lies within a large area including the Indo-Malayan Archipelago and Papua New Guinea, extending northwards as far as western Micronesia (Fosberg, 1960; Coenen and Barrau, 1961). The breadfruit was spread eastwards over the Micronesian and Polynesian islands many centuries before European explorers first arrived. It may have hybridized with A. mariannensis Trécul, a species indigenous in the Marian islands. Breadfruit was first described in 1595 from its occurrence on Tauta island in the Marquesa group. The seedless breadfruit clones, which have been cultivated on certain Pacific islands for centuries, are probably triploid and resulted from diploid x tetraploid crosses, but mutation may also have played a role.

The food value of breadfruit was soon appreciated, and was introduced to several tropical countries. Probable introduction dates were: 1772 - Mauritius, 1782 - Jamaica and some other West Indian islands (first introduction); 1792-1800 - (second introduction - seedless fruits; 1802 - Penang; 1836 - Malacca; 1897 - Guinea (from where it spread to other countries in French West Africa). Currently the main area of breadfruit cultivation is in the Pacific islands, especially Polynesia, although it is grown throughout the tropics.

All of the other Artocarpus species with edible fruits, except jackfruit, also originated in the Indo-chinese - Indonesian centres. A. champeden, the champedan, occurs wild in Malaya, while selected forms of it are cultivated throughout the Malayan archipelago.

The breadfruit is adapted to hot, tropical lowland conditions and grows well on a variety of soils as long as they are well-drained. Cultivars differ in their tolerance of seasonal drought and soil salinity. The tree is susceptible to damage by winds causing branches to break and flowers and young fruit to fall (Purseglove, 1968; Massal and Barrau, 1954).

(b) The jackfruit originated in the Hindustani centre of diversity, but is now only known in cultivation. It has a long history of cultivation in India, and was taken by the Arabs to the east coast of Africa at an early date, but was only relatively recently introduced to the New World. The jackfruit is more tolerant of higher altitudes and cold than the breadfruit.

### 4. AGRONOMY, DISEASES AND PESTS

(a) Seeded forms of breadfruit are usually propagated by seed. Seedless forms are usually propagated by root-suckers, but the method is often unreliable and slow, and there may be losses during transplanting. Several other methods of vegetative propagation are possible, but may give varying degrees of success (Rowe-Dutton, 1976). Breadfruit trees typically yield well, but may suffer from drought when grown on porous coral soils in the Pacific, strong winds and salt spray damage (Reddy, 1970).

Artificial pollination, a relatively simple operation, has resulted in considerably increased fruit yields in some parts of India (Singh et al., 1967).

Breadfruit trees may be affected by up to 16 fungal diseases, including 8 of economic importance: 3 root rots, 1 crown rot, 1 leaf blotch and 3 fruit rots. The fruit rot caused by Rhizopus artocarpi can be partially controlled with copper sprays (Anon., 1978a). One inadequately understood condition is 'pinglap', causing wilting



and tree die-back, but root rots may be involved. Thousands of trees died of 'pingelap' in the Mariana and Marshall islands, Oceania. Some cultivars may possess resistance. There are no records of bacterial or virus diseases (Zaiger and Zentmeyer, 1967).

A few insects and mites, notably the Egyptian fluted scale and coconut scale, may damage breadfruit trees. Both of them can be controlled chemically, and excellent control of Egyptian fluted scale has been achieved in some Pacific island by the introduction of ladybirds (Hill, 1975; O'Connor, 1969).

(b) The jackfruit is normally propagated by seeds, which are often sown in situ, because the seedlings develop a strong taproot and are not easily transplanted. Alternatively, if planted in containers, transplanting is easy. Trees start bearing when between 4 and 14 years old, depending on climatic conditions. The fruits take between 100 and 120 days to develop after pollination (Rowe-Dutton, 1976).

Bhutani (1978) listed 9 fungal diseases on jackfruit, the main ones being Rhizopus artocarpi and Pellicularia salmonicolor, the "pink disease". This fungus, which shows itself as a pinkish colour on the bark, causes premature leaf-fall and drying out of young branches. Control is by removal of affected branches, by applying crude carbolic acid to scraped areas on branches, and by spraying with a systemic fungicide.

Bhutani (1978) listed 41 insect pests of jackfruit in India, about half of them Hemiptera (aphids, scale insects, weevils etc.) or Coleoptera (beetles and weevils). The major pests are:

- Diaphania caesalis (Lepidoptera), a shoot borer which tunnels in young shoots, buds and developing fruits. Control is by removing affected portions, covering the fruits with alkathane bags and spraying with insecticides.
- Several species of bark borers, notably Inderbela tetraonis (Lepidoptera) and Eatocera rufomaculata (Coleoptera). They are controlled by introducing a fumigant into the holes.
- The bud weevil, Ochyromera artocarpi (Coleoptera). The grubs bore into tender buds and fruits and the adults feed on leaves. Control is by plant sanitation and the use of insecticides.
- Spittle bug, Cosmoscerta relata (Hemiptera), which feeds on young shoots and leaves. Control is by collecting the froth produced by the nymphs and destroying them.
- Mealy bugs, Ferrisia virgata and Nipaecoccus viridis (both Hemiptera). Control is by spraying.

Several species of nematodes attack jackfruits. In Bahia, Brazil, 7 species were recorded; 3 of them had been previously noted in India and one in Zaire. Affected trees in Bahia showed die-back of twigs and yellowing of the foliage (Sharma and Sher, 1973).

## 5. GENETICS AND IMPROVEMENT

(a) Chromosome numbers of  $2n=54$ ,  $56$  and  $81$  have been counted in the breadfruit. The basic chromosome number of the genus Artocarpus is probably  $28$ , and the seedless breadfruit is likely to be triploid with  $2n=3x=84$ , explaining the absence of seeds (Jarrett, 1959). To date there has been no deliberate breeding of breadfruit; the only selection has been that done by farmers in seedling populations.

(b) The jackfruit is a diploid with  $2n=2x=56$  chromosomes. There has been no genetic work or breeding.

6. GERMPLASM CONSERVATION

(a) Breadfruit cultivation is declining especially in Polynesia, so genetic erosion resulting from reduced interest in the crop is possible. The 'pingelap' disease, which has caused the death of many trees, may also be a cause of genetic erosion. Sastrapradja (1975) considered that some loss of cultivated breadfruit was occurring in Indonesia, Malaysia and southern Viet Nam, but that there was no corresponding loss in its wild relatives.

The potential value of wild Artocarpus species in breeding work is unknown. Some species, such as A. camansi Blanco, A. elasticus Reinw., and A. rigida Blume have been used with some success as rootstocks. The importance of the breadfruit is both localized and declining, and it has hardly gained popularity outside Oceania despite the high food value. Its potential in relation to agro-forestry remains to be explored.

(b) Moderate genetic erosion of cultivated jackfruit was indicated by Sastrapradja (1975) to be occurring in Southeast Asia, as a result of the replacement of seedlings by clonal cultivars. Singh et al. (1967) found that tree populations grown from seeds were highly variable, although some types maintain their individuality even when seed-propagated. The jackfruit is more widely-grown than the breadfruit.

Both breadfruit and jackfruit have recalcitrant seeds (Ellis, 1984), which must be sown soon after the fruit ripens, so seed storage is not possible.

Table 14. Collections of breadfruit and Jackfruit

Country	Location	Number of accessions		
		<u>Artocarpus altilis</u>	<u>Artocarpus heterophyllus</u>	Other <u>Artocarpus</u> spp.
Brazil	Manaus, Amazonas	10	2	<u>A. odoratissima</u> (1)
Brazil	Jaboaticabal, São Paulo			<u>A. integrifolia</u> (2)
Fiji	Nausori	70		<u>A. integrifolia</u> (3)
Indonesia	Bogor	3	30	<u>A. elasticus</u> (1) <u>A. integrifolia</u> (1) <u>A. rotundus</u> (1)
Jamaica	Kingston	3		
Papua New Guinea	Keravat	6	2	
Peru	Iquitos			<u>Artocarpus</u> spp. (3)
Philippines	Los Baños	1	30	<u>A. odoratissima</u> (4) <u>Artocarpus</u> spp. (9)
Seychelles <sup>1/</sup>	Mahé	1	4	<u>A. altilis</u> var. <u>semitifera</u> (?)
Solomon Islands <sup>2/</sup>	Honiara	60		
Thailand	Chantaburi		6	
USA	Miami, Florida	2	24	<u>A. odoratissima</u> (1) <u>Artocarpus</u> spp. (3)
USA	Hilo, Hawaii	6	3	<u>A. champston</u> (1)
USA	Mayaguez, Puerto Rico	2	1	
Western Samoa	Apia	30		

<sup>1/</sup> Grand'Anse Experimental Centre, Mahé Island, Seychelles.

<sup>2/</sup> Dodo Creek Research Station, Ministry of Agriculture and Lands, P.O. Box 613, Honiara, Solomon Islands.

There is reported to be 1 accession of A. heterophyllus and 1 of A. integrifolia at Nanyang University, 12A Faculty Road, Singapore 22, Singapore.

There are reported to be some accessions at Hainan Botanical Garden of Tropical Economic Plants, Academy of Tropical Crops of South China, Ministry of Agriculture, Hainan Island, Guangdong Province, China.

Moraceae

FICUS CARICA  
(Fig)

INTRODUCTION

About 40% of the world fig crop is dried, the remainder being used fresh, canned, or in jams etc. Low-grade figs can be roasted to produce 'fig coffee', or converted into alcohol. Dried figs and those unfit for human consumption, can be used as fodder. The nutritional value of fresh figs is comparable to that of many other fruits. They are high in calcium. Dried figs, with only 20% water are very nutritious (Table 1). All parts of the fig tree contain a latex rich in the proteolytic enzyme ficin, which can be used as an anthelmintic and for tenderizing meat.

The fig is a moderately important world crop (Table 2). In 1984 about 33% of the crop was produced by Turkey. Other major producers in descending order of production were Greece, Morocco, Spain, Portugal, Syria and Italy. While production by Italy and Spain has decreased over the last decade, that of Turkey, Syria and Brazil has increased.

2. TAXONOMY AND BOTANY

The genus Ficus, family Moraceae, contains over 1,000 woody species ranging from small, creeping shrubs to large trees. Their inflorescence, a 'syconium' is unique to the genus, consisting of a hollow vase-shaped peduncle, inside which are implanted the flowers. It has a narrow mouth, or ostiole, which is closed with interlocking scales. The 'fruit' is actually a pseudo-fruit developed from the syconium. The taxonomy of figs has been studied by Condit (1947, 1969) and Corner (1965). Besides the fig (Ficus carica L.), F. sycomorus L. is grown locally for its fruits mostly in Israel and Egypt. Several other Ficus species have edible, but non-palatable fruits.

The fig tree is deciduous and 4.5-10.0 m tall. Leaves large, broadly ovate or nearly orbicular, more or less deeply 3-5 lobed. Inflorescence a syconium. Flowers numerous, tiny, unisexual; male flowers with a single carpel, containing one ovule, usually a bifid stigma and long (1.75 mm) or short (0.7 mm) styles. Fruit (botanically) a tiny drupe - usually called the 'seed' of the fig.

Two main types of trees are distinguished according to the sex of the flowers in the syconium: the caprifig and the true fig. In caprifigs, the syconia contain short-styled pistillate flowers distributed over most of the inner wall and staminate flowers massed around the interior of the ostiole; in the true fig the syconia contain only long-styled pistillate flowers.

The fig and other Ficus species are pollinated by small wasps, which develop in some of the flowers and live symbiotically inside the syconium. Each Ficus species has its own species of pollinating wasp; in fig it is Blattophaga psenes L. (Hymenoptera). The system is rather complicated, and pollination is a prerequisite for the development of the syconia in certain cultivars. Syconia of caprifig trees fulfil the double role of being - in the short-styled pistillate flowers - the breeding place of new wasps, and of producing pollen in the staminate flowers. Caprifig trees should be grown close to fig trees requiring pollination, or caprifig syconia in a proper stage of development should be hung in them, an operation known as caprification. The fig wasp is indigenous in areas of traditional fig cultivation. In other areas like southern USA, Brazil and Kenya, it has been necessary to introduce the wasp, or to only grow cultivars which do not require pollination.

Numerous fig cultivars have been distinguished, usually considered in 4 types:

- (1) caprifigs (not edible)

(ii) figs (edible)

(a) 'Smyrna': usually develop inflorescences twice a year; the second ones only result in fruit production, assuming that pollination was successful. Pollination is always necessary and the fruits are seedy.

(b) 'San Pedro': also produces 2 batches of inflorescences per year; the first develop parthenocarpically into seedless fruits; the second require fertilization for fruit development.

(c) 'Common': usually produces one, but in some cultivars 2 batches of inflorescences per year. Pollination is not necessary.

Condit (1955) reviewed earlier work on cultivar classification, and described several hundred cultivars. The distinctions within types were mainly made on the basis of skin and pulp colour, but also on fruit size, shape and taste, seasonality and suitability for different uses. Of 625 cultivars (many with different names in different areas), 75% were of the 'Common' type, 18% of the 'Smyrna' type, and the rest of the 'San Pedro' type or caprifigs (Condit, 1941). In a recent study of USSR figs, Arendt (1972) discussed about 270 cultivars.

For many years, the old 'Common' cultivar 'Dottato' dominated dry fig production in Italy (Plinius mentioned it about 2,000 years ago), and California, where it was introduced during the last century. The 'Smyrna' cultivar 'Sari Lop', was grown in the Meander Valley of Turkey for several centuries and has been successfully introduced to California, and is highly valued in both areas. In many new fig-growing countries the principal cultivars used can be traced back to their Mediterranean origin. Some of the cultivars introduced into California, such as 'Azendjar', 'Taranimt' and 'Zidi' show promising levels of nematode resistance.

3. ORIGIN, DISTRIBUTION AND ECOLOGY

The fig probably originated in southern Arabia, where wild fig and caprifig trees are still found. It was mentioned in Jewish and Egyptian writings up to 6,000 years ago. It was spread throughout Southwest Asia and the Mediterranean countries and became naturalized in many places. European explorers carried it to many other countries following the discovery of the New World in 1492 and Magellan's circumnavigation of the world in 1519-21 (Storey, 1976).

The typical fig-producing regions have mild winters and hot dry summers. In sub-tropical and warm temperate areas, the trees lose their leaves in late autumn and early winter, and become dormant for several months in which condition they can withstand considerable cold. The degree of cold-hardiness depends upon cultivar, age, older trees being less susceptible, and tree health, premature defoliation by fig rust or drought making them more susceptible. Temperatures of  $-8^{\circ}\text{C}$  to  $-10^{\circ}\text{C}$  will kill young branches and of  $-12^{\circ}\text{C}$  to  $-15^{\circ}\text{C}$  the trunk, but the underground parts may form new shoots. Fig trees are particularly susceptible to frost damage during spring and autumn.

High summer temperatures ( $35-42^{\circ}\text{C}$ ) do not adversely affect the trees provided there is sufficient soil moisture, but above  $40^{\circ}\text{C}$  the fruit may be tough and ripen prematurely. Where the fig is grown for drying, high temperatures during the drying period are favourable. Figs require a continuous and adequate water supply for high yields, but rainfall during fruiting may cause fruits to split and favour growth of fungal rots. The fig tree can survive severe drought by shedding its leaves and becoming dormant.

Figs can be grown on a wide range of soils, including heavy clays, loams and light sands, ideally well-drained. The plant is moderately tolerant of high salinity, but not of black alkali conditions. It thrives on high lime or calcareous soils, and rarely suffers from iron and zinc deficiency when other species do. Light sands may favour the build-up of nematodes.

#### 4. AGRONOMY, DISEASES AND PESTS

The fig tree can easily be propagated vegetatively by cuttings or layering. Grafting techniques may be used for top-working old trees to effect a change of scion cultivar. Cuttings are commonly used for large-scale production, and may start to bear fruit after 6 months, but high yields can only be expected a few years later. Trees may remain in production for 35 years.

At least 30 species of fungi attack figs, including root rots, branch wilt and canker, leaf rusts, branch and foliage blights, fruit surface mould and spot rot, internal fruit rots, mould and smut, and fruit souring. Most are of slight importance only and can be controlled by chemical sprays, but differences in disease resistance have been noted in some cultivars (Condit, 1947; Cook, 1975). Bacterial canker can be locally important in the USA and Italy, although different bacteria may be involved in the two countries. Control is by pruning diseased wood (Cook, 1975).

Mosaic, the only virus disease of figs, is a major threat to production. It is prevalent in areas of the Mediterranean and the Middle East and has been recorded in Australia, China, India, New Zealand and Puerto Rico. Infected trees are stunted and have severely malformed leaves, and fruits are spotted and may drop prematurely. Several, but not all Ficus species, are susceptible. The virus is transmitted by grafting and by the mite Aceria ficus. Selection of virus-free propagating material may help to limit its spread.

A large number of insect and several mite species cause damage to figs Condit (1947) discussed 84 insect and 4 mite species; Hill (1975) listed 3 major and 17 minor insect pests; Bhutani (1975a) mentioned 59 insect pests, mostly in India. The larvae of several Lepidoptera and Coleoptera (long-horn beetles) cause considerable damage by tunnelling into the branches and sometimes the trunk of fig. Many leaf-eating beetles (Coleoptera) and Caterpillars (Lepidoptera) damage foliage. Branches, leaves and fruits may be attacked by a dozen or more species of scale insects and mealy bugs (Homoptera). The larvae of several fruit flies, species of Dacus and Ceratitir (Diptera), feed on the pulp of fruits, resulting in their rotting and premature drop.

Fully-ripened fruit, either still on the tree or having fallen to the ground may be invaded by several species of insects, which often enter through the ostiole. Some also carry pathogens, like smut and ouring organisms. This group of pests includes the dried fruit beetle (Carpophilus hemiparus - Coleoptera) and the vinegar fly (Drosophila melanogaster and other Drosophila species - Diptera). The fig wasp may be included in this category too. At least 8 species of mites (Acarina), which live on the lower side of leaves and suck the cell sap have been recorded. Leaves become blotchy and ultimately dry and fall off. The eriophyid mite (Aceria ficus) is a vector of the fig mosaic virus.

Dried figs may be infested by the tropical warehouse moth (Ephostia cautella - Lepidoptera), the Indian meal moth (Plodia interpunctella - Lepidoptera), the Angoumois grain moth (Sitotroga cerealella - Lepidoptera), and the saw-toothed grain beetle (Oryzaephilus surinamensis - Coleoptera). Other groups of insects include several leaf rollers (Lepidoptera), a few species of midge maggots (Diptera) feeding on the fruit pulp, and a few species of psyllids (Homoptera), thrips (Thysanoptera) and bugs (Heteroptera), all foliage suckers of minor importance.

Although considerable damage can be caused by insects and mites, the pest populations can generally be kept down to acceptable levels by chemical and cultural means. Differences in cultivar susceptibility and tolerance have been recorded. In California, the Pacific mite (Tetranychus pacificus - Acarina) prefers the cultivar 'Kadota' among the 4 principal fig cultivars. Cultivars with large ostioles are more likely to become infected by organisms causing fruit decay.

The fig is very susceptible to nematodes, including species of Heterodera,

Meloidogyne, Pratylenchus, Trichodorus and Xiphinema. Experiments are in progress to study the feasibility of grafting the fig on to other Ficus species which are nematode-resistant. F. glomerata shows promise in this respect.

5. GENETICS AND IMPROVEMENT

The somatic chromosome complement of F. carica is  $2n=2x=26$ , and all cultivars studied are diploid. Chromosome counts have been made of about 100 Ficus species: 5 African species are tetraploids with  $2n=4x=52$ ; F. elastica var. decora is triploid with  $2n=3x=39$ ; and the rest are diploids with  $2n=2x=26$  (Storey, 1976).

Sex is determined by 2 closely-linked pairs of alleles, G-g and A-a. G is the dominant allele for female flowers with short-styled pistils; g is recessive for female flowers with long-styled pistils. A is dominant for male flowers; a is recessive for flower suppression. Caprifig trees are either GA/GA or GA/ga; fig trees are always ga/ga. All commercial caprifigs are probably GA/ga. When crossed to figs, ga/ga, they produce 50% heterozygous caprifigs and 50% figs. The 2 types can only be separated after the seedlings have started fruiting, since they have no juvenile sex-linked characters.

The genetic control of persistence of syconia, i.e. whether they remain on the tree without pollination, has also been studied. A single pair of alleles, P-p, control the character: P is a dominant mutant allele for persistent syconia and ovule abortion; p is the recessive wild type for non-persistent (caducous) syconia and normal ovule development. Trees with non-persistent syconia have the genotype p/p; those with persistent syconia are P/p. Because the allele P is only carried by the pollen donor, crosses between caprifigs and figs result in the following progeny:

Fig (♀)		Caprifig (♂)	Progeny
non-persistent (p/p)	x	non-persistent (p/p)	all non-persistent
non-persistent (p/p)	x	persistent (P/p)	1 non-persistent; 1 persistent
persistent (P/p)	x	non-persistent (p/p)	all non-persistent
persistent (P/p)	x	persistent (P/p)	1 non-persistent; 1 persistent

Most fig cultivars are probably the result of centuries of selection among open-pollinated seedlings, and few are from seedlings grown because of their superior parentage. The breeding of cultivars by controlled pollination only dates back to 1922, when work was started in California (Storey and Condit, 1969; Storey, 1975) and to 1939 and work by Tanikawa in Japan and Rjabov in the USSR (Condit, 1947).

The major objectives of the breeding programme early this century in California were (Storey, 1975):

- Elimination of the need for caprification. The cultivar 'Calimyrna' (synonym for 'Sari Lop') is a Smyrna type needing caprification for fruit setting. Apart from being time-consuming and costly, there is also the risk of transmission of Fusarium moniliforme var. fici and other pathogens by the fig wasp. The French cultivar 'Croisic', which sets edible persistent fruits, but also has some male pollen-producing flowers, was used as the caprifig pollen parent in this work.

- Resistance to nematodes, particularly the root-knot nematode Meloidogyne incognita var. acrita, which can be very damaging on light, sandy soils.

The production of inter-cultivar crosses in figs is relatively straightforward. Pollen can be easily collected, stored for at least 120 days and blown into fig fruits to be pollinated. One fruit may yield 300-500 seeds, or drupelets. Seeds germinate and grow rapidly. The juvenile period, usually 5-7 years, can be shortened to about 4 years by grafting buds from seedlings on the branches of trees of 3 years or older. The scion grows rapidly and may produce fruit within 1 to 3 years. Additional advantages of the method are: one tree may carry up to 20 seedlings; there is no problem of sucker growth; and the branches of the carrying tree can be cut back and re-used for testing the following year.

The cultivar 'Condria' was released in 1956, and several others are in various stages of development. Progress is being made at Louisiana State University on the development of nematode-resistant cultivars based on 'Hunt' and 'Celeste', but none have yet been commercially released. A new very cold-hardy fig, 'Alma', was released in 1975 by the Texas Agricultural Experiment Station (Storey, 1975).

Of the many Ficus species, only a few such as F. palmata, F. pseudocarica and F. pumila have been used as parents in fig breeding: F. pumila, an evergreen climber, was crossed with the fig in order to develop a vine-like fig plant in California. An F<sub>1</sub> pistillate plant was successfully back-crossed with a F. carica caprifig in 1971, and the work is still in progress. In the USSR, figs have been pollinated with various species of the Moraceae and even of some other families, which led to apomictic fruit production, but no hybrids were released (Storey, 1975).

#### 6. GERMPLASM CONSERVATION

Loss of fig germplasm in traditional areas of cultivation is expected to follow a reduction in the number of cultivars grown. There are in principle two groups of wild fig trees: those directly descended from wild trees; and escapes of cultivated trees. Fig production is declining, especially in some Mediterranean countries with an ancient history of cultivation, and in newer fig-growing areas, like California and Brazil, the crop may have a more or less narrow genetic base. Rather few related Ficus species have been used in fig breeding. The collections listed are mostly of cultivars, but some, notably that at Miami, Florida include large numbers of wild Ficus species. Seeds can and should also be stored.



Table 15. Collections of fig

Country	Location	Number of accessions	
		<u>Ficus carica</u>	Other <u>Ficus</u> spp.
Algeria	Boufarik	58	
Chile	Santiago	3	
Cyprus	Nicosia	39	
Greece	Kalamata	34	
India	Bangalore	23	
India	Rahuri, Maharashtra	6	
India	Yercaud, Tamil Nadu	9	
Italy	Rome	450	
Jamaica	Kingston		<u>F. aurea</u> (18)
Japan	Nagasaki	37	
Papua New Guinea	Keravat		<u>F. copiosa</u> (4) <u>F. tinctoria</u> (1) <u>F. wassa</u> (1)
Syria	Damascus	360	
Thailand	Bangkok	18	<u>F. auriculata</u> (2) <u>F. racemosa</u> (1) <u>F. semicordata</u> (1)
Turkey	Izmir	291	
USSR	Yalta, Crimea	270	
USA	Davis	67	<u>F. natalensis</u> (1) <u>F. roxburghii</u> (1) <u>F. stephnocarpa</u> (1) <u>F. superba</u> (1) <u>F. virens</u> (1) <u>F. wightiana</u> (1) <u>Ficus</u> spp. (2) <u>F. afzeli</u> (1) <u>F. altissima</u> (4) <u>F. amplissima</u> (3) <u>F. aurea</u> (1) <u>F. auriculata</u> (4) <u>F. benghalensis</u> (14) <u>F. benjamina</u> (21) <u>F. bussei</u> (2) <u>F. callosa</u> (2) <u>F. capensis</u> (2) <u>F. citrifolia</u> (8) <u>F. clementia</u> (1) <u>F. cocculifolia</u> (1) <u>F. costaricana</u> (1) <u>F. cotinifolia</u> (7) <u>F. cumingii</u> (1) <u>F. drupacea</u> (1) <u>F. duseuil</u> (1) <u>F. elastica</u> (8) <u>F. fulva</u> (2) <u>F. gnaphalocarpa</u> (2) <u>F. heteropoda</u> (1) <u>F. hispida</u> (4) <u>F. ingens</u> (2) <u>F. iteophylla</u> (3) <u>F. kerstingii</u> (1)
USA	Miami		

Table 15. Collections of fig (Continued)

Country	Location	Number of accessions	
		<u>Ficus carica</u>	Other <u>Ficus</u> spp.
USA (Continued)	Miami		<u>F. lucasiana</u> (1) <u>F. lyrata</u> (1) <u>F. macrophylla</u> (6) <u>F. malotocarpa</u> (1) <u>F. marianensis</u> (3) <u>F. microcarpa</u> (4) <u>F. minahassee</u> (1) <u>F. mysorensis</u> (24) <u>F. natalensis</u> (3) <u>F. nebulosa</u> (1) <u>F. nerifolia</u> (1) <u>F. nota</u> (4) <u>F. nymphifolia</u> (2) <u>F. obliqua</u> (5) <u>F. obtusifolia</u> (2) <u>F. odorata</u> (5) <u>F. papaya</u> (3) <u>F. perforata</u> (4) <u>F. pertusa</u> (4) <u>F. praeorisea</u> (1) <u>F. pseudopalma</u> (1) <u>F. pumila</u> (2) <u>F. racemosa</u> (22) <u>F. radulina</u> (3) <u>F. religiosa</u> (8) <u>F. rubiginosa</u> (5) <u>F. septica</u> (3) <u>F. stricta</u> (1) <u>F. subcordata</u> (5) <u>F. superba</u> (2) <u>F. sycomorus</u> (5) <u>F. tinctoria</u> (10) <u>F. tinctoria</u> subsp. <u>parasitica</u> (4) <u>F. triangularis</u> (1) <u>F. trigonata</u> (5) <u>F. ulmifolia</u> (6) <u>F. umbellata</u> (2) <u>F. virens</u> (24) <u>F. vogelii</u> (3) <u>F. watkinsiana</u> (10) <u>Ficus</u> spp. (11)

PSIDIUM GUAJAVA  
(Guava)

1. INTRODUCTION

The guava is consumed principally as a table fruit, but is also used in juices, jams, jellies and other preserves, often different cultivars being grown for each type of use. The aroma of guava fruits is quite thermostable, which makes them well suited for processing. Guavas have a remarkably high vitamin C content, sometimes 3 or 4 times that of many citrus fruits (Table 1), and red-fleshed guavas are a fair source of carotene (Nagy and Shaw, 1980). Guavas are rich in pectin. The leaves are rich in tannins which can be used for tanning leather, and also contain an aromatic oil used as a flavouring. The bark also contains tannins used for tanning and dyeing. Various parts of the plant have medicinal uses.

Though not a major crop, guavas are widely grown throughout the tropics. A recent estimate of the world crop was 1 million tons, with India, Pakistan and Mexico being the major producers.

2. TAXONOMY AND BOTANY

The genus Psidium contains about 150 species of trees and shrubs, mostly native to tropical and sub-tropical America, about 20 of which have edible fruits. The following species, apart from the guava, may be cultivated (Wester, 1915; Zeven and de Wet, 1982; Chandler, 1958):

- (i) P. cattleianum Sabine, syn. P. littorale Raddi (strawberry guava) has small fruits. It is more tolerant of cool summers and frost than the common guava, and could be a replacement of guava in conditions like those of tropical highlands;
- (ii) P. friedrichthalianum (Berg.) Nied. (Costa Rican guava). Indigenous in Central America. A small tree cultivated for its acid fruits;
- (iii) P. guineense (Sw.) Araca. Indigenous in the West Indies and tropical America, and occasionally cultivated. The small (1.5 cm) fruits are of excellent flavour;
- (iv) P. molle (Bertol.) Guisare. Southern Mexico and Central America. A species closely related to P. guajava. The fruits are very small but quite aromatic and of excellent flavour;
- (v) P. montanum Sw. Indigenous in the West Indies, but rarely cultivated. Fruits globose, about 2 cm in diameter, aromatic and of good flavour;
- (vi) P. sartorianum (Berg.) Nied. Wild and cultivated in Mexico; and
- (vii) P. chinensis, a dwarf shrub which may have potential as a dwarfing rootstock.

The guava plant is a small shrub or tree up to 6 m high, with broad, spreading top. Leaves opposite, oblong, 7-17 cm long, with prominent veins and finely pubescent below, especially when young. Flowers hermaphrodite, white, fragrant, solitary or in small groups in leaf axils of younger branches; calyx tubular; petals 4, white, free; ovary inferior, of 4-5 united carpels, each with numerous ovules, placentation axile; stamens numerous, arranged in groups surrounding the central style. Fruit a globular or pear-shaped berry, 5 cm or more in diameter. Seeds small and hard, naturally spread by birds.

Pollination is mechanical or by insects such as the honey bee. Cross-pollination frequently occurs; Sobrinho and Gurgel (1962) recorded up to 41% in São Paulo. Some cultivars are cross-incompatible, due to inhibition of pollen tube growth in the styles (Seth, 1960). Incompatibility may be a cause of seedlessness.

Two botanical varieties are recognized within *P. guajava*: var. *pirifera* (pear-shaped fruits), and var. *pomifera* (apple-shaped fruits). In earlier classifications they were given species status, but they are not completely genetically isolated.

Open-pollinated guava seedlings are very variable as reported, for example, in Mexico (Lakshminarayana and Moreno Rivera, 1978b). There are relatively few clonally-propagated cultivars. Fruit characters, such as shape, size, skin texture, and colour, texture and flavour of the flesh may vary widely, and are useful in cultivar identification. While some cultivars are almost seedless, most contain hundreds of seeds comprising up to 35% of the fruit weight. Some of the best cultivars in Florida are: 'Supreme' (white-fleshed), 'Ruby' (red-fleshed), 'Blitch' and 'Patillo' (pink-fleshed), 'Miami red', 'Miami white' and 'Red Indian'. Two of the best hybrids are 'Ruby' x 'Supreme' and 'Webber' x 'Supreme'.

### 3. ORIGIN, DISTRIBUTION AND ECOLOGY

The guava originated in tropical America, probably in an area extending from Mexico to Peru (Chandler, 1958). It was grown in Panama and the West Indies by 1526 (Patiño, 1963), and was taken to many other tropical countries after the discovery of the New World.

The crop is now grown roughly within the latitudes 25°N and 25°S. It is at its limits of cultivation in Florida (USA), South Africa, northern New South Wales (Australia) and Israel. Growth is severely reduced at temperatures below 16°C. A climate with practically no frost and at least 4 rainy months is required. Soils ranging from heavy clay to very light sands may be suitable for guava, and it is quite tolerant of wet soil conditions (Anon., 1969). In several countries it has become naturalized.

### 4. AGRONOMY, DISEASES AND PESTS

The guava is easy to propagate from seeds, which germinate in 3-4 weeks. Plants start flowering at about 2 years old, and are in full production after a further 4 years. Vegetative propagation is necessary to maintain the characteristics of selected cultivars, but is relatively difficult. Air layering is the easiest method, but is impractical when large numbers of plants are needed, and the source of material is limited. Veneer grafting and chip budding can be used, and leafy stem cuttings can also be rooted in a mist box (Maló and Campbell, 1968). Vegetatively propagated trees begin to flower in the second year and are in full production after 6 years. A tree may continue to crop for over 50 years. Fruit development from flowering to maturity takes 3-5 months.

At least 15 fungi may attack guava. *Fusarium* wilt (*Fusarium oxysporum* f. *psidii*), which is soil-borne and may remain viable in infected soil for many years, is a serious disease in India. Control is by using pathogen-free nursery sites, by chemical disinfection of nursery soil, by destroying diseased plants, and by plantation hygiene. Injury to roots should be minimized to reduce the chance of infection. Other fungal diseases may be controlled chemically. A number of fungi cause fruit rot., either on the tree or during storage, such as *Colletotrichum* spp. (anthracnose), *Pestalotia* spp. and *Penicillium* spp. (Lakshminarayana and Moreno Rivera, 1978a).

About 60 species of insects and mites may damage the guava, the following being significant on a world scale: *Ferrisia virgata* (Homoptera), a mealybug; *Icerya purchasi* (Homoptera), cotton cushion scale, or fluted scale; *Selenothrips rubrocinctus* (Thysanoptera), red-banded thrips; and *Anastrepha* spp. (Diptera), fruit flies, the larvae of which burrow through the ripe fruit. Control of these pests is by plant and orchard hygiene, and the use of insecticides. There may be differences in cultivar susceptibility to mealybugs.

Other less important groups of pests include: cockchafer larvae which feed on roots; moth caterpillars which feed on bark and bore into wood; scale insects which suck cell sap and excrete honey dew on tender stems and leaves (on which the sooty mould fungus grows); root knot nematodes which damage the roots; moth caterpillars which feed on fruit pulp; and mites which damage the epidermis of leaves and fruits (Hill, 1975).

#### 5. GENETICS AND IMPROVEMENT

Most guavas are diploids with  $2n=22$ , but a seedless triploid cultivar with  $2n=33$  chromosomes has been found. Little is known about the inheritance of various characters. White pulp is recessive to red pulp, but other genes and environmental factors may modify expression.

The improvement of guavas has for centuries depended only on selection of seedlings by farmers. Many countries now have programmes of selection, followed by vegetative multiplication, and in a few the work is based on hybridization followed by selection in the  $F_1$  generation. Interspecific hybridization has been attempted in India, where the  $F_1$  hybrids of *P. chinensis* x *P. guajava*, *P. molle* x *P. guajava*, and *P. chinensis* x *P. molle* are under observation (IIHR, 1980).

Countries with guava breeding programmes include Brazil, Colombia, Côte d'Ivoire, Egypt, India, Mexico, Nigeria and USA (Puerto Rico, Hawaii and Florida), many of which have released improved cultivars. The aims generally include high and reliable yield of large bright red, tasty fruits containing few seeds but a high soluble solid content, and good keeping and transporting qualities. Fruits for processing should be relatively acid. Lakshminarayana and Moreno Rivera (1979) reported work in Mexico in which trees were selected on the basis of several characteristics, including vitamin C content of the fruits. Ten selections were made, 9 of which had 500 mg or more vitamin C per 100 g of pulp, while 1 had more than 1,000 mg. Some breeding programmes have resulted in hybrids which also grow well outside the area where they were developed.

#### 6. GERMPLASM CONSERVATION

In common with several fruit species, genetic erosion of cultivated guava is likely to accelerate as clonally produced cultivars increasingly replace trees grown from seeds. Sastrapradja (1975) reported that moderate erosion is already occurring in Southeast Asia. Insufficient information on the wild related species is available, and they have generally not been used in breeding. Related wild species have occasionally been used as rootstocks for guava, and advantages related to tree size, resistance to *Fusarium* wilt, and to nematode resistance have been noted (Bourke, 1976; Singh *et al.*, 1976).

Guava seeds can be stored at low moisture content and low temperature (Ellis, 1984), but it is not known whether seeds are stored in any collections.

Table 16. Collections of guava

Country	Location	Number of accessions	
		<u>Psidium guajava</u>	Other <u>Psidium</u> spp.
Australia	Aistonville, New South Wales	12	
Brazil	Jaboticabal, São Paulo	10	<u>P. acutangulum</u> (1) <u>P. cattleianum</u> (3)
Brazil	Bahia	23	<u>Psidium</u> spp. (3)
Brazil	Londrina, Parana	21	
Brazil	Itajai, Santa Catarina	15	
Brazil	Manaús, Amazonas	5	<u>P. acutangulum</u> (7) <u>P. araca</u> (3) <u>P. cattleianum</u> (1) <u>Psidium</u> spp. (10)
Cameroon	Njombe	8	
China	Taiwan	10	
Colombia	Palmira Valle	24	<u>P. acutangulum</u> (3)
Costa Rica	Turrialba	18	<u>P. friedrichsthalianum</u> (1) <u>P. guineense</u> (1) <u>P. littorale</u> (2) <u>Psidium</u> spp. (18)
Cuba	Habana	142	
India 1/	Bangalore	111	<u>P. araca</u> (1) <u>P. cattleianum</u> (2) <u>P. coriaceum</u> (1) <u>P. friedrichsthalianum</u> (1) <u>P. guineense</u> (1) <u>P. molle</u> (1) <u>P. montanum</u> (1)
Malawi	Limbe	8	
Peru	Lima	35	
Philippines	Los Baños	48	
Seychelles 2/	Mahé	43	<u>P. littorale</u> (2)
South Africa	Nelspruit	10	
Sudan	Wad Medani	49	
Thailand	Bangkok (Kasetsart University)	11	
USA	Miami	17	<u>P. friedrichsthalianum</u> (3) <u>P. littorale</u> (3) <u>Psidium</u> spp. (14)
USA	Mayagüez, Puerto Rico	32	
USA	Hilo, Hawaii	41	

1/ Parts of the collection maintained at 17 different institutes.

2/ Grand'Anse Experimental Centre, Mahé Island, Seychelles.

IBPGR (1984) also lists small collections of guava at: Nambour, Queensland, Australia; Rajshahi, Bangladesh; Nicosia, Cyprus; Guilaçan, Sinaloa and Cozolapa, Oaxaca, Mexico; Keravat, Papua New Guinea; Iquitos, Peru; Bangkok (Dept. Agric.), Thailand.

EUGENIA JAMBOS, E. MALACCENSIS AND E. UNYFLORA  
(Rose apple, Malay apple and Pitanga)

1. INTRODUCTION

This chapter covers three species of the genus Eugenia cultivated for their edible fruits. The Malay apple has the largest fruit followed by the rose-apple, while the pitanga is the size of a cherry. They differ also in other fruit characteristics, such as shape, colour, texture and flavour. All are juicy, of low calorific and nutritional value (Table 1), and can be eaten fresh, or in jams, pickles, syrups etc. Members of the genus Eugenia are rich in tannins and essential oils, which are the basis of some secondary uses of the plants. A yellow essential oil can be steam-distilled from the leaves of the rose-apple tree. The root, bark and leaves of the Malay apple, and the leaves and fruit of the pitanga have various medicinal uses (Anon., 1976). The pitanga is also grown as an ornamental plant in Florida.

All 3 species are minor crops in the tropics and sub-tropics, and statistical production data covers limited areas only (Lum, 1975; Anon., 1978b). The pitanga grows at higher altitudes in the tropics, and is more widely grown in the sub-tropics than the other 2 species.

2. TAXONOMY AND BOTANY

Kostermans (1931) published a monographic revision of the genus Eugenia, family Myrtaceae. Distinguishing characteristics of the genus are: evergreen trees or shrubs; leaves opposite, mostly entire and finely penninerved; flowers white or creamy or pinkish red; stamens numerous; fruit a drupe-like berry, globular or pear-shaped, 1-5 seeded. Many of the species have at times been placed in different genera, notably Syzygium. Kochummen (1973) recognized 193 species of Eugenia, at least 20 of which have edible fruits. The species E. semarangensis (Jambu semarang), which has seedless fruits, is a highly-esteemed local crop in Java.

(a) E. jambos L. (syn. Jambosa vulgaris D.C., Syzygium jambos (L.) Alston), the rose-apple, is known by various names, including pomar(r)osa and manzanita de rosa in Spanish, pomme-rose in French, jambu mawar in Malay, and jambo rosa in Brazil. The rose-apple is an attractive glabrous tree up to 9 m high. Leaves oblong-lanceolate, 12-20 cm long, acuminate, thick and shiny, short-petioled. Flowers greenish-white, 6-8 cm or more across, in short terminal corymbs; stamens numerous much longer than the petals. Fruit a berry, round or oval, 2-5 cm long, greenish to pale yellow flushed with pink, with a taste rather like apricot and an aroma of rose.<sup>1/</sup> Seeds gray, 1-2, loose in cavity of succulent pericarp, polyembryonic, producing 1-2 plants (Bailey, 1949; Anon., 1976; Flesch, 1976; Ochoe and Bakhuizen van den Brink, 1931).

(b) E. malaccensis L. (syn. E. domestica Bailey, Jambosa malaccensis (L.) DC, Syzygium malaccense (L.) Merrill and Perry), the Malay apple, mountain apple, jambo-vermelho (Malay) or pomarrosa de Malaca (Spanish-Cuba), is larger than the rose-apple, and has red, but sometimes white fruits.

The Malay apple is a small to medium-sized tree, 5-20 m high, branched near the base with a broadly-ovoid, dense leafy crown. Leaves opposite, shortly stalked, elliptic-oblong, or obovate-oblong with entire margin, 15-50 x 7-20 cm. Inflorescence in the axils of the fallen leaves, short, dense, 1-12-flowered. Flowers very

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<sup>1/</sup> The fruit of rose-apple is sometimes woolly and tasteless, although usually sweet and crisp, and rather inferior to several other species in the genus.

shortly-stalked, brilliant red, 5-7 cm in diameter when expanded; calyx oblong-campanulate or turbinate, calyx-tube 1.5-2.0 cm long, at the base 0.3-0.5 cm, at the mouth 1.2-1.5 cm diameter, segments 4, the outer 2 ones 3-5 mm long and 10-15 mm wide, the 2 inner ones 7-10 mm long and 10-15 mm wide; petals 4, dark wine red, 12-20 mm long and 7-15 cm wide; stamens numerous, inserted on a quadrangular disc, unequal, the outer ones 2.5-3.5 cm, the inner ones often hardly 1 cm long, filaments red; ovary oblong, red, style straight, 3.0-3.5 cm long. Fruit ellipsoid-globose, rarely elongate and pear-shaped, flattened at the apex, crowned by the enlarged, fleshy calyx segments, when ripe dark red or often pale yellow with purple streaks, rarely uniformly yellowish-white, 1 seeded, usually 5-8(-12) cm long, 5-6 cm diameter, flesh thick, juicy white, fragrant savoury, 0.5-2.5 cm thick. Seed globoso, brown, 2.5-3.5 cm diameter, polyembryonic (Ochse and Bakhulzen van den Brink, 1931).

Where the Malay apple has traditionally been seed-propagated in Indonesia, there are at least 3 different types, including cultivars which are entirely red, ones with light red fruits and dark red longitudinal stripes, and white ones with oblong to pear-shaped fruits (Ochse and Bakhulzen van den Brink, 1931; Sastrapradja, 1983 pers. comm.). Oblong and pear-shaped fruits are also found in Indonesia, with other less common shapes. A white-fruited cultivar was cultivated in Hawaii, and a race with 90% seedless fruits was found in the Philippines (Burkill, 1966).

(c) E. uniflora L. (syn. E. uniflora Berg, E. michelii Lam., E. parkeriana DC, E. michelii Aublet, Myrtus brasiliense L.), the Surinam(e) cherry, is also known as the pitanga, Cayenne cherry, cerisier de Cayenne, cerise carré, ginga (Amazonia, Brazil), cerise à côtes or cerise-côtes (French Antilles), corezo de Cayenne (Cuba) and goraka jambu (Sri Lanka).

The pitanga is a broad, compact glabrous shrub or small tree up to 7.5 m high. Leaves nearly sessile, ovate to ovate-lanceolate, 2.5-5.0 cm long, acuminate, rounded at base, dark green and shiny above. Flowers solitary on the ends of long slender peduncles, one or several together in the axils of leaves, about 1.3 cm across, white, slightly fragrant. Fruit a berry, oblate, 1.3-1.5 cm in diameter, conspicuously 8-ribbed, deep crimson when ripe, with a spicy flavour. Seed usually 1, relatively large and round, sometimes 2, (or 3 or 4 in Florida), hemispherical (Poponoe, 1920; Bailey, 1949).

The pitanga is pollinated by bees and probably by other insects (Poponoe, 1920). Little data is available about cultivars. Sturrock (1940) reported 2 types in Florida: one with black fruits brought in by early settlers; and one with fruits varying from pink to dark red. These types hybridized but the fruits of the resultant seedlings were inferior to the original black fruits. Variation within the types was also observed. The cultivar 'Selected Black' is maintained at a nursery in Florida (Fogle 1981). Argles (1976) noted that some superior grafted selections of pitanga are grown for juice production in Florida.

### 3. ORIGIN, DISTRIBUTION AND ECOLOGY

(a) The rose-apple has had a long history of cultivation in the Malesian archipelago and in India, and grows wild in these areas. Domestication probably occurred in Malaysia, from where it was moved to southern and later, northeastern India, areas where it is now naturalized. Ridley suggested that rose-apple originated in India (Burkill, 1966).

The rose-apple has been introduced to many countries, including Sierra Leone where it is semi-naturalized, Cuba, USA (Florida and Hawaii), and Brazil. It is very adaptable, since it grows under quite different climatic regimes in both tropical and sub-tropical areas. Many soils also are suitable, provided they are not waterlogged, but plants grown in Florida on highly calcareous soils (pH 8.0+) are often chlorotic.

(b) The Malay apple also probably originated in Malaysia, and has been



introduced to many areas, including Cuba, Florida, Honduras, India, Philippines, West Africa and the West Indies. It grows in a wide range of tropical and sub-tropical climates, and soils, if well-drained, but will not stand frost. It also naturalizes easily, for example, on Hawaii (Popenoe, 1920).

(c) The pitanga grows wild in Uruguay and southern Brazil (Zeven and de Wet, 1982). It is not known whether it was cultivated before The Spanish conquest, but the Portuguese took it from Brazil to Italy and Goa, India (Burkill, 1966). In the present century it has been widely distributed in countries with a suitable climate.

Though sub-tropical in origin the pitanga thrives at both low and higher altitudes in tropical areas, for instance in Java, Indonesia, Singapore (Burkill, 1966) and Central America from sea level to 2,000 m (Popenoe, 1953). It survives some frost, and is quite drought-resistant, although in dry areas like Algeria and California, yields may be low compared with those in warm, moist areas like southern Florida, and even here it responds well to irrigation. A good water supply is especially important during fruit development. The pitanga succeeds remarkably well on shallow, sandy and calcareous soils in southeast and southern Florida, where it is often grown in hedges (Campbell, 1983 pers. comm.); in its native area it grows on clay or clay loams (Popenoe, 1963).

#### 4. AGRONOMY, DISEASES AND PESTS

(a) The rose-apple is easily propagated from seeds, which are polyembryonic and contain sexual and asexual embryos. The seedlings are difficult to distinguish, so methods of vegetative multiplication by grafting, air layering, layering and cutting have been developed but are not widely used. E. densiflora and E. javanica have been used as rootstocks in Java; the former being the better (Argles, 1976; Anon., 1976).

A number of fungal diseases attack rose-apple, but none are serious: Asterinella puiggarii (black spot or black mildew), and Glytocybe tabascens (mushroom root rot) occur in Florida (Fisch, 1976); Antennularia spp. (sooty mould) occurs in Jamaica (Leather, 1967); Capnodium ougeniarum is found in India (Anon., 1976); and Puccinia psidii occurs in Jamaica (Leather, 1967) and Cuba (Rojas, 1973).

Several insects which feed on plant sap or eat leaves of rose-apple have been recorded, but control measures were not indicated (Anon., 1976). The plant is also host to several species of fruit flies in different areas: Ceratitis capitata (Mediterranean fruit fly), Pterandrus rosa syn. Ceratitis rosa (Natal fruit fly), Anastrepha ludens (Mexican fruit fly), and Dacus dorsalis (Oriental fruit fly) (Fisch, 1976). At least 2 species of scale insect have been recorded on the rose-apple.

(b) Most of the comments made on rose-apple propagation apply also to Malay apple. Propagation by budding was highly successful in Indonesia (Argles, 1976). A seedling tree may start fruiting at 4-5 years. Fruit development takes about 3 months. An average yield in Indonesia was 370 fruits per tree per year, but up to 25,000 has been recorded (Tohir, 1970).

Similar diseases - 2 species of sooty mould, 2 species of leaf spot, a rust species and a thread blight (Leather, 1967; Singh, 1973; Williams and Liu, 1975) - also affect it. Its pests include the fruit flies Dacus dorsalis and Anastrepha spp., and several sap feeders, defoliators, miners and borers. Seedlings may be affected by termites. In Java trees sometimes die after a heavy attack of the stem borer (Nothopeus hemipterus - Coleoptera). The nymphs of Psyllidae usually deform young leaves by inducing gall formation and thus reducing photosynthesis (Sastrapradja, 1983 pers. comm.).

(c) Pitanga plants grown from seeds begin to flower and fruit at 3-4 years old. They may be propagated by grafting and cutting (Argles, 1976). The fruits

take 3-6 weeks to develop. Usually one, but occasionally 2 crops are produced per year. In India yields of 3-4 kg per tree have been recorded (Singh et al., 1967).

5. BREEDING AND IMPROVEMENT

Somatic chromosome numbers of 28, 33, 42, 44, 46 and 54 have been reported for the rose-apple, which may be a polyploid. Both the Malay apple and the pitanga are diploids with 2n=22 chromosomes. There has been no other genetic work, and virtually no breeding of any of the species.

6. GERMPLASM CONSERVATION

Sastrapradja (1975) considers that there has been some genetic erosion of cultivated rose-apple in Indonesia and southern Viet Nam, but no erosion in Malaysia, the Philippines and Thailand; there has been some loss of wild rose-apple germplasm in Malaysia but not in other countries. Similarly, there has been moderate genetic erosion of Malay apple in Indonesia, Malaysia and southern Viet Nam, but not in the Philippines and Thailand. The wild Malay apple does not currently seem to be at risk.

It is unlikely that there is a risk of genetic erosion either of wild or cultivated pitanga. The cultivated crop is variable and seed-propagated, while the wild pitanga was reported to be common in Rio de Janeiro, Parana, Santa Catarina, and Rio Grande do Sul in Brazil (Anon., 1935; Shamel and Popenoe, 1916), and naturalized in India (Anon., 1952), Jamaica (Adams et al., 1972) and the French Antilles (Fournet, 1978).

Various field genebanks contain one or more species of Eugenia. Seed could also be stored. The seeds of rose-apple (and possibly the other 2 species as well) are polyembryonic, so 2 genotypes - one clonal and one segregating - can be stored at the same time.

Table 17. Collections of Eugenia spp.

Country	Location	Number of accessions			
		<u>E. jambos</u>	<u>E. malaccensis</u>	<u>E. uniflora</u>	Other <u>Eugenia</u> spp.
China	Taiwan				<u>E. javanica</u> (11)
Philippines	Los Baños				<u>Eugenia</u> spp. (3) <u>Syzygium cumini</u> (20) <u>Syzygium</u> spp. (25)
USA	Miami, Florida				<u>Eugenia</u> spp. (9) <u>Syzygium</u> spp. (16)

No collections of cultivars of E. jambos, E. malaccensis and E. uniflora exceed 3 samples, but small collections are listed in the following countries in IBPGR (1984): Alstonville, N.S.W., Australia; Rajshahi, Bangladesh; Jaboticabal, São Paulo, Brazil; Amazonas, Brazil; Njombe, Cameroon; Palmira Valle, Colombia; Turrialba, Costa Rica; Habana, Cuba; Yercaud, Tamil Nadu, India; Cozolapa, Oaxaca, Mexico; Keravat, Papua New Guinea; Iquitos, Peru; Hilo, Hawaii, USA.

Palmae

PHOENIX DACTYLIFERA

(Date Palm)

1. INTRODUCTION

Most dates are consumed where they are produced as a staple food, either as an ingredient of many recipes, or in syrups, juices, jams, paste etc. Dates have a high nutritional value, and because of their low moisture and high sugar content, a long storage life. They are a good source of energy, minerals and some vitamins (Table 1).

Dates are one of the less important world fruit crops (Table 2), and are almost entirely produced in developing countries. In 1984, the major producers, in descending order were: Egypt (450,000 tonnes), Saudi Arabia (450,000 tonnes), Iran (330,000 tonnes), Pakistan (225,000 tonnes), Algeria (207,000 tonnes) and Iraq (115,000 tonnes). Production in Iraq has declined dramatically since 1980 when 597,000 tonnes were produced, while production in Algeria, Egypt and Saudi Arabia has increased in the last decade. Exports consist of either low-grade dates used as an inexpensive food or for processing, or of high-grade dates used as a table fruit, or in confectionary or baked products.

2. TAXONOMY AND BOTANY

The genus Phoenix contains about 12 species, the most important of which are P. dactylifera L., the date palm; P. atlantica Chev., the false date palm which closely resembles the date palm (but may not be a good species); P. canariensis Chabaud. (syn. P. jubae), an ornamental palm; and P. sylvestris Roxb., a wild date palm, and a source of sugar and wine in Pakistan, India and southern Iran. P. dactylifera differs from P. sylvestris and P. canariensis in that it can produce basal suckers, and from the other species by its tall, columnar, and relatively thick trunk. It could be argued that all Phoenix species should be included in a single species because of the ease with which they hybridize.

The date palm may reach a height of over 30 m. The trunk only increases in diameter at any height while the leaves are growing, and the stem and new leaves grow from the single terminal bud at the stem apex. Roots grow from the base of the trunk, sometimes about 50 cm above the ground. Main roots, about 1.5 cm thick, are branched, and secondary roots give rise to a network of very fine, hair-like roots. Leaves have a normal life of 3-7 years and dead ones are usually removed.

The date palm is dioecious. The inflorescence, which is produced in the axil of a one year old leaf, is a branched spadix enclosed in a tough spathe which bursts open when the flowers are mature. Male flowers are waxy and creamy with 6 stamens and no carpels; female flowers are whitish, with 6 rudimentary stamens and 3 carpels; and both flowers have 3 petals and 3 sepals. Pollen is produced in abundance, and spread over short distances by wind. The inflorescences are often hand-pollinated, a single male palm producing sufficient pollen for 30 to 50 female palms. Unfertilized flowers can set fruit parthenocarpically; such fruits are often smaller and ripen later than fruits containing embryos, but are almost as sweet. Only one carpel develops in fertilized fruits, the other 2 abort; all 3 carpels may develop in parthenocarpic fruits.

The fruits are yellow to reddish-brown in colour, and ripen 6-7 months after fertilization. The fruit has a single seed up to 2.5 cm long, which is deeply grooved and has a very hard endosperm. Date growers distinguish several stages of ripening:

- (i) "kimri" - green fruit;
- (ii) "khalaal" - includes full-sized dates changing in colour to red or yellow;
- (iii) "rutab" - characterized by a discoloration process to shades of brown or black, and by squashy texture and loose skin; and
- (iv) "tamar" - the last stage of maturity which is best for storage.

There are hundreds of date cultivars, of which only about 60 are widely grown throughout the 15 major date-growing countries (Munier, 1973b). Cultivars are usually classified on the basis of fruit characteristics into 3 groups:

- (a) soft cultivars in which a very high proportion of the sucrose in the unripe fruit is converted into reducing sugars during ripening;
- (b) semi-dry cultivars with a medium degree of sucrose conversion; and
- (c) hard cultivars containing up to a third of their sugars as sucrose when ripe.

Fruit consistency is also affected by climatic conditions and methods of handling. Other characters used in cultivar classification include: ripening season; fruit size and shape; colour of unripe and ripe fruits; chacking, i.e. the presence of irregular buff-coloured lines generally confined to the apical half; suitability for consumption fresh or after boiling; keeping quality; seed dimensions; tree dimensions; and leaf size and structure. Some fruit characters are influenced by the pollen source. It is difficult to distinguish between all cultivars unambiguously.

Some work has been done on date descriptors (Munier, 1973b). Nixon (1950) produced a key to cultivars which have been introduced into the USA. Groups of cultivars are often known by an Arabic name in their country of origin, which may describe a single member of such a group introduced elsewhere.

### 3. ORIGIN, DISTRIBUTION AND ECOLOGY

Areas which have been suggested as being where the date palm originated range from southeast of the Azores, an area now under the Atlantic Ocean in the west, to Pakistan in the east. Domestication may have occurred simultaneously in several locations (Oudejans, 1969). Munier (1973b) suggests that hybridization between different Phoenix species may have played a part in its origin, and P. sylvestris and P. dactylifera, which are closely related, may have a common ancestry.

Wild Phoenix species are found in the tropics and sub-tropics of Africa and Asia. P. reclinata occurs in much of Africa south of the Sahara, including Madagascar. P. atlantica grows chiefly in the Canary and Cape Verde islands. The distribution of P. paludosa extends roughly from Bangladesh to the southern tip of Sumatra, crossing the equator. P. farinifera has the most easterly distribution, ranging from eastern mainland China to Taiwan. Date palms are now mainly grown in desert areas from northwestern Africa to India, although they are also grown in California.

The date palm can survive temperatures ranging from  $-5^{\circ}\text{C}$  to  $+50^{\circ}\text{C}$  without damage. For commercial production, the following climatic conditions are required: a long summer with high day and night temperatures; a mild winter without prolonged frost; and dry and sunny weather at pollination, flowering and fruit-setting. The optimum temperature for fruit maturation varies with cultivar: that for soft cultivars being  $26.6^{\circ}\text{C}$ ; for hard ones  $32.2^{\circ}\text{C}$ ; and for intermediate types between these 2 figures.

Though palms are grown in soils varying from sands to clays, soils should be well-drained. They are tolerant of salinity, but excessive salt reduces growth and results in fruits of poor quality. The high salt tolerance of the date palm is attributed to its ability to exclude chloride ions during water absorption from saline soils.

### 4. AGRONOMY, DISEASES AND PESTS

As the date palm is dioecious, its seedling offspring is heterogeneous. Propagation is best effected by using the spontaneous shoots from the base of the trunk, but the multiplication rate is slow. Rapid methods of vegetative propagation using in vitro techniques have been developed in several countries, and commercial propagation of date palm by such methods is now possible (Tisserat, 1981).

Yields of date palm are generally low, but may be increased by improved cultural practices and disease and pest control. Artificial pollination is required for commercial production of dates, but is often neglected, and yields are consequently poor. The pollen source largely determines fruit quality, the efficiency of pollination being influenced by the amount of pollen, the receptivity of female flowers and the weather conditions. Pollen may be collected, dried and stored until required. The trees have to be climbed several times during the flowering period for effective manual pollination. Other important management aspects include the pruning of dead or dying leaves, and fruit thinning to allow remaining fruit adequate space for growth, and to improve flowering in the succeeding year, and nitrogen fertilization and irrigation (Dowson, 1982).

Carpenter and Elmer (1978) reviewed the diseases and pests of date palm: 11 fungal diseases were mentioned with 21 associated pathogens. The most serious is bayoud or fusariosis, caused by Fusarium oxysporum f. sp. albedinis, and characterized by congestion of the vascular tissues, and perhaps also a toxic effect. Bayoud, which is soil-borne, had killed 2-thirds of the date palm crop in Morocco by 1950, including most of the vigorous and productive trees of the best cultivars, and is a serious threat to production in southwestern Algeria and elsewhere. The disease can be mitigated by careful irrigation and choice of cultivar. Several countries have adopted strict quarantine measures to prevent or delay the spread of bayoud. Other fungal diseases of note are khamedy or inflorescence rot (Hauginiella caetiae), fruit rots (at least 6 different pathogens), and graphiola loaf spot (Graphiola phoenicis). Most of the fungi need high humidity and rain for development, and are more common in marginal date areas.

A minor disease in Egypt called dry bone may be caused by bacteria, but this has not been confirmed. Several Phoenix species including the date palm have shown symptoms resembling the lethal yellowing disease of coconut, probably caused by a mycoplasma-like organism and spread by insects. There are a number of disorders of date palm of unknown cause, none yet of widespread importance, including: faroun, a rapid and fatal palm decline in Mauritania; rhizosis or rapid decline in California; al-wijam decline in Saudi Arabia; barhee disorder, a crown-bending in the cultivar 'Barhee' in California and at Basra, Iraq; internal fruit browning in several cultivars in California; and black scald in the USA.

Four species of mites and 50 insects, including 23 Coleoptera, 11 Lepidoptera, 7 Isoptera and 7 Homoptera, and 7 nematodes are listed as damaging to date palm. The Banks grass mite (Oligonychus pratensis) in USA, and the Old-World date mite (O. afresiatricus) damage the leaves and the fruit skin, and may ruin entire bunches of fruit. In most date-growing regions, except the USA, the parlatoria date scale (Parlatoria blanchardi), and in Iran and Iraq the green scale (Asterolecanium phoenicum) feed on the foliage and fruit, reducing tree vigour, fruit yield and quality. The dubas or Old-World date bug (Ommatissus binotatus var. lybicus) feeds on foliage and fruits and excretes honey dew on which bacteria and fungi develop. Affected parts shrivel and dry up. Several species of nitidulid beetles (e.g. Carpophilus hemipterus) damage fruits on palms, on the ground, and in storage, in both California and the Old-World, making them prone to damage by micro-organisms. The palm stalk borer (Pseudophilus testaceus) is especially prevalent in Iraq and parts of Saudi Arabia. Poor fruit development may result from attack by the fruitstalk borer (Oryctes elegans) in Iran, Iraq and Saudi Arabia. The larvae of several species of fruit moths damage the ripening fruits on the tree and in storage. Entire crops can be destroyed by the desert locust (Schistocera americana gregaria), in addition to reducing the cropping capacity in subsequent years.

Among control measures, plant sanitation, plantation and packhouse hygiene and pesticide sprays are important. The parlatoria date scale was checked in oases in Mauritania by introducing parasites. Some differences in cultivar susceptibility have been noted: 'Deglet Noor' is especially prone to damage by Banks grass mite in California; several cultivars are tolerant to the Old-World date mite; and the nitidulid dried fruit beetle prefers certain cultivars.

## 5. GENETICS AND IMPROVEMENT

The chromosome number of 6 Phoenix species and 10 P. dactylifera cultivars studied was  $2n=36$ . The chromosomes of all species and cultivars were very similar in shape and size, which may explain the cross-compatibility of several of the species (Oudejans, 1969). Virtually nothing is known about inheritance of characters in date palm, a subject difficult to study because of the effects of dioecy, metaxenia and the long juvenile growth period.

Most currently grown date palm cultivars have resulted from thousands of years of selection and clonal propagation albeit in a non-systematic way. An inbreeding programme was started in 1912 in Arizona to improve the cultivar 'Deglet Noor' from Algeria, which suffers from high humidity, and has a narrow range of adaptation to climate and soil, but the project was discontinued after 3 generations. An attempt was made to develop a line of 'Deglet Noor' in Algeria between 1947 and 1962 which would breed true from seed. Male cultivars were also selected for early flowering and abundant production of high quality pollen. A date breeding programme was initiated at Indio, California in 1948. A programme was also started in Morocco to select bayoud-resistant cultivars.

There are different objectives for male and female trees. In California, the objectives for female cultivars were: fruit quality and yield equal or superior to Deglet Noor; freedom from the physiological disorder black nose; tree and fruit adapted to mechanical harvesting and processing (large fruit clusters with uniformly long strands borne on a long and flexible stalk; simultaneous ripening of the fruits in a cluster; firmness of fruit); reduced growth rate, short trees being easier to manage than tall ones; spineless leaves, which makes working with palms easier; hermaphrodite flowers, making pollination unnecessary; and precocious flowering and fruit production, which both reduces the length of the breeding cycle and gives the grower an earlier return on investment.

Selection criteria for male cultivars were: a flowering season coinciding with that of the female; large inflorescences with many flowers and abundant easily-shed pollen, with a favourable effect on maturity, quality and size of fruits. The metaxenic effect of pollen can only be evaluated in test crosses. Breeding methodology is relatively easy because: the date palm is dioecious; male and female inflorescences can easily be bagged; pollen is abundant and can be stored; and seeds are numerous and easily stored for 5-6 years with little loss of viability.

A number of female and male palms were chosen as parents from existing cultivar collection in California. Each female was crossed with a male, and in each of the first generations, comprising both male and female seedlings, some males were chosen to back-cross with their female parent. The process was repeated from the 2nd to the 5th generation. Males selected in the progeny of the fifth back-cross are used to pollinate a different female cultivar. It is hoped that seedling offspring will contain some female trees worthy of recognition as cultivars.

Date breeding is a lengthy process. The average cycle between pollination and a new generation is 5-6 years, so 3 back-crosses and a first selection from a cross between cultivars takes at least 25 years. A further 5 years elapses before offshoots are available, and the rate of vegetative reproduction is comparatively low, but in vitro methods should be much faster. Apart from the unpredictable inheritance of some characters in date palm, several undesirable features may appear in the back-crossed generations, the most serious being failure of some or all of the flowers in male palms to produce pollen. Another is the tendency for shedding in some female progeny, and a third is the absence of chlorophyll (albino leaf) in some advanced back-cross lines.

Hitherto the programme in California has not yielded any new commercial cultivars (Carpenter and Ream, 1976; Carpenter, 1979a). Of the 35 cultivars originally in the collection in 1948, 14 are still being grown. Several have advanced to the 4th or 5th

back-cross generation, and a number of crosses between cultivars have been made and are being evaluated. The programme in Morocco has not resulted in any improved cultivars resistant to bayoud, but is still active.

#### 6. GENETIC CONSERVATION

Although there are numerous date palm cultivars, many are represented as a few specimens in collections or grown in limited geographical areas, and most of the world crop is the produce of relatively few cultivars. As production methods are standardized, a further reduction in the number of cultivars grown is likely.

There are assumed to be no truly wild dates. A number of Phoenix species, including the date palm are easily hybridized, and some species may be useful in date breeding and pollination, but the fruit of the progeny is generally of greatly inferior quality. There is little information on the occurrence, frequency and variability of wild Phoenix species. The species P. theophrasti Greuter, the Cretan date palm, is now known at only 5 localities in Crete, and its habitat is threatened. It is a multi-stemmed species (IUCN, 1978). Pollen of P. humilis has been found to induce small-seededness in several date cultivars. The much smaller tree size of many wild species might usefully be transferred to the date palm.

The field genebanks are shown in the table. The only wild species in any collection are in the USA, and not in their ancestral home in Africa and Asia. Though the seeds can be stored, they are not known to be in any major collections.

Table 18. Collections of date palm

Country	Location	Number of accessions	
		<u>Phoenix dactylifera</u>	Other <u>Phoenix</u> spp.
Algeria <sup>1/</sup>	El-Arfine	413	
India	Jodhpur, Rajasthan	14	
India	Abohar, Punjab	34	
Iraq	Baghdad	182	
Morocco	Marrakech	51	
Niger (IRFA)	Bonloulou	12	
Nigeria	Zaria	174	
Saudi Arabia <sup>2/</sup>		198	
Sudan	Wad Medani	26	
USA <sup>3/</sup>	Brawley, California	65+	<u>P. sylvestris</u> (2)
USA	Miami, Florida	3	<u>P. abyssinica</u> (4)
			<u>P. acaulis</u> (1)
			<u>P. canariensis</u> (1)
			<u>P. pusilla</u> (8)
			<u>P. reclinata</u> (2)
			<u>P. roebelenii</u> (5)
			<u>P. sylvestris</u> (2)
			<u>Phoenix</u> spp. (13)

<sup>1/</sup> Institut National de la Recherche Agronomique d'Algérie (INRAA), Direction Générale, B.P. 15, El-Anasser, Alger.

<sup>2/</sup> For details see: Asif et al. (1983).

<sup>3/</sup> At Imperial Valley Conservation Research Center, Brawley, California - moved from Indio, California in September 1982 (Carpenter, 1979b and pers. comm. 1982).

NOTE: It is likely that there may be a collection at Guea no. 2 near Tripoli, Libya, but further details are not known. Somalia was reported to have a collection of about 1,000 palms representing over 80 cultivars from 7 countries, but up-to-date information is lacking. There was also a collection of 70 local cultivars at the Agricultural Station at Ahwaz in Khuzistan, Iran, but many of these died because of inadequate drainage, and the current situation is not known.



BACTRIS GASIPAES  
(Pejibaye)

1. INTRODUCTION

The pulp of pejibaye fruits is edible when cooked. It has twice the starch content of potatoes, and is high in oil, protein and carotene, and so is highly nutritious (Table 1). The starch can be extracted and used for making tortillas, a staple food in Central America usually made with maize flour. The fruits can be stored for 10-14 days in a dry room, and are sometimes canned. Poor quality fruits may be fed to pigs. The heart of the young palm, or palmito, is also edible, a wine (coquillo) can be tapped from the stems, and a beer (chicha) is sometimes made from the cooked, mashed unmalted fruits. The outer 2.5-5.0 cm of the stem is a very hard timber used in carpentry and building, while split stems can be used for re-inforcing concrete. The palms are also grown as shade trees for cocoa and coffee.

Despite its qualities, pejibaye is a minor crop cultivated on a small-holder rather than plantation scale, and is rarely grown outside central and northern South America and the West Indies. Palmito production is of commercial importance in Costa Rica. No production statistics are available.

2 TAXONOMY AND BOTANY

The pejibaye, Bactris gasipaes HBK (Wassels Boer, 1965) is one of over 200 species in the genus (McCurrach, 1960). Pejibaye has also been classified in the genus Guilielma, and has other synonyms including Gasipaes chontadurna Triana, G. microcarpa Hub., G. utilis Oersted, G. racana Mart. and G. ciliata (R. and P.) Wendl. (Almeyda and Martin, 1980; Hora-Urp! and Clement, 1981).

The pejibaye plant has a straight, slender stem (10-15(-25) cm in diameter, and 13(-20) m tall after 10-15 or more years. The circular leaf scars leave smooth zones on the stem about 2.5 cm across. The internodes are 10-15 cm long on the lower part of the stem decreasing to 2.5-5.0 cm higher up the tree. The nodes are normally densely covered with sharp, hard, black spines up to 10 cm long, which become erect within hours of leaf abscission, but all gradations from very dense to spineless occur. The leaf sheath is also normally covered with spines.

A new leaf (frond) is formed every 2-4 weeks depending on the vigour of the palm and the climate. Fronds are spirally arranged around the trunk with a phyllotaxy of 110°, and are 2.4-3.6 m long. The petiole normally has short, firm spines in 3 longitudinal strips on its lower surface, especially near the basal attachment. Typically there are 10-13 fronds per palm; the leaflets (pinnae) are linear-lanceolate with a bristly or prickly margin, (20-)40(-60) cm long and (1-)3(-5) cm wide, and with a dark green upper surface and light green lower surface. They are grouped in units of 2-9, the spacing within the unit being about 0.5 cm and between units 1.0-1.5 cm.

Though suckers can grow from the base of the stem throughout its life, most are formed during the first 5 years. Old palms may produce a flush of suckers from the stump after felling. Most palms produce an average of 8, but up to 18 shoots can grow, of which 2-4 are usually allowed to develop. After 10-15 years the oldest shoot may be as long as the main stem.

The inflorescences, or racemes, develop in the leaf axils of older fronds or very occasionally above the leaf scars just below the crown. They are protected by an erect spiny spathe of 45-60 cm. The inflorescence is about 50 cm long with a central stalk (rachis) to which branchlets (rachillae) are attached. The small, sessile cream-coloured flowers are found on the rachillae, with female flowers scattered between the more abundant male flowers. They have an annular, lengthy calyx, a small

round-campanulate 3-toothed corolla, and a trilocular ovary with 3 sessile stigmas. The male flowers normally drop within 24 hours of releasing their pollen. A bunch of fruits may weigh 10-15 kg, with 3-5(-13) bunches on a single palm and 50-100(-300) fruits per bunch.

The base of the fruit is nearly covered by a 3-toothed green, leathery calyx. The fruit is 2-6 cm in diameter and length, and round, rippled, cylindrical or pyramidal. Fruit colour is constant for any given palm, but different palms may have green, yellow, orange-red to brown fruits, orange being most common. Many palms produce fruits with 2 or 3 colours in specific bands around the fruit. Fruits weigh 29-100 g. The nut is conical, about 2 cm long and has a hard black shell of 1-2 mm thick enclosing a white kernel. The average nut weight is around 3 g. Mainly seedless fruits, known as pejibaye macho, are produced in some palms and are in some demand.

Essig (1971) studied pollination in Bactris species, while Mora-Urpi and Solis (1980) studied pollination in pejibaye, but more work is required on the identification of insect pollinators. The information is needed both for plant breeding and seed production.

Many different forms of pejibaye have been distinguished, either as cultivars or, in the past, often as different species. Morera Monge (1981) assessed the value of several descriptors, and described the collection at CATIE, Costa Rica.

### 3. ORIGIN, DISTRIBUTION AND ECOLOGY

The genus Bactris is native to northern South America. Pejibaye probably originated from Bactris microcarpa of eastern Peru, which is known locally as pupunha (Corner, 1966), but a hybrid origin has also been suggested. The pejibaye grows in virgin forest on slopes too steep for agriculture in eastern Peru and Ecuador, suggesting that it is endemic. It has been cultivated since pre-Columbian times. Pejibaye is also found from Tapachula, Mexico and the West Indies in the north to Peru and the Amazon basin in the south. It may have been spread to these areas by Carib peoples; though locally abundant, its scattered distribution at old village sites or along streams navigable by canoe, indicates spread by man. Pejibaye has never been established on a commercial scale outside Central and South America, but many areas of Africa and Asia are suitable for its cultivation.

The optimum temperature for pejibaye is 18-24°C, in sub-tropical pre-montane wet forest formations. The palm grows well up to 700 m, and is very occasionally even found at 1,500 m. At low altitudes there is sometimes a second fruiting season. Some 2,000-4,000 mm of evenly-distributed rainfall is required per annum; drought is deleterious as many of the roots are near the surface. Growth and yield are greatly influenced by soil type, which is ideally loamy and developed from river alluviums (Johannesson, 1966b).

### 4. AGRONOMY, DISEASES AND PESTS

Pejibaye is usually propagated from seeds germinated in trays containing a mixture of coconut fibre and sand, and kept moist and shaded. Germination is slow and starts after 30-70 days, the shoot emerging in 10-14 days later. Seedlings are planted in a nursery after a month when at the 2(-3) leaf stage, and in the field 3-5 months later.

Vegetative shoots in the axils of basal leaves can be grown to produce rapidly-established, uniform plants. Methods of enhancing sucker formation by removing apical dominance (Blaak, 1980), and by treating young palms with 10 ppm flurenol (Arias, 1979) have been reported, but in practice clonal propagation is rather difficult. The development of tissue culture techniques for propagation is expected to have a significant impact in the future.

Palms typically begin to flower at 3-4(-8) years old. In the lowlands in Costa

Rica, flowering is from April to June, and fruits ripen roughly 6 months later. Harvesting is awkward because fruit bunches are 10-12 m above the ground, and because of the very sharp spines. Fruit yields depend on plant age, planting density, and environmental factors. Densities used range from 1,667 plants/ha for palmito production (not for fruit); to 400 plants/ha for multiple-stemmed fruiting palms. At the widest spacing, 4-year old plants yielded 6.7 t/ha, while mature plants yielded 10.5 t/ha on average over a 4 year period (Johannessen, 1966c). High yields depend on effective pollination. Pejibaye introduced into West Africa failed to set good seed presumably because its native pollinating insects were not present.

In general pests and diseases do not seriously limit production. Several fruit diseases are known, such as white rot (Monilia spp.), "tizón de racimo" (Graphium spp.), and black rot (Ceratocystis spp.). Several fungi cause leaf diseases, including Pestalotiopsis spp. (yellow spotting), Mycosphaerella spp. (grey spotting) and Colletotrichum spp. (black spotting). Phytophthora spp. causes a heart rot (Vargas and Vilaplana, 1979). The larvae of Metamasius hemipterus bore through the peduncle of the fruit cluster which then rots before ripening. Ants can cause considerable damage to the shoots of germinating seeds (Anon., 1973; Braun, 1968; Johannessen, 1966a; Popence and Jiménez, 1921).

#### 5. GENETICS AND IMPROVEMENT

The chromosome number of pejibaye is  $2n=28$  (Mora-Urpi and Solis, 1980), but little else is known about its genetics. Blaak (unpublished) studied the presence of spines on seedlings from open-pollinated seed from a spineless, a slightly spiny, and a very spiny palm. The results indicated that absence of spines is a recessive trait but several genes may be involved. The genetic control of spine length on the leaf stalk seems to be related to that of spine density.

Very little work has been done on pejibaye improvement, but fruit quality and absence of stem spines were characteristics selected during its domestication. As pejibaye grown for palmito production is already a commercial crop, breeding programmes to support this potential are a first priority. Relatively few variables such as spinelessness and palmito volume, which is related to leaf growth, need to be considered. Other programmes may attempt oil production, protein and carotene rich pulp for human and animal consumption, and flavour. A collection has been established by CATIE at Turrialba in Costa Rica from which improved seed could be produced. The Instituto Nacional de Pesquisas de Amazonia, Manaus, Brazil started a pejibaye breeding programme in 1980.

#### 6. GERMPLASM CONSERVATION

The genetic resources and variability of pejibaye were discussed at an IBPGR-sponsored meeting held at CATIE, Costa Rica. Genetic erosion was considered to be a significant threat in parts of Latin America. Pejibaye populations in Bolivia are generally less variable than those in Central America and the Amazon basin. There seem to be 3 distinct populations in the Brazilian Amazon:

- (i) Rio Amazonas (Amazonia Oriental) types which may be a hybrid, now being mixed with and replaced by those from further west;
- (ii) Rio Solimoes (Amazonia Occidental), noted for the oil content of the fruit; and
- (iii) Rio Negro (western Amazonia), which has dry fruits and dwarf plant characteristics.

The southwest Amazon area extending into Bolivia and Peru, where B. coccinea and B. insignis also grow, may also contain a primitive population of pejibaye. Related wild species were observed in Colombia in Nariño (Patía-Telembí rivers), Valle del Cauca, Sierra Nevada and Guajivá, Cordillera Oriental (Santanderes). All pejibaye populations in Costa Rica are highly variable. A related, but unidentified wild

species, occurs between 1,200 and 1,700 m in the eastern foothills of the Andes in Ecuador. There is great variability in populations in Peru, including a high degree of spinelessness and reduced spininess.

Characteristics which plant breeders currently require include precocity of production, absence of stem spines, short-stemmed types with shorter internodes and seedless fruits. Pest and disease resistance may be required in future breeding work. Improved methods of vegetative propagation are expected to accelerate the introduction of superior selections from breeding programmes. The few collections containing pejobaye are listed overleaf. Accessions can be maintained both as seeds and as trees. USAID sponsored collection of pejobaye in the Amazon basin between 1981 and 1984.

Other sources: Blaak (1976), Burrett (1938), Camacho V. (1969), Camacho V. and Soria V. (1970), Hunter (1969), Mora-Urpi et al. (1984), del Parrugia (1955), Raymond and Squires (1951).

Table 19. Collections of pejobaye

Country	Location	Number of accessions	
		<u>Bactris gasipaes</u>	Other <u>Bactris</u> spp.
Brazil	Manaus, Amazonas	283	<u>Bactris</u> spp. (3)
Colombia <u>1/</u>	Valle del Cauca	220	
Costa Rica <u>1/</u>	Guápiles	372	
Costa Rica	Turrialba	292	
Panama	RENARE	65	
USA	Miami, Florida	17	<u>Bactris</u> spp. (2)

1/ Collection partly maintained as seed.

IBPGR (1984) also lists the following small collections of pejobaye, but these can probably not be regarded as genetic resources collections: Habana, Cuba; Cozolepu, Oaxaca, Mexico; Hilo, Hawaii, USA.

PASSIFLORA spp.  
(Passion Fruits)

1. INTRODUCTION

Passion fruits have an aromatic pulp surrounding the seeds, which is eaten fresh, or processed into juices, sherberts etc. Nutritionally, they are similar to many other juicy fruits with no special merit (Table 1). A ton of yellow passion fruits yield about 360 kg of juice, 110 kg of skins and 510 kg of seeds. After drying or ensiling, the skins are suitable as a livestock feed. The seeds contain 20% of an edible oil, which compares favourably in feeding value and digestibility with cotton seed oil (Seale and Sherman, 1969).

The crop is grown widely throughout the tropics and sub-tropics in gardens and small-holdings, but production statistics are not compiled by FAO. Commercial production occurs in coastal areas of New South Wales, and Queensland, Australia; Hawaii and South Africa.

2. TAXONOMY AND BOTANY

There are about 370 species of Passiflora L., 350 of which are native to America, and 20 to Asia and Australia (de Wilde, 1976). A key to the American Passiflora species (Killip, 1938) is useful for identifying species with edible fruits also, because they are native to the area. Bailey (1949) provides a key to 11 cultivated species, but does not completely cover the 16 minor edible species listed by Martin and Nakazono (1970).

The major cultivated species is P. edulis Sims, the purple passion fruit or purple grenadilla, with its yellow form P. edulis f. flavicarpa Deg. Next in importance is probably P. quadrangularis L., the giant grenadilla, which is frequently cultivated in tropical lowland gardens. Some other cultivated species are: P. nieta Dry. (Brazil), P. laurifolia L., water lemon or bell-apple (West Indies, northeastern South America), P. ligularis Juss., sweet grenadilla (throughout the Andes to Central America, mostly between 2,200 and 2,700 m), P. maliformis L., curuba (low valleys in Ecuador and Colombia, and on some West Indian islands), P. mollissima (HBK) Bailey, tasco (throughout the Andes between 1,800 and 3,000 m in altitude, and also in Hawaii and New Zealand), P. pinnatistipula Cav., tasco, gutupa (grown on a small-scale from Chile to Colombia at 2,500 to 3,000 m), P. popenovii Killip, grenadilla de quiijos (small-scale production in Ecuador), P. tripartita (Juss.) Poir, tasco (garden plantations in Ecuador at 1,800 m), and P. van-volkemii (occasionally grown in Colombia). At least 30 other species have edible fruits.

P. edulis is a vigorous, woody, perennial climber up to 15 m long with green, grooved stems and robust axillary tendrils. Leaves with stipules, petiole 2-5 cm long; lamina usually deeply palmately 3-lobed, but often ovate and undivided on young plants. Flowers hermaphrodite, solitary, fragrant 5-10 cm in diameter; calyx tubular at base with 5 spreading reflexed lobes, white above; petals 5, free, inserted on the throat of the calyx, white; corona of 2 outer rows of wavy, radiating filaments, 2-3 cm long, purple at base, white above, and several inner rows of short purple-tipped papillae; stamens 5, filaments united in a tube around gynophore for about 1 cm and then widely parted for 1 cm; anthers large, versatile, pale yellow, hanging downwards below level of ovary; ovary carried on a gynophore, ovoid, pale yellow, 1-locular with 3 parietal placentas; styles 3, horizontal, pale green, 1.0-1.5 cm long. Fruit of the purple form a globose or ovoid berry, deep purple when ripe, dotted, glabrous, 4-6 cm long; pericarp hard, thin with greenish mesocarp and white endocarp. Seeds many, attached to peg-like funiculi on ovary wall, surrounded by yellowish, aromatic juicy aril; testa blackish, 3-toothed at base, flattened 5 cm x 3 cm (Purseglove, 1968).

Flowers of P. edulis are pollinated most effectively by honey bees and carpenter bees. Though bisexual, most flowers are self-sterile, the pollen being released before

the flowers open, and the stigma is receptive for only a short time. Some plants are also self-incompatible (Crane and Walker, 1984).

Seedling populations, though fairly homogeneous, are not uniform, and are best described as strains rather than cultivars. A number of clonal cultivars of both the purple and yellow forms of P. edulis, as well as seedling rootstocks, are recognized, and are routinely used in Australia. Single clone plantations may be unfruitful because of self-incompatibility, so clones grown together should be cross-compatible. Seale and Sherman (1969) mentioned 9 selected types (of one or more strains) grown in Hawaii. Work on cultivars is in progress at La Réunion, Cameroon, Côte d'Ivoire and the West Indies by IRFA (Gaillard, 1978).

### 3. ORIGIN, DISTRIBUTION AND ECOLOGY

Most of the cultivated species of Passiflora originated in South America. The purple passion fruit came from southern Brazil, and is now widely distributed throughout the tropics and sub-tropics. The yellow passion fruit originated as a sport from the purple passion fruit in Australia or South America. Other cultivated species originated as follows: P. quadrangularis (tropical South America), P. alata (Peru and Brazil), P. laurifolia (West Indies and northeastern South America), P. ligularis (tropical America), P. maliformis (tropical America), P. mollissima (Andes), P. pinnatistipula (Andes of Peru and Chile), P. popenovii (slopes of eastern Andes), P. tripartita (Ecuador), and P. van-volxemii (Colombia) (Zeven and de Wet, 1982; Fouqué, 1972a).

Many species of Passiflora, including cultivated ones, naturalize easily outside their area of origin. De Wilde, (1976) noted 8 native and 25 exotic species in the Malaysian and Australasian Pacific flora, and at least 5 cultivated species grow wild in Hawaii (Akamine et al., 1979).

As a group the cultivated species of Passiflora grow in climates ranging from lowland equatorial to mountainous sub-tropical. The species of Passiflora have probably not yet been spread to all suitable areas. They also grow on a range of soil types.

### 4. AGRONOMY, DISEASES AND PESTS

Most commercial production of passion fruit is based on seed-propagation, the seeds usually being sown in nursery beds. The young seedlings are transferred to baskets or pots, and 3-4 months after sowing when about 30 cm tall are planted in the field, to be trained on trellises of posts and wires.

One way of overcoming the problem of root diseases, especially Fusarium spp., is to graft seedling scions on to disease-resistant vegetatively-propagated rootstocks. The yellow passion fruit is commonly used as a rootstock for the purple passion fruit in Queensland.

Flowering begins at about 10 months and fruits develop in about 10 weeks. A reasonable crop may be harvested 18 months after sowing, and thereafter there may be 2 crops annually. Fruits are only produced on new growth, which is stimulated by pruning. For table use the fruits are picked by hand, while for processing ripe fruits are allowed to fall on the ground, and are collected every 2-3 days. A plantation is best renewed every 5-6 years. Average yields of the yellow passion fruit in Hawaii are 27-55 tons/ha, and of the purple form somewhat less; elsewhere cultivation standards and yields may be lower.

Serious losses can be caused by Alternaria passiflorae (brown spot), which affects vines, but can be controlled by spraying leaves and fruits, and Fusarium oxysporum f. passiflorae (wilt). Wilt is soil-borne affecting the whole plant; field resistance is found in a selected strain of the yellow passion fruit and several other Passiflora species, but not the major cultivated ones. Control is also effected by using resistant rootstocks. The main fungus diseases of passion fruit in Queensland,

Australia are septoria spot (Septoria passiflorae), phytophthora leaf blight (Phytophthora nicotianae var. parasitica), damping-off (Rhizoctonia solani and Pythium spp.) and base rot (possibly Pythium spp.) in addition to those mentioned above (Inch, 1978).

Cucumber mosaic virus (CMV) and passion fruit woodiness virus (PFWV) frequently occur in Australia, separately or together. PFWV, also called "bullet disease", affects leaves and stems, and the fruits become hard, distorted and inedible. The yellow passion fruit has some field tolerance, as also do yellow and purple hybrids. Some control has been achieved by infecting the plants with wild strains of the virus. The bacterium Pseudomonas passiflorae causes grease spot which may result in serious damage to stems, leaves and fruits. Control is by pruning of diseased leaves, runners and fruits, and spraying with Bordeaux mixture.

Pests of passion fruits include aphids, mealybugs, leaf hoppers and naked scales (Homoptera), bugs and shield bugs (Heteroptera), thrips (Thysanoptera), butterflies and moths (Lepidoptera), fruit flies (Diptera), a beetle (Coleoptera) and mites (Acarina). Control is usually by pesticides, resistance breeding having received little attention.

The passion fruit is susceptible to nematodes, the root-knot nematode (Meloidogyne javanica) being particularly damaging (de Villiers and Milne, 1972; Levitt and McGillivray, 1958). Control is by fumigation and crop rotation.

#### 5. GENETICS AND IMPROVEMENT

According to Darlington and Wylie (1955), and based on work with 7 species, the genus Passiflora has a basic chromosome number of  $x=9$ . Storey (1950) examined 26 plants, mainly different species, but also botanical forms, interspecific hybrids and a polyploid race, and concluded that it was 3 or 6. Most of the species, including those of horticultural importance, were  $2n=18$  with regular meiosis, as was also a cross between purple and yellow passion fruit. Some had up to 84 chromosomes, but their origin and relationships in the genus were not clear. Beal (1969, 1973) found that the chromosome numbers of 3 native Australian species, P. aurantia Forst., P. herbertiana Lindl., and P. cinnabarina Lindl. were  $2n=2x=12$ ; those of 3 exotic species - P. maliformis L., P. seemanni Griseb. and P. quadrangularis L. - were  $2n=2x=18$ ; and that of P. suberosa L. was  $2n=2x=4x$ .

The inheritance of a few characteristics has been studied in cultivated passion fruits. Nakasone et al. (1967) working with crosses of purple and yellow passion fruit, noted that the purple form was susceptible to crown rot and leaf wilt disease (probably Fusarium spp.), and the yellow resistant; probably a single dominant gene was involved. Purple tendril colour in yellow passion fruit is dominant to green in purple passion fruit. Fruit shell colour appears to be controlled by a single pair of genes with no dominance, as 3 colour types were found in the  $F_2$ . Other characteristics have been studied by Rubertó-Torres and Martin (1974) and Beal (1975).

Many of the species in the genus can be crossed; at least 13 species, 9 of them with edible fruits have been used in interspecific hybridization. Growth regulators have been used with some of the crosses to prevent fruit abscission (Martin and Nakasone, 1970; Rubertó-Torres and Martin, 1974; Payán and Martin, 1975). Most breeding has been with yellow and purple forms of P. edulis. A major aim has been to overcome the Fusarium wilt susceptibility of the purple form. Another has been to combine the delicate flavour of the purple form with the greater disease resistance and adaptation to warmer conditions of the yellow form.

Crossing is simple and large numbers of  $F_1$  seedlings can be produced quickly. The earliest breeding work was in Queensland, where Kajewski (1941) crossed P. edulis with P. incarnata, an American cultivar with fruits of a golden colour (possibly synonymous with P. edulis f. flavicarpa). The  $F_1$  was back-crossed using P. edulis as the pollen source, but further reports of results have not been found. Grossmann and

Furss (1958) also reported crosses between yellow and purple forms of *P. edulis* aimed at combining the best characteristics of each. Hybrids with resistance to Fusarium wilt, tolerance of PFVW, longer cropping periods and higher yields were released in 1959 (Beal, 1975). Several clonal cultivars have been released in Hawaii, including 'Noel's Special', which is tolerant of Alternaria passiflorae, and fruits at one year old. It is self-incompatible and needs a pollinator (Ito, 1978). The aim of some work currently in progress at the IRFA station in Guyana is to select self-compatible types, and/or types with a long flowering period (Gaillard, 1983 pers. comm.).

#### 6. GERMPLASM CONSERVATION

While commercial passion fruit production continues to be based on seed propagation, the cultivated crop is buffered somewhat against genetic loss. The wild species naturalize easily in new areas. Insufficient data on the potential of most Passiflora species in breeding, or for use as rootstocks, is currently available.

It is possible to conserve passion fruit seeds (Ellis, 1984), and they are included in some collections, for instance at Hawaii, USA. The present level of genetic erosion in both wild and cultivated Passiflora species relative to their value as a crop is not a cause for concern.



Table 20. Collections of Passiflora spp.

Country	Location	Number of accessions		Other <u>Passiflora</u> spp.
		<u>Passiflora edulis</u> purple	yellow	
Australia	Nambour, Queensland		4	<u>P. edulis</u> x <u>P. incarnata</u> (10)
Brazil	Bahia			<u>Passiflora</u> spp. (20)
Brazil	Londrina, Parana			<u>Passiflora</u> spp. (5)
Cameroon	NJonbe	2		
Colombia <sup>1/</sup>	Bogotá			<u>Passiflora</u> spp. (41)
Colombia	Palmira			
	Valle	7		
Costa Rica	Turrialba			<u>Passiflora</u> spp. (12)
Ecuador	Quito	5		<u>P. mollissima</u> (3)
Jamaica	Kingston			<u>Passiflora</u> spp. (16)
Malawi	Limbe			<u>Passiflora</u> spp. (3)
New Zealand	Ormiston <sup>2/</sup>			<u>Passiflora</u> spp. (10)
Papua New Guinea	Xaravat			<u>Passiflora</u> spp. (2)
Peru	Lima		16	
Peru	Iquitos			<u>Passiflora</u> spp. (6)
Seychelles <sup>3/</sup>	Mahé	18	1	
South Africa	Neispruit			<u>Passiflora</u> spp. (5)
USA	Miami	23	28	<u>P. alata</u> (3)
	Florida			<u>P. cincinnata</u> (2)
				<u>P. foetida</u> (4)
				<u>P. incarnata</u> (6)
				<u>P. laurifolia</u> (14)
				<u>P. ligularis</u> (3)
				<u>P. lutea</u> (2)
				<u>P. malliformis</u> (3)
				<u>P. platyloba</u> (2)
				<u>P. quadrangularis</u> (8)
				<u>P. rubra</u> (2)
				<u>P. suberosa</u> (3)
				<u>Passiflora</u> hybrids (58)
				<u>Passiflora</u> spp. (33)
USA <sup>4/</sup>	Puerto Rico			<u>Passiflora</u> spp. (7)
USA	Hilo, Hawaii	2	14	<u>Passiflora</u> spp. (5)

1/ ICA - Tibeltatá-A.A. 151123, Eldorado-Bogotá, Colombia.

2/ Redlands Horticultural Research Station, Delancey Street, Ormiston, New Zealand.

3/ Grand'Anse Experimental Centre, Mahé, Seychelles. Plants and seeds stored.

4/ Mayaguez Institute of Tropical Agriculture, Puerto Rico (Payán and Martin, 1975).

IRPGR (1984) also lists the following small collections of Passiflora spp., but these can probably not be regarded as genetic resources collections: Habana, Cuba; Nicosia, Cyprus; Veracruz, Mexico; los Baños, Philippines. There are also likely to be specimens in the Wilson Popenoe Botanic Garden in Lancailla, Honduras and the Summit Gardens in the Panama Canal Zone, but further details are not available.

MACADAMIA INTEGRIFOLIA AND M. TETRAPHYLLA  
(Smooth-shell and Rough-shell Macadamia)

1. INTRODUCTION

The edible seed kernels of macadamia nuts are eaten in desserts and cocktails, or used in confectionary, chocolate, ice-cream and baking. They have a very high fat content as do pecan nuts, but compared with cashew and pistachio nuts, are relatively low in protein (Table 1), which is also of a rather low biological value. The oil is about 65% oleate, 19% palmitoleate and 7% palmitate.

The macadamia is a minor nut crop. Most commercial production is in the Hawaiian Archipelago with at least 4,000 ha; over 90% of the world crop is produced in Hawaii itself. Other countries/states growing or experimenting with the crop are Australia, Brazil, California, Costa Rica, Guatemala, Kenya, Malawi, South Africa and Zimbabwe. The total world crop is about 14,000 tons of in-shell nuts annually (Hamilton et al., 1980).

2. TAXONOMY AND BOTANY

Of the 10 evergreen trees and shrubs in the genus Macadamia F. von Mueller, 6 are native to Australia, 3 to New Caledonia and 1 to Sulawesi, Indonesia (Storey, 1965).

M. integrifolia Maiden and Betche, the smooth-shell macadamia, is the most important commercial species. M. tetraphylla L.A.S. Johnson, the rough-shell macadamia, has by comparison a minor role, and may only produce about 1% of the crop. These 2 species have been known incorrectly as M. ternifolia F. von Mueller, a species with small, bitter and unpalatable seeds which has rarely been cultivated.

The smooth-shell macadamia is an evergreen tree 18 m or more high and with a spread of about 15 m. Leaves, long linear-lanceolate and often spiny when juvenile, usually entire or nearly so when adult, 10-30 cm long and 2.5-7.5 cm. wide, in whorls of 3 or occasionally 4. Inflorescence racemose, pendant, borne on 2, 3 or more year-old wood; rachis 10-30 cm long. Flowers 100-300, small (ca. 12 mm at anthesis), perfect, in pairs in the axils of minute bracts; perianth regular, of 4 petaloid sepals; ovary superior, with single carpel containing 2 ovules, only one of which usually develops; stamens 4, perigynous and attached to the upper part of perianth. Fruit a follicle comprising a more or less fleshy pericarp (husk). Seed spherical, 1.2-2.5 cm in diameter with a very hard testa (shell) and a creamy white kernel, rich in fat. The husk splits open along a suture from the stalk to the distal end as the fruit ripens.

Only a small proportion (3% or less) of the flowers result in harvestable fruits. Honey bees are the usual pollinating insects of macadamia in Hawaii, but wind pollination may also occur. Most cultivars are partially self-incompatible and some are completely so. Cross-pollination gave greatly increased fruit set in Hawaii (Urata, 1954), and the beneficial effects of inter-clonal pollination have also been observed in South Africa.

Natural stands of macadamia in eastern Australia are highly variable in characteristics like fruit size and shell thickness. Individual trees are heterozygous and predominately out-breeding, so clonal propagation is the only way of maintaining selected cultivars. A number of cultivar descriptions based on tree vigour, branch angle, fruit size etc. have been published (Hamilton et al., 1952; Hamilton and Fukunaga, 1970).

3. ORIGIN, DISTRIBUTION AND ECOLOGY

The 2 cultivated macadamias are indigenous and still both occur wild in the

rainforests on the eastern slopes of the Great Dividing Range in Queensland and New South Wales, Australia. M. integrifolia is found between latitudes 28° and 25° S, and M. tetraphylla between 29° and 27°S (Strey, 1965). The aborigines of eastern Australia gathered the nuts, but did not cultivate the trees. European settlers cultivated them from about 1870 and they were introduced to California and Hawaii 10-25 years later. Macadamia trees are now grown in many sub-tropical areas and tropical areas at higher altitudes, albeit often on a small scale.

The trees require between 1,250 and 3,000 mm well-distributed rainfall, and are best irrigated under drier conditions. An average temperature during the growing season of 25°C with a maximum rarely over 38°C, and only slight frost in winter are suitable conditions. M. tetraphylla is slightly more frost-resistant than M. integrifolia. Macadamia trees are very easily damaged by wind, so both staking and the use of windbreaks is important (Allan, 1972).

#### 4. AGRONOMY, DISEASES AND PESTS

All of the commercial orchards in Hawaii are of the smooth-shell macadamia. The rough-shell macadamia is less suitable for processing because of its lower oil and higher sugar content, and its major use has been as a rootstock for smooth-shell cultivars. Several methods of vegetative propagation have been developed, such as cutting, air-layering, inarching and grafting on to seedling rootstocks (Cormack and Buchanan, 1973; Leijn et al., 1971; Ohler, 1969; Tonks, 1972). Trees in orchards are spaced at 9.0-10.5 m x 6.0-8.0 m in Hawaii. Yields of mature trees, over 16 years old, grown from seed vary widely from 60-120(-180) kg kernels per year; grafted trees usually yield 4-5 times as much, with an orchard producing 8-9,000 kg/ha. M. tetraphylla may be valuable in countries with a greater risk of frost, and Australia, California, South Africa and Kenya have included the rough-shell types in their development programmes (Gathungu and Likimani, 1975). Mature nuts are usually gathered from the ground.

Trunk and branch canker caused by Phytophthora cinnamomi is probably the major disease of macadamia in California, Hawaii and Queensland. Control measures include avoiding poorly-drained soil on which avocado may previously have been grown, tree and plantation hygiene and appropriate use of chemicals. Other diseases are relatively unimportant, but the following are listed by Cook (1975): raceme and nut blight (Phytophthora palmivora or P. nicotianae var. parasitica), raceme blight (Botrytis cinerea), anthracnose and husk rot (Colletotrichum spp.), blossom blight (Gloeosporium spp.), branch canker (Dothioralla gregaria), crown gall (Agrobacterium tumefaciens), and pythium root rot (Pythium carlinianum).

The most comprehensive information on insect and mite pests of macadamia comes from Hawaii (Hamilton et al., 1980) and Queensland (Ironside, 1973). The larvae of a number of moths (Lepidoptera) damage nuts, flowers or leaves in both areas. Two bugs (Heteroptera) feed on the nuts in Queensland. A species of scale insect (Homoptera), the macadamia felted coccid, may have severe effects on production in Queensland. Other pests in Hawaii include the black citrus aphid, the southern green stink bug (Homoptera), the broad mite (Acarina) and various other thrips and mites. Most pests can be controlled if necessary by the use of insecticides. Stink bug has been reduced in Hawaii by introducing parasites (Hamilton et al., 1980).

#### 5. GENETICS AND IMPROVEMENT

The cultivated Macadamia species and M. ternifolia have 2n=28 chromosomes. At least one tetraploid clone of M. integrifolia has been found with 2n=56. In certain valleys in southern Queensland where M. integrifolia and M. tetraphylla are sympatric, fertile hybrid trees are found. Chance hybrids are also occasionally found in Hawaii and California.

The key to progress in the selection of superior macadamia cultivars was the development of methods of clonal propagation. Criteria for selection of smooth-shell

macadamia in Hawaii include: a tree which is vigorous, wind resistant, high-yielding, regular cropping and with a short harvesting season; branches which are strong and widely-angled; fruits which are of medium size (2 cm diameter) or larger, with shells which are not too thin because this may result in damage to the kernel during cracking; and a high proportion of well-filled fruits containing at least 35% by weight of kernel, with over 72% oil and with a mild, nutty flavour, and a creamy-white colour.

Macadamia breeding started in Hawaii in 1936 (Hamilton and Fukunaga, 1959). Five cultivars were released in 1948, and since then a further 6 have been produced (Hamilton et al., 1980), several of which have been successfully grown in other countries. Breeding was started in Queensland, Australia in 1948 and several selections have been released, including a *M. integrifolia* x *M. tetraphylla* hybrid (Anon., 1961). Selections with thin shells at the apical end of the nut are rejected in Queensland because they are attacked by ants and often germinate whilst still on the tree. They are also often attacked by the fruit spotting bug (*Amblypelta lutescens*), a cause of serious kernel damage. Germination in the fruit is not a problem in California because ripening takes place in the dry season (Leverington, 1962). Improved cultivars have also been selected in South Africa (Anon., 1969/70-1978/79), Zimbabwe (Hobson, 1972), Costa Rica (Anon., 1974) and Brazil (Ojima et al., 1976).

#### 6. GERMPLASM CONSERVATION

There is likely to be some genetic erosion of cultivated macadamia as clonal propagation is more widely used, and as stands of wild trees in Australia are cleared. Other *Macadamia* species may be important for future breeding work, for use as rootstocks, or as crops in their own right. Areas where these grow are New Caledonia (*M. francii*, *M. rousselii*, *M. vellardii*), Sulawesi, Indonesia (*M. hildebrandii*) and eastern Australia (*M. heyana*, *M. proalta*, *M. ternifolia*, *M. whelani*) (Storey, 1965). *M. hildebrandii* has cyanogenic and inedible kernels, but is interesting as a species suited to the wet tropics. *M. whelani* is a tropical species with edible nuts (Sloumer, 1955).

Germplasm collections of macadamia trees are shown in the table. It is not known whether seed storage is possible or practised.

Table 21. Collections of macadamia

Country	Location	Number of accessions		
		<u>M. integrifolia</u>	<u>M. tetraphylla</u>	Other <u>Macadamia</u> spp.
Australia	Aistonville, N.S.W.	23	6	
Australia	Nambour, Queensland	25		<u>Macadamia</u> hybrids (3)
Chile	Santiago			
Israel	Beit-Dagan	16	9	<u>M. integrifolia</u> x <u>M. tetraphylla</u> (1)
Malawi	Limbe	6	4	<u>M. integrifolia</u> x <u>M. tetraphylla</u> (1)
Mexico	Cozolapa, Oaxaca			<u>Macadamia</u> spp. (6)
South Africa	Nelspruit			<u>Macadamia</u> spp. (14)
USA	Miami, Florida	10	3	
USA	Hilo, Hawaii	9	9	<u>M. hildebrandii</u> (1)

IBPGR (1984) also lists the following small collections of macadamia, but these can probably not be regarded as genetic resources collections: Njunde, Cameroon; Habana, Cuba. Other countries which may have small collections are Brazil, Costa Rica, El Salvador, France (La Réunion), Guatemala, Indonesia, Kenya, New Zealand, the Philippines and Zimbabwe.

PUNICA GRANATUM  
(Pomegranate)

1. INTRODUCTION

The pomegranate may be eaten as a fresh dessert fruit, or processed into juice, often being blended with other juices. Further processing may yield a syrup, citric acid and a type of wine. Pomegranates are high in easily-digestible reducing sugars, but do not have any special nutritional value (Table 1). Other parts of the plant can be used: the fruit rind for tanning leather, as a source of dye for wool and silk, and as an astringent for diarrhoea and dysentery; the dried bark of the root and stem as a medicine against tapeworm; the leaves in preparing ink; and the powdered flowerbuds for treating bronchitis. Pomegranate seeds with the adhering portions of flesh are sold in India as 'anardana', which is used in food flavouring. The chemical constituents of the tree include: a drying oil from the seeds with anti-bacterial properties; alkaloids from bark and stem with medicinal value; and alkaloids and tannates with insecticidal and antibiotic properties from many parts of the tree (Anon., 1969).

Pomegranates, though locally important in several Asian and Mediterranean countries, are not a major crop. The total world crop was estimated as 0.8 m tons of fruit in 1982 (Levin, 1983, pers. comm.). They are rarely traded internationally.

2. TAXONOMY AND BOTANY

The family Punicaceae contains a single genus Punica L. of 2 species, P. granatum L. (pomegranate) and P. protopunica Balf.f., syn. Socotria protopunica Balf.f. (Heywood, 1978). The latter is indigenous to the island of Socotra, Democratic Republic of Yemen. Two subspecies of P. granatum have been distinguished on the basis of ovary colour, a stable character which is retained when they are grown from seeds. Subspecies chlorocarpa is found mainly in the Transcaucasus and subspecies porphyrocarpa mainly in central Asia. (Anon., 1969).

The pomegranate is a shrub or small tree (2-)5-10 m high with a smooth, dark grey bark and branchlets which are sometimes spiny. Leaves opposite, short-petioled, 2-8 cm long, oblong or obovate, glossy, bright green and glabrous. Flowers bisexual, axillary, solitary or in small clusters borne towards the ends of the branchlets, 4-6 cm in diameter; calyx tubular, persistent 5-7 lobed; petals 5-7, brilliant orange-red, lanceolate, inserted between the calyx lobes, wrinkled; stamens numerous; ovary inferior, with several locules in 2 series, one above the other. Fruit a berry, globose or somewhat flattened, 5-12 cm in diameter, crowned by thick tubular calyx; pericarp smooth, coriaceous, woody, from brownish-yellow to red when ripe; interior divided in several chambers by a horizontal diaphragm and vertical septa, each chamber being filled by many seeds crowded on thick, spongy placentae. Seeds many-sided, ca. 1.3 cm long consisting of thin, transparent fleshy testa containing reddish juice and surrounding the elongated angular seed kernel (Anon., 1969; Bailey, 1964; Purseglove, 1968).

Flowers are typically of 2 types: large fertile ones with anthers and stigma at the same height on old wood; and smaller sterile flowers on new wood in which the stigma is much below the anthers. The latter have defective pollen and do not usually form fruits. Pollination of pomegranate is probably effected by beetles. As little or no nectar is produced by the flowers, any insects visiting them are likely to be pollen collectors. Both self and cross-pollination probably occur (Crane and Walker, 1984).

There are numerous cultivars and some of the literature dates back to the 13th century (Popovoe, 1920). Publications on cultivars include: Bois, 1928; Evreinoff, 1947, 1949 (33 cultivars in Afghanistan, Greece, Malta, Saudi Arabia, Spain, Tunisia,

Turkey and USA); Cheema et al., 1954; Anon., 1969 (10 Indian cultivars); Brooks and Olmo, 1972 (3 American cultivars); Levin, 1980; Arendt and Sinjko, 1981 (USSR cultivars); and Dokuzoguz and Mendilcioglu, 1978 (12 Turkish cultivars). Many of the cultivar descriptions are inadequate.

Characters used to distinguish cultivars include: size, weight and shape of fruit (oblate, globose, round, obovate); colour (deep purple red, bright red, pale yellow etc.) and roughness of skin; rind thickness; flesh colour; number of seeds; size (including stoneless), colour and hardness (very soft to hard) of seeds; and juice content and taste of pulp.

### 3. ORIGIN, DISTRIBUTION AND ECOLOGY

The pomegranate grows wild and probably originated in Iran, Afghanistan and Baluchistan (Zeven and de Wet, 1982). The wild types of central Asia vary widely in fruit size, sweetness, ripening time, juiciness and the proportions of seeds and flesh. Pomegranates have been cultivated in the Middle East for over 5,000 years. They were introduced from Syria and Israel to Egypt about 1,600 B.C., became widely grown and naturalized in the Mediterranean area, and were also moved to India. After the discovery of the New World, they were taken to the Americas. They are now grown in many tropical and sub-tropical countries, both for the fruits and as an ornamental plant.

Pomegranates grow best in semi-arid sub-tropical climates with cool winters and hot summers. They can be grown in conditions ranging from the deserts of California to the moist lowlands of Java, Indonesia, but yields are usually low in tropical climates. Although there is variation in frost resistance, the trees are not usually damaged until temperatures are down to about -11°C, and even lower in parts of the USSR. High temperatures and an adequate water supply are important during fruit ripening.

Deep, loamy soils are best for good yields, preferably calcareous and containing lime nodules, but pomegranates will also grow on light and poor soils (Anon., 1969).

### 4. AGRONOMY, DISEASES AND PESTS

The pomegranate is usually propagated by hardwood cuttings; root suckers and air layering may also be used. Seed propagation is not recommended because of segregation. After 1-2 years in a nursery, the young trees are planted in the field at a spacing of 4-7 m, but at closer spacings of 4 x 2 or 3 m in Tadjikistan, Uzbekistan and Turkmenistan, USSR (Levin, 1983, pers. comm.). They require some pruning and begin to produce a regular crop when about 7-8 years old. Fruits usually take 6-7 months to develop. In areas where there is a distinct winter, the trees are deciduous, but in more temperate climates and with sufficient moisture, they may flower and fruit more or less continuously, unless deliberately prevented from so doing by root pruning and manipulation of the irrigation supply. The fruits can be stored for 5-6 months if picked when not fully mature. The numbers of fruits per tree may vary from 20-25 (4 years old), to 100-150 (10 years old) to 200-250 at maturity (Singh et al., 1967).

In general, fungal diseases do not seriously limit production. Levin (1983, pers. comm.) noted that up to 50 may occur in USSR. Cook (1975) mentions only 3 diseases, none of which are serious, although Ceuthospora phyllosticta, a twig canker, occasionally kills trees. Bacterial leaf spot (Xanthomonas punica) causes irregular, light-brown lesions that become dark-brown with distinct water-soaked margins, and leaves may drop if infection is severe. Fruit pulp rot (Agrobacterium tumefaciens) occurs only in more humid climates. The bacterium penetrates the fruit through the pistil, causing the fruit to rot, although the skin remains intact. Control is only possible through the use of resistant cultivars (Evreinoff, 1949).

Bhutani (1976) listed 38 insect species which attack pomegranate, mostly minor pests; Levin (1983, pers. comm.) calculated that there may be 100 in USSR. The anar (= pomegranate) butterfly (Virachola isocrates) is a serious pest in India, and sometimes

half or more of the fruits are attacked by the larvae. Control is by the removal and destruction of affected fruits and use of insecticides. The related V. livia has been reported from Egypt (Awadallah et al., 1971). Next in importance are several species of fruit flies, including Anastrepha ludens, Dacus dorsalis and D. zonatus in India, and Ceratitis capitata especially in Mediterranean countries. The larvae feed inside the fruit and cause rotting and fruit drop. Bark-eating caterpillars (Indarbela tetraonis and I. quadrinotata) prevent sap translocation in pomegranate, and several other species, by tunnelling into the bark. Other insects include 10 species which cause defoliation, 1 termite, 1 whitefly, 2 thrips and mealy bugs and 8 species of scale insects. Control of most of them is by orchard hygiene and insecticides.

#### 5. GENETICS AND IMPROVEMENT

Somatic chromosome numbers of  $2n=16$ , 18 and 19 have been reported for Punica granatum (Darlington and Wylie, 1955). Nath and Randhawa (1959) found  $2n=16$  for 6 Indian cultivars, except for the ornamental cultivar 'Double Flower' which had  $2n=18$ . Das and Sur (1968) found a tetraploid with  $2n=32$  which was obtained from the cultivar 'GB-1' ( $2n=16$ ) by air-layering. The tetraploid had somewhat larger and broader leaves, slightly larger stomata, larger fruits and much larger pollen grains, but also a high percentage of sterile pollen. Kihara (1965) found a somatic chromosome number of  $2n=16$  for a cultivar from Pakistan with soft seed kernels in which only 1 of the 2 layers enclosing the embryo and endosperm was lignified, but the flowers were pollen sterile.

Crop improvement in pomegranate has for centuries depended on the selection of spontaneous seedlings and their clonal propagation. Selection of seedlings from open-pollinated or artificially-pollinated mother trees is more recent. The cultivar 'Ganeshkind no. 1' was selected in India from cultivars suited to the Deccan conditions of soil and climate (Cheema et al., 1954). Strebkova (1969), and Strebkova and Masaceva (1969) reported the selection of 13 cultivars from 612 hybrid seedlings in USSR. Breeding work in USSR is also discussed by Levin (1979).

#### 6. GERMPLASM CONSERVATION

There is a continuing loss of genetic variability of cultivated pomegranate because propagation is mostly clonal, despite the fact that the plants naturalize easily. Nasir and Ali (1976) reported that wild pomegranate trees are frequent in Pakistan at 1,000 - 2,000 m altitude throughout the Western Range (Baluchistan, north and south Waziristan, North West Frontier Province, Kurram, Dir and Chitral) on limestone soils, and in Salt Range and Haqzara, but they become scarcer further east. They also grow in Kashmir and the Himalayan areas. In India, wild pomegranate trees were reported in the warm valleys and outer hills of the Himalayas between 900 and 1,800 m (Anon., 1969). Levin (1977) discussed variability in wild pomegranate in the USSR, especially Turkmenistan, while Levin (1982) considered the genetic diversity of pomegranate at the VIR Turkmenian Experimental Station. There is serious genetic erosion of pomegranate in USSR, and the plant is included in "The Red Book of the USSR" and "The Red Books" of the Transcaucasus and Middle Asian republics.

P. protopunica has not been used either in pomegranate breeding or as a rootstock. The species is listed in the 'endangered' category (IUCN, 1978) due to excessive grazing by goats and cattle, but it is being cultivated at several botanical gardens including the Royal Botanic Gardens, Kew, UK. There is considerable scope for in situ conservation of pomegranate.



Table 22. Collections of pomegranate

Country	Location	Number of accessions
		<u>Punica granatum</u>
India	Jodhpur, Rajasthan	33
India	Hissar, Haryana	37
India	Rahuri, Maharashtra	37
Thailand	Bangkok	9
Turkey	Izmir	60
USSR	Leningrad	800+
USA	Byron, Georgia	35
USA <sup>1/</sup>	Puerto Rico	16

<sup>1/</sup> Fogle (1981).

IBPGR (1964) also lists the following small collections of pomegranate, but these can probably not be regarded as genetic resources collections: Rajshahi, Bangladesh; Santiago, Chile; Habana, Cuba; Nicosia, Cyprus; Kingston, Jamaica; Keravat, Papua New Guinea; Los Baños, Philippines; Wad Medani, Sudan. There is also a pomegranate specimen at Grand'Anse Experimental Centre, Mahé Island, Seychelles. Other collections are likely to exist in Afghanistan, Iran and Morocco at Ahl Sousse and Zagora.

Rhamnaceae

ZIZYPHUS MAURITIANA  
(Indian Jujube)

1. INTRODUCTION

The Indian jujube or ber is grown chiefly for its fruits, which may be eaten fresh, dried or candied, or canned or used in drinks. The fruits are a rich source of vitamin C, and are high in vitamin A, and generally quite nutritious (Table 1) (Bal, 1982). The tree is one of the principal host plants for rearing lac insects in India, which are used in the manufacture of shellac (Anon., 1962a; Maurya et al., 1967). Other uses include: fruit, bark, leaves and roots as medicines; wood for carpentry and construction; leaves as fodder; as a food for honey bees; and as a hedge plant (Burkill, 1966; Crane and Walker, 1984; Dalziel, 1955).

Few production statistics are available on the Indian jujube and those that exist may be misleading as trees are often very scattered. Singh et al. (1967) mentions an area of 10,000 ha in India, but improved budded cultivars were subsequently planted on a large scale in Punjab, Rajasthan and Uttar Pradesh (Sidhu and Singh, 1979). It is grown in several other places, including the West Indies, much of the drier parts of tropical Africa, e.g. Mozambique along the Zambezi river, and in tropical Asia, including Sri Lanka.

2. TAXONOMY AND BOTANY

Zizyphus mauritiana Lam., the Indian jujube, is one of about 80 species in the genus Zizyphus, family Rhamnaceae, of mainly spiny drought-resistant trees and shrubs, several of which are cultivated.

Munier (1973a) mentions 5 major and 14 minor cultivated Zizyphus species. The Chinese jujube (Z. jujuba Lam.) is quite widely grown. According to Bailey (1949) the Chinese jujube is deciduous and has leaves that are glabrous underneath, while the Indian jujube is evergreen and has densely tomentose twigs, inflorescences and lower leaf surfaces. Singh et al. (1967), however, states that Indian jujube sheds its leaves during the hot, dry season. The Chinese and Indian jujube are rather similar and have occasionally been confused in the literature. The following species may also be grown: Z. sativa Gaertn. (jujube), Z. lotus (L.) Lam., Z. lotus Desf. (lotus fruit, jujubier de Berbérie) and Z. spina-christi (L.) Willd. (Christ's thorn, jujubier de Palestine).

The Indian jujube is a semi-deciduous shrub or small tree up to 12 m tall. Leaves alternate, simple, 3-nerved, minutely denticulate, obtuse, broadly oval to rounded-elliptical, slightly unequal at the base, up to 8 cm long and 5 cm broad, densely whitish woolly beneath, with single or paired stipular thorns. Inflorescence a cymule, sub-capitate in the leaf axils. Flowers bisexual, small, actinomorphic, pentamerous, greenish-cream, acrid-scented; petals 5, arising between and smaller than the calyx lobes; calyx shortly tubular, 5-lobed, lobes valvate; stamens 5, opposite the petals, arising outside the margin of a usually conspicuous disc; anthers 2-locular, opening lengthwise; ovary superior to half inferior, 2-locular, basal placentation; ovules anatropous; style 2-lobed. Fruit a drupe, persistent lower part of the calyx often evident, ellipsoid to sub-globose, ripening brownish-orange, fleshy, 2.0-2.5(-5.0) cm long (Adams et al., 1972).

Pollination of the Indian jujube is effected by honey bees which collect both nectar and pollen from the flowers; house flies and wasps may also visit them in India (Crane and Walker, 1984). Josan et al. (1981) found that the Indian jujube was self-incompatible, but that the pollen was highly viable.

At least 50 clonally-propagated cultivars of Indian jujube are known in India,

but many of them are rather poorly described (Singh et al., 1971). Bal and Jawanda (1981) studied the physico-chemical characteristics of 36 cultivars at Punjab Agricultural University. One of the most widely-grown cultivars in Punjab, which has golden-yellow fruits, is 'Umran'.

### 3. ORIGIN, DISTRIBUTION AND ECOLOGY

The origin of the Indian jujube is a matter of some controversy. According to de Candolle (1884) it originated in India, where it is known by 3 Sanskrit names and 11 names in newer languages. It spread gradually both to Southeast Asia and to Zanzibar, and the east coast of Africa. Further spread in Africa may have been via ships calling at ports on the west coast, and partly overland. According to Zeven and de Wet (1982) the centre of diversity of the Indian jujube is the Chinese-Japanese centre, but Bourke (1976) gives its probable origin as Africa.

The Indian jujube is now found in many tropical countries. It naturalizes easily in widely varying climatic conditions and thrives where many other trees fail to grow. A hot and dry climate is ideal, provided there is an adequate water supply during fruiting. Excessive atmospheric humidity is considered to limit production. The trees become dormant at the end of May in India and can tolerate some frost until growth resumes with the onset of rains (Singh et al., 1967). Frost damage occasionally occurs in Florida, especially to young trees. The Indian jujube can grow well on a range of soil types, and can withstand both waterlogging and drought; deep sandy loams of pH 7 are ideal.

Z. sativa originated in an area comprising Afghanistan, southern China, northern India, Mongolia, Pakistan and Turkestan, and is now cultivated both in these areas, and in the Mediterranean area, the Middle East, Japan and California. Z. lotus grows wild in Afghanistan, north Africa, Cyprus, Greece, Saudi Arabia and Turkey, and is cultivated also in southern Portugal, Spain and Sicily. Z. spina-christi grows wild in the Middle East, Turkey, Iran, Saudi Arabia, the Sahara, Chad and Ethiopia, and is cultivated in India, Pakistan, Egypt, Tunisia, the Saharan oases and Zanzibar.

Z. sativa is suited to dry climates with cold winters and hot summers, while Z. lotus and Z. spina-christi are best adapted to sub-tropical climates but also grow in the tropics.

### 4. AGRONOMY, DISEASES AND PESTS

The Indian jujube has traditionally been propagated by seed; now vegetative methods, particularly shield and patch budding are increasingly being used. Z. mauritiana is usually used as a rootstock, but Z. oenoplia Mill., Z. rotundifolia Lam., and Z. rugosa Lam. have also been recommended for use in India (Bourke, 1976). Bal (1983, pers. comm.) has recently established a rootstock trial, in which the cultivar 'Umran' was grafted on to rootstocks of the following species: Z. jujuba, Z. mauritiana, Z. numularia, Z. xylopyrus and Z. zoziroo. The tree grows quickly, depending of course on the rootstock used, and the first crop can usually be harvested 2-3 years after planting. The trees are regular bearers, and the mature trees of grafted cultivars can bear 100-250 kg of fruit per tree. Fruits take 22-26 weeks to mature.

Fungal diseases are in general not a great problem in Indian jujube, and can usually be controlled chemically. The following may be found: Glomerella cingulata, a brown rot of the fruit in India; a rust causing defoliation and failure to set fruit in Florida (Cook, 1975); Cercospora jujuba, which causes dark spots on leaves in many countries; Oidiopsis spp. causing leafspots and premature fruit drop in humid areas or during the rainy season in India and Pakistan; Isariopsis spp., especially I. griseola, causing leaf drop in India and elsewhere (Munlur, 1973a); Cladosporium spp. on leaves in western India (Cheema et al., 1954); Alternaria spp., a leafspot in India (Jeyarajan and Cheema, 1972); Oidium erysiphoides, powdery mildew (Gupta et al., 1977); and Phoma macrotoma, a leafspot in Punjab, India (Sidhu and Singh, 1979). Differences in

cultivar susceptibility have been noted, for instance to Alternaria leafspot and powdery mildew (Jayarajan and Choema, 1972) and to Phoma macrostoma (Sidhu and Singh, 1979).

The bacterium Agrobacterium tumefaciens has been reported from Egypt on Zizyphus spp. (Munier, 1973a). A witches' broom disease in India was ascribed to a mycoplasma-like agent (Pandey et al., 1976). Galls in floral buds which prevented fruit production were attributed to mites and thrips in Punjab, India (Yamdagni and Gill, 1968).

Bhutani (1973) reviewed the insect pests of the crop, listing 43 species, including 7 of major, and 10 of minor importance. The major pests are: Carpomyia vesuviana, the ber fruit fly, the maggots of which feed on the pulp; Droschiella tamarindus, the ber mealy bug; Xanthochelus superciliosus, the ber weevil and 3 species of Adoreetus spp. beetles, commonly known as cockchafers. Control measures for these and other pests include the use of insecticides, plant and plantation hygiene and cultural and chemical treatment of the soil. Differences in susceptibility have been observed, for instance, to the ber fruit fly (Saxena and Rawat, 1968; Mann and Bindra, 1976).

Some nematodes also attack Indian jujube: Hemicricomoides communis, H. litchi and Pratylenchus neonanus occur in India (Mathur et al., 1967).

#### 5. GENETICS AND IMPROVEMENT

The somatic chromosome number of the Indian jujube, which may be a tetraploid, is  $2n=48$ . Z. jujuba Mill. has  $2n=24$  chromosomes; polyploid variants are also found with  $2n=48$  and  $2n=96$ .

The improvement of Indian jujube has been based upon selection by farmers of the best trees and their clonal propagation by grafting. Cultivars differing in fruit characteristics have been recognized in India for many years (Watt, 1893), and some cultivars now have a degree of pest and disease resistance.

#### 6. GERMPLASM CONSERVATION

The development of clonally-propagated cultivars may be expected to lead to loss of genetic diversity in cultivated Indian jujube. The rootstocks, which are usually grown from seeds, are an untapped source of variability, and wild trees have sometimes been top-worked with improved cultivars (Singh et al., 1967). Wild Indian jujube is found either native or naturalized in a wide area of tropical Africa and Asia (Hutchinson and Dalziel, 1958) and is unlikely to be under much risk of genetic erosion. Other Zizyphus species also are not known to be under threat.

The Indian jujube and related species are particularly valuable because of their ability to grow in tropical areas with very low rainfall, and also because of the secondary uses of the tree. Collections containing Zizyphus species are mostly of cultivars of Indian jujube, and there are few related species. All collections are likely to be of trees only, although the seeds can probably also be stored.

Table 23. Collections of Jujube

Country	Location	Number of accessions	
		<u>Zizyphus mauritiana</u>	Other <u>Zizyphus</u> spp.
India	Bahadurgherh, Punjab	41	
India <u>1/</u>	Jodhpur, Rajasthan	?	<u>Z. nummularia</u> (?) <u>Z. oenoplia</u> (?) <u>Z. rotundifolia</u> (?)
India <u>2/</u>	Hissar, Haryana	?	<u>Z. rotundifolia</u> (?)
USSR	Leningrad	?	

1/ Total of 81 accessions.

2/ Total of 72 accessions.

IBPGR (1984) also lists the following small collections of Jujube, but these can probably not be regarded as genetic resources collections: Rajshahi, Bangladesh; Alquizar, Nicosia, Cyprus; Los Baños, Philippines; Nelspruit, South Africa (Z. nummularia); Wad Madani, Sudan; Izmir, Turkey; Miami, Florida, USA. Also a few accessions exist at CATIE, Turrialba, Costa Rica; Estación Central de Investigaciones de Cítricos y Otras Frutales, Alquizar, Cuba; Wilson Popenoe Botanical Garden, Lancelilla, Honduras (Dickson, 1978); Grand'Anse Experimental Centre, Mahé Island, Seychelles. There are also some accessions of Jujube in China at: Zhengzhou Institute of Pomology, Chinese Academy of Agricultural Sciences, Zhengzhou, Henan Province, Provincial Academy of Agricultural Sciences, Shaanxi.

CITRUS SPECIES AND PONCIRUS TRIFOLIATA  
(Citrus Crops and Trifoliata Orange)

1. INTRODUCTION

(a) Most citrus fruits are eaten fresh or as juice, but lemons and limes are often used for flavouring. Many products can be prepared or extracted from the fruits, including jams, essential oils from the glands in the peel, and livestock feed from the pulp. The juicy interior of citrus fruits contains some sugar, but is notably high in organic acids, mainly citric acid, and vitamin C (Table 1). Oranges also provide significant amounts of folic acid and vitamin B6.

Citrus fruits are collectively the second world fruit crop after grapes (unless plantains are included with bananas, in which case they are the third). Production has increased considerably over the last decade with a concomitant increase in the percentage grown in developing countries (Table 2). The major groups of crops in descending order of yield are: sweet and sour oranges; tangerines, mandarins, clementines and satsumas; lemons and limes; and grapefruit and pummelo. 126 countries are listed by FAO as growing citrus fruits, the major ones in 1984, in descending order of production, being Brazil, USA, Italy, Japan, Spain, Mexico, India, China, Israel, Argentina, Turkey and Morocco.

(b) The trifoliata orange is most frequently grown as a hardy rootstock for citrus, the fruits being acid and inedible. It has been crossed with species of Citrus as a source of cold-hardiness, but the fruits of the hybrids are also bitter. Some of the hybrids have also been used as rootstocks. The dried fruits of trifoliata orange are used in Chinese medicine, and the juice can be made into a syrup used in flavouring, while the candied peel can be used to enhance the flavour of cakes. The species is occasionally grown as a hedge plant (Anon., 1969).

About 20% of the world's commercial citrus crop is grown on rootstocks of trifoliata orange, or on hybrid rootstocks in which trifoliata orange is one of the parents.

2. TAXONOMY AND BOTANY

Species of Citrus belong to the sub-family Aurantioidae of the Rutaceae and the tribe Citreae. All of the species in the Aurantioidae are evergreen trees and shrubs, except those in the 3 monotypic genera Poncirus, Aegle and Feronia, in 3 species of the genus Clausena and in one species of Murraya. The Aurantioidae include 6 other species with edible fruits of some commercial importance: Aegle marmelos (L.) Corr. Bal fruit (east Indian), Clausena dentata (Willd.) Roem., Clausena lansium (Lour.) Skeels (south China), Feronia limonia (L.) Swing., elephant apple or wood apple (South Asia), Fortunella japonica (Thunb.) Swing., Marumi kumquat (Japan) and Fortunella margarita (Lour.) Swing., Nagami kumquat (Japan).

Members of the tribe Citreae all have a characteristic fruit known as a hesperidium, a type of berry containing juice-filled pulp vesicles. There are currently 2 systems of citrus taxonomy in common usage, namely due to W.T. Swingle and to T. Tanaka (Hodgson, 1965).

According to Swingle, whose classification is used here, the citrus fruits are assigned to 3 genera: Fortunella (kumquats) with 2 sub-genera and 4 species; Poncirus (trifoliata orange) with 1 species; and Citrus with 2 sub-genera and 16 species. The economically important Citrus species belong to 8 of 10 species of the sub-genus Eucitrus, Papeda being the other sub-genus.

Tanaka treats the genera Fortunella and Poncirus approximately as does Swingle, but recognizes 2 sub-genera, 8 sections and at least 144 species in the genus Citrus. The sub-genus Archicitrus contains 98 species in 5 sections: Papeda (12 species), Limonellus (16), Citrophorum (21), Cephalocitrus (21) and Aurantium (21). The sub-genus Metacitrus with 48 species comprises 3 sections: Osmocitrus (9), Acrumen (36) and Pseudofortunella (1) (Hodgson, 1965).

Formal taxonomic methods are difficult to apply in the genus Citrus because of the ease with which many of the species hybridize, and because of polyploidy, polyembryony and spontaneous mutation (Purseglove, 1968). Chemotaxonomy and the use of scanning electron microscopy on pollen are assuming increasing importance in determining relationships. Field work is being initiated in 1986 by the IBPGR, and it is expected that materials for taxonomic revision will result.

(a) Citrus plants are evergreen shrubs or small trees, often with spines in the leaf axils. Leaves dotted with glands, simple with petiolar wings in some species. Flowers usually hermaphrodite, fragrant, single or in small groups; calyx persistent, cup-shaped with 3-5 projections; corolla (4-)5(-8) petals, white; stamens 20-40 in groups; ovary superior of 8-15 carpels, each containing several ovules in 2 rows, placentation axile. Fruit a hesperidium in which the exocarp and mesocarp are leathery in texture; exocarp has numerous glands containing an essential oil; mesocarp is rich in pectins, sugars and cellulose. The centre of the fruit is occupied by carpels filled with multicellular hairs in which juice is produced as the seeds develop; the carpels develop into the segments. The endocarp is the thin, transparent membrane surrounding the segments. Seeds polyembryonic, except in C. grandis, varying in number with species and cultivar, some seedless and parthenocarpic (Swingle and Reece, 1967).

Most citrus flowers are homogamous. Pollination is mainly by insects, often honey bees, which collect both pollen and nectar from flowers. Self-pollination may occasionally occur, although some species are self-incompatible (Crane and Walker, 1984).

There are very many cultivars. Hodgson (1967) described 419, including 173 sweet orange cultivars and 97 with mandarin-like fruits. Of cultivars which are commonly grown, Chapot (1975) listed 11 of orange, 6 of mandarin and tangerine, 2 of lime, 3 of grapefruit and one of shaddock. A number of these cultivars may comprise several clones. Samson (1980) presents a concise summary of information on cultivars within the major citrus crop groups. Fewer rootstocks are commercially used: Chapot mentions 8. IBPGR is due to publish a descriptor list for citrus in 1986.

(b) The trifoliolate orange (Poncirus trifoliata (L.) Raf.) is a small and much-branched tree with twigs of 2 types: normal twigs with 1-8 cm long internodes and a single leaf at each node, in the axils of which is a bud and often a strong spine; foliage spurs, which arise from twigs of the previous year's growth and have 1-5 extremely short nodes each with a normal foliage leaf but no spine. They are tipped with a small green bud. Leaves palmately 3-lobed; spines straight, acute 1-6 cm long. Flowers almost sessile, usually 5-merous, produced on one year-old twigs from sub-globose flower buds; calyx of 5 small sepals, persistent; corolla of 5 white petals, 18-30 mm x 8-15 mm, flat when fully open, papery thin, soon shed; stamens 20 or more; filaments free, unequal in length; ovary sub-globose, 2 mm in diameter with 6-8 locules; ovules numerous; styles short, 1.0-1.5 mm long, merging into a rather large stigma. Fruit almost sessile, 3-5 cm in diameter, pale lemon-coloured and fragrant when ripe, finely pubescent; pulp 5-10 mm thick with numerous oil glands, rather rough; pulp vesicles filled with very acid juice and numerous small droplets of acrid oil. Seeds ovoid, plump, often polyembryonic, numerous (Swingle and Reece, 1967).

Though there is little morphological variation in trifoliolate orange, the following 3 botanical varieties have been recognized in Japan (Swingle and Reece, 1967), although Bitters (1983, pers. comm.) considers that the second and third may now be extinct:

- (i) var. monstrosa, the 'cloud dragon' trifoliolate orange, characterized by its extreme dwarfness, tortuous slender branches, curved spines and very small leaflets which may be reduced to linear filaments on which there are groups of oil glands. It is known as 'hiryo' in Japan and is grown as a potted plant;
- (ii) var. microcarpa, which has minute fruits; and
- (iii) var. punctata, known as 'sunago' or 'gold-dust' trifoliolate orange, which has leaves dotted with golden-yellow spots.

Platt and Opitz (1973) mention 2 groups of cultivars: one with large flowers, upright seedlings and a single trunk; and the other with small flowers, bushy seedlings and multiple trunks. Numerous clones can be distinguished within each group, mostly on the basis of differences in vigour, which influences scion growth, flower size, and resistance to pests and diseases. Over 40 clones have been named, many of them from the USA, but some also come from other countries, including Argentina, Brazil, Mexico, Morocco, Algeria and USSR (Laville and Blondel, 1979). Many of the clones are known only by code numbers.

Clones of trifoliolate orange in China can be classified in 2 groups as 'Dayezhi' and 'Xiaoyezhi'. The 'Dayezhi' have larger leaves and fruits, a rougher fruit peel, approximately 13% of monoembryonic seeds, and a later season than 'Xiaoyezhi' clones, which have approximately 33% of mononebryonic seeds (Yin-min, 1983, pers. comm.).

### 3. ORIGIN, DISTRIBUTION AND ECOLOGY

(a) The lime is the only important species of Citrus which is still found growing wild, so evidence on which to assess the origin of most Citrus species is limited. The home of C. sinensis (L.) Osbeck, the sweet orange, is probably southern China or Indo-China (southern Viet Nam); Israel and Spain have become secondary centres of diversity. The sour orange (C. aurantium L.) probably comes from Southeast Asia or Indo-China. The mandarin or tangerine (C. reticulata Blanco) may have originated in the Philippines or Indo-China, but now has a secondary centre of diversity in Japan. Wild lime trees grow in northern India and the Malesian archipelago, and these may be areas where C. aurantifolia (Christm.) Swing. originated. C. grandis (L.) Osbeck (pummelo) and C. limon (L.) Burm. (lemon) are both probably of Southeast Asian origin, the area east of the Himalayas in northern Burma and southern China having been suggested with respect to the lemon. C. medica L. (citron) probably originated in southwest Asia, quite possibly originally from India. The grapefruit (C. p. adisi Macf.) is of fairly recent origin, either as a bud mutation of pummelo, or as a hybrid between pummelo (pomelo, shaddock) and sweet orange, probably before 1750 in the West Indies (Zeven and de Wet, 1982).

Citrus species are now widely grown between 40° north and south of the equator, especially in Mediterranean and sub-tropical areas. They are infrequent in tropical lowlands, despite the fact that many of them originated in Southeast Asia, and are more common above 500 m in the tropics. Grapefruit and pummelo are more common in tropical lowlands than oranges.

Most species of Citrus can withstand a wide temperature range, but only grow between about 13°C and 37°C. Resistance to cold varies with species, the most resistant in descending order being mandarin, sour orange, sweet orange, grapefruit, lemon, lime, citron and pummelo. Adult trees, especially those which are dormant, can withstand more cold than young and actively-growing trees. While citron, lime, lemon and pummelo grow and flower almost continuously in suitable conditions, grapefruit, sweet orange, sour orange and especially mandarin, tend to become dormant in cool weather. Trifoliolate orange and kumquat, both of which have citrus fruits but are not Citrus species, are both more cold-hardy than Citrus species and have a pronounced winter rest period.

When there is insufficient rainfall, the formation of flower buds may be delayed



and young fruits and leaves may be shed or fail to grow. Many commercial citrus crops are irrigated, but excessively wet conditions should be avoided as there may be increased disease spread. Windbreaks are commonly planted to protect crops from high winds. Light, fertile loams are ideal although a wide range of soils support good crops.

(b) The trifoliolate orange probably originated in central and northern China, where it has been grown for thousands of years. The first description, which included reference to its use as a rootstock, was in a Chinese document written in 1178. The plant was brought to Japan around the 9th Century A.D., and in the last few centuries has been introduced as a citrus rootstock to the USA and other countries (Hodgson, 1967).

The trifoliolate orange grows best in warm temperate climates and requires some winter chilling. Flower bud dormancy is sometimes broken by excessively high autumn temperatures. Tropical or hot sub-tropical climates with mild winters are unsuitable. Vigorous growth occurs on fairly heavy soils, which may often be too wet for other rootstocks, but the tree will not tolerate saline and alkaline conditions (Hodgson, 1967).

#### 4. AGRONOMY, DISEASES AND PESTS

(a) Commercial citrus plantations are usually established by budding selected scions on to seedling rootstocks. The rootstock controls the growth of the scion, for example conferring cold-hardiness by inducing dormancy. In addition to effects on disease resistance, fruit quality etc. The rootstock used depends on the species and cultivar of the scion, common ones being sour orange, rough lemon and sweet orange and Poncirus trifoliata (Bitters et al., 1977).

Many citrus seeds are polyembryonic, containing both sexual and nucellar embryos. The nucellar embryos tend to produce more vigorous seedlings than the sexual ones. Seeds can in principle therefore be used for vegetative propagation, but plants grown from sexual and nucellar embryos can not be distinguished visually, so they are only normally used for growing rootstocks. Citrus fruits nearly all mature slowly, and maintain their flavour well for long periods at ambient temperatures.

Citrus crops are affected by numerous diseases, several of which are very serious either locally or worldwide. Klotz (1978) mentioned 65 fungal diseases in a recent survey. Most can be controlled by cultural or chemical methods, but often at high cost. Different rootstocks and cultivar combinations can also be useful.

Four bacterial diseases attack citrus, the most important being canker (Xanthomonas citri), which is most prevalent in humid tropical areas where the rainfall is evenly-distributed and the temperatures are high (20-32°C), and is not a problem in California and the Mediterranean countries. Affected trees should be destroyed. Tangerines, citron, calamondin and kumquats have some resistance.

Wallace (1978) recently described 30 virus and virus-like diseases of citrus, but some may be caused by mycoplasmas. The most serious and widespread are 'psorosis' and 'tristeza'. A serious problem in India is 'citrus die-back' 'leaf mottle yellows disease' has caused widespread damage in the Philippines; and numerous trees have died of 'citrus vein phloem degeneration' in Java, Indonesia. Most virus diseases may be controlled by using virus-free budwood, by controlling vectors if appropriate, and plant sanitation and quarantine are also crucial. Propagation by seed in cases of nucellar embryony is generally a safe way of obtaining virus-free plants.

Almost 900 species of insects and mites may feed on citrus crops worldwide, about 75 of which may be major pests. Talhouk (1975) listed the distribution and economic importance of 143 insects and mites; a further 56 species occurring in only one country were mentioned. The most important pests are aphids, scale insects, mealy bugs, white flies, fruit flies (Diptera), fruit feeders and leaf miners (Lepidoptera), twig and trunk borers (Coleoptera) and phytophagous mites. Many damaging insects are only found

in the Asiatic region where citrus is grown. The major pests in other areas are of foreign origin, including scale insects, mealy bugs, white flies, fruit flies and mites. Pest control in citrus crops is mainly based on the use of insecticides, but promising results have been obtained by biological methods, and methods of integrated control are being developed in some countries.

Over 200 species of nematodes have been reported in association with citrus roots, 16 of which are important parasites. Two major pests are the burrowing nematode (Radopholus similis) and the citrus nematode (Tylenchulus semipenetrans) (Baines *et al.*, 1978).

(b) The trifoliolate orange is usually grown from seeds, although it is occasionally propagated as cuttings and by grafting. Most of the seeds are polyembryonic (Nishiura *et al.*, 1974).

Many of the diseases of Citrus species also attack the trifoliolate orange. Klotz (1978) listed 40 fungal and 4 bacterial pathogens. The trifoliolate orange is immune to Phytophthora root rot, and to Phymatotrichum root rot, but is highly susceptible to dry root rot and citrus canker.

Likewise, many of the virus diseases of citrus crops also affect it. The trifoliolate orange is, however, immune to tristeza virus and to citrus yellow vein, but is highly susceptible to exocortis, and susceptible to cristicortis and gum pocket (South Africa). The species is also a symptomless host of the leaf-mottle-yellows disease. The trifoliolate orange has been extensively used as a rootstock in Japan, where the tristeza virus has caused minimal losses.

Most insect and mite pests of citrus crops also attack P. trifoliata, but as the tree is typically grown as a rootstock, they hardly present a problem. The tree is very susceptible to red spider (Bitters, 1983, *pers. comm.*). It is susceptible to the burrowing nematode (Radopholus similis), but many cultivars are highly resistant or immune to the citrus nematode (Tylenchulus semipenetrans).

## 5. BREEDING AND IMPROVEMENT

(a) Most Citrus species and related genera are diploid with  $2n=18$ , but higher chromosome numbers have frequently been found. Spontaneous tetraploids are quite frequent in Citrus and poncirus as nucellar seedlings, but tend to grow slowly, yield less than diploids and have fruits with thick rinds and little juice. They are useful for producing triploids, which are generally more vigorous than tetraploids and more or less seedless, but many also are unproductive. The small stature of tetraploid trees may be of practical value in developing dwarf trees for planting at high density. There is some information on the heritability of characters such as tree dwarfness, nucellar embryony, fruit acidity, tolerance to Phytophthora root rot and cold-hardiness.

The aims of citrus breeding programmes may vary widely between countries, in some of which there may be adequate variation among hitherto untested cultivars. It is important to distinguish between the requirements for scion and rootstock improvement, and to understand the way in which the 2 interact. Frost hardiness is needed at higher altitudes, while in the tropics there is a need for cultivars which crop well under continuously high temperatures. Types suitable for mechanical harvesting may be important where labour costs are high, while in some cases salt-tolerant cultivars may be needed. Fruits for table use must be easy to peel, but this may be unimportant if fruits are to be processed for juice.

The improvement of citrus crops depended for many years on the selection of desirable seedlings from amongst chance seedling populations. Programmes for the genetic improvement of citrus based on artificial pollination were started by the United States Department of Agriculture in California in 1948 and in Florida in 1893, by the University of California in 1914, in the USSR in 1930, in Japan and Italy in 1950 and in

Corsica in 1966, and there are many others. Breeding programmes were started but later interrupted in Indonesia, Zimbabwe and the Philippines.

Mutations have been artificially induced by irradiating budwood, seeds and callus cultures with X-rays, neutrons and cobalt-60. Few useful results have been reported, although Honsz (1977) developed a colourful and high-yielding grapefruit, 'Star Ruby' in Texas by this means. In the USSR, the treatment of Meyer lemon pollen with a chemical mutagen before using it to pollinate Citrus ichangensis Swing., a wild species from China (used as a rootstock), resulted in seedless fruits unlike those obtained with normal cross-pollination (Diasamidze, 1970).

(b) Most trifoliate orange cultivars are diploids with  $2n=18$  chromosomes. Spontaneous autotetraploids have been found but have not yet been utilized. The trifoliate orange can be hybridized with many Citrus species; hybrid seedlings are easily distinguished from nucellar seedlings because they exhibit the genetically dominant trifoliate leaf characteristic.

There are few reports of genetic improvement of trifoliate orange per se. At least 4 new selections (for early-bearing, early-ripening, a dwarf and a tetraploid) resulted from a programme in Georgia, USSR (Tutberidze, 1974; Tutberidze and Kalandarishvili, 1978). The trifoliate orange is important in many citrus rootstock breeding programmes because of its resistance to cold, tristeza virus, Phytophthora root rot and nematodes. Some of the hybrid rootstocks, such as Troyer and Carrizo citranges, which were selected amongst the  $F_1$  progeny of navel orange x trifoliate orange crosses in Florida in 1909, have become widely grown (Hodgson, 1967; Cameron and Frost, 1968).

#### 6. GERMPLASM CONSERVATION

Commercial citrus production is based on relatively few scion cultivars. The present risk of genetic erosion in cultivated citrus is difficult to assess, but in various parts of the world such as Colombia (Rios-Castaño, 1967), and in Southeast Asia, the growing of non-uniform seedling trees is discouraged. A brief survey of the degree of genetic erosion in 10 cultivated Citrus species in 5 Southeast Asian countries indicated extensive erosion in Indonesia and Malaysia in the pummelo, moderate erosion of orange in Indonesia, and of pummelo in southern Viet Nam and some erosion in the other cases (Sastrapradja, 1975).

Early this century the only orange cultivar grown in Spain was 'Comuna'. Later the range of cultivars grown was increased to lengthen the harvesting period (Gonzales-Sicilia, 1960). The range of genetic variability may widen if spontaneous seedlings are allowed to grow into productive trees, as in some mixed gardens in Sri Lanka, Malaysia and Indonesia (Mendel, 1963; Lum, 1975). Seedlings are often allowed to grow near the house, where food wastes are dumped. So, though genetic erosion of citrus is likely to have occurred in some areas, there may actually have been an increase in variability elsewhere.

Members of the sub-family Aurantioidae are probably at risk because of land clearance for agriculture, or the selective felling of forests. The following categories of citrus germplasm can be recognized:

- (i) currently cultivated as rootstocks or scions;
- (ii) germplasm which either has been used in breeding new cultivars, or possesses characteristics which are of interest; and
- (iii) germplasm which may be required for future breeding work.

Germplasm in category (i) is easily-defined. That in the second category covers all of the cultivated Citrus, Fortunella (kumquat) and Poncirus species. Kumquats are valuable both for their edible fruits and potentially also as parents in crosses with

Citrus species and interspecific hybrids, but these have not yet become important. P. trifoliata, the trifoliolate orange, is useful as a cold-hardy rootstock for citrus, for its possible contribution in the improvement of Citrus species, and for its occasional medicinal or ornamental use. Much of the useful genetic variation of cultivated trifoliolate orange is physiological. The wild plant was reported to grow in Kiangsu Province in eastern China (Burke, 1967), but its current distribution and genetic variability is not clear.

The following members of the Aurantioideae comprise the third category for germplasm conservation:

- Clausena lansium, the wampi, a highly-esteemed fruit tree in southern China, now widely grown in tropical and sub-tropical regions for its small berries.
- Severinia buxifolia (Poir.), the Chinese box orange, is tolerant of high salinity and boron, is immune to many Citrus diseases, and is useful as a rootstock for citrus.
- Limnocitrus littoralis (Mig.) Swing., the swamp orange, which grows wild in tidal swamps in Vist Nam, Java and Bali may be useful as a rootstock, because of its high tolerance of salinity.
- Emrocitrus glauca, the Australian desert lime, a xerophytic species tolerant of high salinity and boron, which may also be useful as a rootstock.
- Microcitrus spp., a genus of 6 species, 5 of which grow wild in Queensland and northern New South Wales, Australia, and one in southeastern Papua New Guinea. The hybrid M. australis x M. australasica may be valuable as a rootstock in soils low in organic nitrogen.
- Swinglea glutinosa (Blanco) Merr., the tabog or boyag (Tagalog language), a small, thorny tree widely distributed in Luzon island in the Philippines, grows well at high temperatures, and may have potential as a citrus rootstock, but is susceptible to canker.
- Feronia limonia (L.) Swing., the wood-apple (syn. Limonia acidissima L., Feronia elephantum Correa), is the only species in the genus Feronia (Swingle, 1914). It is distinguished from citrus crops by having a hard fruit shell and a single cavity instead of segments. The wood-apple stimulates early flowering in Citrus species when used as a rootstock, which is of interest in breeding programmes. The sweet and aromatic pulp of the wood-apple may be eaten fresh, or used in drinks, chutneys, jelly etc. The fruit also has some medicinal uses (Anon., 1956). India and Sri Lanka are the only countries where wood-apple is grown to any extent.
- Feroniella oblata Swing., the Indo-China feroniella is a medium-sized forest tree, which is fairly common in the plains and mountains of Indo-China and eastern Thailand. It stimulates early flowering in Citrus when used as a rootstock.
- F. lucida (Scheff.) Swing., the Java feroniella, is native to central Java, and may be a possible rootstock for dwarfing Citrus and also for stimulating early flowering in the scion.

Of the 16 species of Citrus distinguished by Swingle, 8 are of ancient cultivation, while most of the other wild relatives may be of possible value for breeding. They are:

- C. indica Tan., the Indian wild orange, which originated in the Eastern Himalayas.

- C. tachibana (Mak.) Tan., the Tachibana orange, which occurs wild from southern Taiwan to the southwestern province of the main island of Japan. The form 'Shekwasha', which may be a hybrid of C. tachibana x C. reticulata, is a possible rootstock.
  
- C. ichangensis Swing., the Ichang papada, which grows wild in central and southwestern China, is the most cold-hardy of all the evergreen Aurantioideae, and is of interest for breeding. The 'Yuzu', probably a natural hybrid between C. ichangensis and C. reticulata is occasionally cultivated in China and more frequently in Japan, for its acid fruits, and as a rootstock for the satsuma and other citrus. The Ichang lemon (probably C. ichangensis x C. grandis) is an ornamental tree in China, the ripe fruits of which are used as a deodorizer. It is a hardy plant which merits further study as a potential rootstock.
  
- C. latipes (Swing.) Tan., a thorny tree occurring wild in northeastern India and northern Burma, at altitudes from 500 to 1,830 m. It is of potential value as a parent in breeding new hardy acid citrus fruits and hardy rootstocks.
  
- C. celebica var. southwickii (Wester) grows wild in the Philippines and in Sulawesi, Indonesia. It may be of value in breeding as its fruits are juicy, smooth and thin-skinned, and 10 cm in diameter.
  
- C. macroptera Montr., the Melanesian papada, grows wild in Thailand, Indo-China, the Philippines, Papua New Guinea, New Caledonia and Polynesia. It may have value in breeding for its vigour, fruit size (6.3 cm diameter), resistance to citrus canker and immunity to withertip.

At least 2 new species of Citrus have been discovered since Swingle and Poore (1967) was published: C. hallimii in Malaya and peninsular Thailand (Stone et al., 1973); and Microcitrus papuana in Papua New Guinea (Winters, 1976). Their potential value needs to be studied.

(a) Numerous collections around the world contain Citrus species s trees. Wider use will doubtless be made of all classes of germplasm as breeding methods improve. Citrus seeds are probably not kept in collections for long-term storage, although they may often be used for germplasm exchange, but seeds of related genera are stored in Argentina. The collections maintained by EMBRAPA in Bahia includes trees, seeds, rootstocks, scions and clones in both store and in tissue culture. IBPGR (1982) is a report dealing specifically with citrus genetic resources, and should be consulted for further details.

(b) Many of the collections of citrus crops also contain some trifoliolate orange. The seeds, like those of Citrus species, may need special attention for long-term storage. They are very sensitive to drying, and should be conserved at low temperature (ca. 4°C) and high relative humidity (96%). Satisfactory, though often much reduced germination, was thus obtained after 1 year. Germination can often be enhanced by treating the seeds with gibberellic acid (Platt and Opitz, 1973). Collection and conservation of the trifoliolate orange should be included in the programme for the genetic resources of Citrus species and its wild relatives.

Table 24(a). Collections of citrus

Country	Location	Number of accessions					Related genera
		Sour and sweet oranges	Lemons and limes	Mandarin	Grapefruit, citron and pummelo	Other Citrus spp.	
Algeria	Boufarik	106	25	22	22	56 (9)	5 (3)
Argentina	Bella Vista	-----	-----	-----	-----	277 (7)	-----
Argentina	Concordia	-----	-----	-----	-----	474 (7)	-----
Argentina	Montecarlo	-----	-----	-----	-----	180 (7)	-----
Argentina	Tucuman	-----	-----	-----	-----	119 (7)	-----
Argentina	Colombes	-----	-----	-----	-----	530 (7)	-----
Australia	Daraton (NSW)	87	26	45	10	66 (7)	-----
Australia	Merbeln	-----	-----	-----	-----	-----	16 (4)
Australia	Gosford (NSW)	-----	-----	-----	-----	332 (7)	-----
Australia	Nambour	20	4	8	5	-----	4 (4)
Bangladesh	Rajshahi	-----	-----	-----	-----	-----	4 (1)
Bolivia	La Paz	48	29	24	8	-----	2
Bolivia	Saavedra	-----	-----	-----	-----	54 (7)	-----
Brazil	Bahia	243	1	18	37	138 (20)	7 (2)
Brazil	São Paulo	294	28	166	98	185 (11)	50 (9)
Brazil	Rio Granda do Sul	115	17	5	7	322 (24)	2 (2)
Brazil	Manaus	-----	-----	-----	-----	70 (7)	-----
Brazil	Itajai	-----	-----	-----	-----	60 (7)	-----
China	Sichuan	44	5	44	29	13 (6)	8 (7)
China	Taiwan	-----	-----	-----	-----	74 (23)	9 (7)
Colombia	Palmira Valle	45	12	22	17	13 (9)	24 (7)
Colombia	Toilma	-----	-----	-----	-----	61 (7)	-----
Costa Rica	Turrialba	-----	-----	-----	-----	37 (7)	-----
Côte d'Ivoire	Abidjan	30	15	16	17	-----	-----
Cuba	Habana	-----	-----	-----	-----	394 (7)	-----
Ecuador	Quito	-----	-----	-----	-----	60 (7)	-----
Fiji	Labassa	8	9	6	5	4 (2)	4 (2)
France	Corsica	877	35	496	143	1535 (9)	104 (10)
Greece	Crete	29	18	3	26	48 (15)	1
India	Bangalore <sup>1/</sup>	81	36	54	10	86 (4)	24 (1)
India	Meghalaya	-----	-----	-----	-----	86 (12)	-----
Indonesia	Ball	-----	-----	-----	-----	200 (7)	-----
Indonesia	Malang	38	-----	-----	-----	121 (3)	-----
Indonesia	Bogor	1	-----	-----	17	38 (7)	-----
Italy	Palermo	59	75	26	9	26 (4)	-----
Jamaica	Kingston	-----	-----	-----	-----	63 (7)	-----

<sup>1/</sup> The collection is maintained in 7 Indian Institutes.

NOTE: The figures in brackets in the last 2 columns represent the numbers of species and/or hybrids of Citrus, or of related genera. It may be an underestimate in many cases.

Table 24(a). Collections of citrus (Continued)

Country	Location	Number of accessions					
		Sour and sweet oranges	Lemons and limes	Mandarin	Grapefruit, citron and pummelo	Other Citrus spp.	Related genera
Japan	Hiroshima	08	24	52	19	84 (7)	10 (3)
Japan	Nagasaki	79	17	57	23	77 (7)	8 (3)
Japan	Shizuoka	111	39	70	36	201 (14)	29 (5)
Japan	Saga	61	25	58	19	94 (9)	43 (25)
Japan	Yusea Wakayama	-----135 (7)-----					
Kenya	Kikambala	18	10	5	6		
Madagascar	Tananarive	15	13	20	5		3 (2)
Malawi	Limbe	17	6	5	6	2	
Mauritius <sup>2/</sup>	Barkly	-----7-----					
Mexico	Nuevo Leon	16	6	23	6		
Mexico	Sinaloa	33	6	21	6		
Mexico	Guanajuata	21	23	25	6		
Morocco	Kenitra	211	123	97	76	57 (7)	30 (7)
Nepal	Kosi Zone	-----43 (7)-----					
Nigeria	Ibadan	49	19	24	19	19 (1)	31 (7)
Philippines	Los Bafics		7	4	43	16 (7)	
Seychelles	Mahé <sup>3/</sup>	52	5	61	18	24 (7)	1 (1)
South Africa	Nalspruit	355	69		111	148 (7)	100 (7)
Spain	Valencia	108	30	58	14	26 (15)	21 (16)
Sudan	Wed Medanl	20	42	6	9	3 (3)	6 (2)
Thailand	Bangkok	40	59	62	213	158 (7)	11 (7)
Thailand	Chentaburi				80		
Tunisia	Ariana	17	8	13	5	8 (7)	
Turkey	Izmir	140	53	54	31	44 (7)	6 (3)
Turkey	Adana	188	110	86	19	81 (7)	78 (7)
USSR	Leningrad	-----969 (7)-----					
USA	Riverside	166	138	76	135	82 (20)	156 (46)
USA	Orlando	138	56	62	50	22 (7)	48 (7)
USA	Miami	4	3	2	3	5	68 (43)
USA	Hawaii	27	9	33	41		

<sup>2/</sup> Department of Horticulture, Barkly Experiment Station, Mauritius.

<sup>3/</sup> Grand'Anse Experimental Centre, Mahé Island, Seychelles.

NOTE: The figures in brackets in the last 2 columns represent the numbers of species and/or hybrids of Citrus, or of related genera. It may be an underestimate in many cases.

Table 24(b). Collections of trifoliate orange

Country	Location	Number of accessions
		<u>Poncirus trifoliata</u>
Brazil	Bahia	5
Brazil	São Paulo	39
Colombia	Palmira Valle	6
France	Corsica	50
India	Bangalore	24
Japan	Hiroshima	7
Japan	Shizuoka	14
Morocco	Kenitra	5
Nigeria	Ibadan	20
South Africa	Nelspruit	54
Turkey	Adana	52
USA	Riverside	42
USA	Orlando	42

IBPGR (1984) also lists the following small collections of trifoliate orange, but these can probably not be regarded as genetic resources collections: Boufarik, Algeria; Rio Grande do Sul, Brazil; Sichuan, China; Taiwan, China; Labassa, Fiji; Crete, Greece; Nagasaki, Japan; Saga, Japan; Tananarive, Madagascar; Valencia, Spain; Wad Medani, Sudan; Izmir, Turkey. Numerous collections contain specimens of Poncirus trifoliata x Citrus spp. (most frequently C. sinensis)



LITCHI CHINENSIS  
(Litchi)

1. INTRODUCTION

The juicy aril is the edible part of the litchi or lychee. It may be eaten fresh or preserved in syrup and canned, dried or frozen and has a delicate flavour, but no special food value (Table 1). "Litchi nuts" are fruits which have been dried, either artificially or in the sun. The seeds have some medicinal properties and the tree bark contains tannins (Anon., 1962a).

China has been the leading producer of litchi and probably remains so (Evreinoff, 1950), while India is likely to be in second place with 11,410 ha in 1966 (Anon., 1962a; Singh et al., 1967). There were 7,151 ha in Taiwan in 1981 (Yen, 1983, pers. comm.) and Thailand grew 2,611 ha in 1978 (Vangnai, 1980). Litchis are also grown in Australia, Madagascar, Mexico, South Africa and USA (Florida, Hawaii).

2. TAXONOMY AND BOTANY

The genus Litchi was earlier seen as containing 2 species, but was recently revised to have only one species, Litchi chinensis Sonn. (syn. Nephelium litchi Camb.), with 3 geographical subspecies (Leenhouts, 1978). A key to the subspecies is provided below:

- (i) (a) Inflorescences with a few spike-like branches, flowers in sessile clusters. Twigs thick, to 7 mm diameter.....subsp. javanensis
- (b) Inflorescences widely branched, flowers in lax cymes. Twigs slender, no more than 3.5 mm diameter.....(ii)
- (ii) (a) Leaves 1- or 2-, rarely 3-jugate. Stamens mostly 7, rarely 6. Fruits with acute, pyramidal warts up to 3 mm high.....subsp. philippensis
- (b) Leaves 2-4 jugate. Stamens mostly 6, exceptionally up to 10. Fruits nearly smooth or rarely with acute, pyramidal warts up to 1 mm high.....subsp. chinensis

L. chinensis subsp. javanensis is known mainly from West Java, where it is occasionally cultivated in gardens, but a few herbarium specimens exist from southern Indo-China, particularly Kampuchea. L. chinensis subsp. philippensis is widely distributed in the Philippine islands (Luzon, Sibuyan, Samar and Mindanao), but is not cultivated.

This chapter mainly concerns the Chinese litchi, L. chinensis subsp. chinensis, an evergreen tree, 10-12 m high with a broad, round-topped crown of glossy green foliage. Leaves pinnate with 2-9 leaflets. Flowers small, greenish-white or yellowish, in terminal panicles; male flowers with functional stamens and an abortive ovary; female flowers with a well-developed pistil and rudimentary non-functional stamens; ovary usually with 2 loculi, only one of which may grow to form a fruit; when both develop a double fruit is formed. Fruits 8-22 g in weight, globose, or oblong to ovate, 2.5 cm or more in diameter. Kind dark or light red, or yellow, brittle, and with slight or sharp tubercles. The aril is pearl-white, translucent and juicy and surrounds a large, dark brown, elliptic seed, except in seedless cultivars (Khan, 1929).

Pollination is effected by a number of insects, including flies, ants and wasps, but bees are very effective (Crane and Walker, 1984). Pollination is a requirement for

fruit development in some seedless cultivars. The first flowers to open within an inflorescence are males, followed later by females and then males again (Joubert, 1970). The factors determining flower sex at different times are not clear, but the different cycles on a tree overlap such that sufficient pollen is always available when the female flowers are receptive. A small proportion only of the many flowers on one panicle eventually develops into fruits.

There are numerous cultivars of litchi which may be derived from more than one ancestor (Anon., 1962a), the largest number being in China. Higgins (1917) recorded the local name and its meaning, the fruit characteristics and the areas of production of 15 Chinese cultivars. Groff and Su-Ying (1951) described 49 local cultivars, about half of the estimated number of named cultivars in China. At least 20 cultivars are known in India (Anon., 1962a; Higgins, 1917; Kanwar and Nijjar, 1975; Singh et al., 1967), but whether they originated in India, or are derived from cultivars introduced from China is not clear.

Cultivars grown in other countries can often be traced back to introductions from China or India, and sometimes retain their original name or a name related to it. Popenoe (1967) mentioned a high-yielding cultivar from Ambon (Molucca, Indonesia), albeit with rather poor quality fruits, but the trees, which are smaller than most litchi trees and grow true-to-type from seed, may possibly be of a different species. Hamilton and Yee (1970) discuss litchi cultivars in Hawaii.

### 3. ORIGIN, DISTRIBUTION AND ECOLOGY

The litchi originated in southern China. The area of origin may also extend over the north of Indo-China where the litchi has been found wild. It was common in the forests of Mont-Bavi at an altitude of about 250 m (Chevalier, 1942). The crop was mentioned in early Chinese literature, and several cultivars had already been described by the 14th century.

The litchi spread little outside its area of origin until relatively recently. It was probably introduced into India and Jamaica towards the end of the 18th century; to the USA, Madagascar, Queensland and South Africa during the 19th century and to Israel in 1934 (Evreinoff, 1950; Higgins, 1917; Harloth, 1934; Moreuil, 1973; Oppenheimer, 1947; Stephens, 1935).

The litchi is adapted to sub-tropical conditions with relatively high summer and low winter temperatures. A cold period is required for flower initiation, but frost is damaging. High temperatures and humidity during late spring and summer favour fruit development. Though the trees grow well in the tropics, they may only flower and fruit occasionally. Other factors which reduce yield are low humidity, warm dry winds, causing skin cracking and hail. About 1,500 mm rainfall per annum is ideal.

The litchi thrives on a number of different soil types provided they are deep and well-drained. In India it grows well on the banks of irrigation canals. The soils of suitable areas in Bihar and Uttar Pradesh are rich in lime, while in South Africa the tree grows vigorously on acid soils, sometimes in association with root mycorrhiza (Anon., 1962a).

### 4. AGRONOMY, DISEASES AND PESTS

Seeds do not produce seedlings true-to-type, so vegetative propagation is necessary to maintain selected cultivars. Trees grown from seeds may take 20 years before starting to fruit, compared with 4-5 years for vegetatively-propagated trees. Aerial-layering (marcottage) is the usual commercial method for superior clones, but is slow and expensive, and the root system of air-layered plants may be somewhat superficial. Grafting onto seedling rootstocks is possible, and mist propagation of cuttings has been successful in India.

Trees are spaced in the orchard at about 8 m square (156 trees/ha), or 12 m square with one tree in the middle of each square (138 trees/ha) at the initial planting. The population may be reduced later by thinning. A certain amount of formative pruning is needed to ensure good tree structure, with regular maintenance pruning thereafter. Fruit development takes about 2 months. Major obstacles to the expansion of litchi production have been: the lack of consistently-producing cultivars; the rather exacting climatic requirements; and the difficulty of transporting the fruits without loss of taste and appearance.

There are no serious disease problems of litchi (Singh et al., 1967). Cook (1975) mentions only canker and foot rot in Florida (Clitocybe tabescens) and leaf spots in India and South Africa (Botryodiplodia theobromae, Colletotrichum gloeosporioides, and Pestalotia pauciseta), which are usually of minor significance (Anon., 1979b).

There are no records of virus diseases of litchi, but Popenoe (1967) reported a disorder known as rough-bark in Honduras, which caused die-back and death of some trees. This condition was also found on rambutan (Nephelium lappaceum) and pulasan (N. mutabile). In South Africa an abnormality known as browning may occur on the litchi fruit during ripening, which spoils the appearance and lowers its value. The cause is not known, but it is apparently not due to insects, fungi or mechanical effects (Joubert, 1970).

In a recent review a total of 49 insect and mite pests were mentioned as damaging to litchi in India, but only leaf curl mite (Aceria spp.), and bark-boring caterpillars (Indarbela spp., Lymantria mathura) were serious (Bhutani, 1977). The control measures recommended are usually tree and plantation hygiene and the use of pesticides. Several nematodes cause serious root damage resulting in tree decline and death in South Africa, but may be controlled by soil fumigation (Milne and de Villiers, 1975).

#### 5. GENETICS AND IMPROVEMENT

The chromosome number of the litchi has been reported as  $2n=28$ , 30, 32, or 34 (Su-Ying, 1954). The genetic improvement of litchi to date has been by selection among existing cultivars, or selection amongst the open-pollinated seedlings from such cultivars. The aims of selection include: regularity of bearing; high yield; large fruit size; seedlessness or seed abortion resulting in small, shrivelled seeds ("chicken tongue" seeds); changes in the ripening period; flavour; and fruit colour, bright red being considered attractive.

#### 6. GERMPLASM CONSERVATION

The extent of genetic erosion in cultivated litchi is probably slight, but is difficult to assess. The other 2 subspecies of L. chinensis, subsp. javanensis and subsp. philippensis, which are adapted to wet tropical conditions, may be of interest in the future as crops in their own right, or for the genetic improvement of the Chinese litchi.

The collections listed are of trees of the Chinese litchi, mostly of cultivars, although some include a few breeders' lines. The other 2 subspecies should also be collected and conserved. Seeds of litchi can be stored (Ellis, 1984), but no records of storage are known.

Table 25. Collections of litchi

Country	Location	Number of accessions
		<u>Litchi chinensis</u>
Australia	Alstonville, New South Wales	17
Australia	Nambour, Queensland	8
Bangladesh	Rajshahi	6
China	Taiwan	10
Indonesia	Malang	7
Israel	Bet-Dagan	14
Mexico	Guilicán, Sinaloa	5
Seychelles 2/	Mahé	52
South Africa	Nelspruit	40
Thailand	Bangkok (Kasetsart University)	10
Thailand	Bangkok (Agriculture Dept. )	28
Thailand	Chantaburi	30
USA	Miami, Florida	39
USA	Hilo, Hawaii	20

IBPGR (1984) also lists the following small collections of litchi, but these can probably not be regarded as genetic resources collections: Jaboticabal, São Paulo, Brazil; Njombo, Cameroon; Habana, Cuba; Nicosia, Cyprus; Kingston, Jamaica; Limbo, Malawi; Guilicán, Sinaloa, Mexico; Cozolapa, Oaxaca, Mexico; Koravat, Papua New Guinea. In addition there are a few accessions at: Institut de Recherches sur les Fruits et Agrumes (IRFA), B.P. 180, 97455 Saint-Pierre Cedex, La Réunion; Wilson Popenoe Botanic Garden, Lantana, Honduras (Popenoe, 1967); Philippine Council of Agricultural Research, Los Baños (Valmayor and Espino, 1975); Grand'Anse Experimental Centre, Mahé Island, Seychelles. There are also quite likely to be collections in India, Mauritius and Zimbabwe, but no further details are available. The litchi is represented in the following collections in China: Provincial Academy of Agricultural Sciences, Fujian; South-China Botanical Garden, South-China Botanical Institute, Academia Sinica, Longyandong, Guangzhou, Guangdong Province; Hainan Botanical Garden of Tropical Economic Plants, Academy of Tropical Crops of South China, Ministry of Agriculture, Hainan Island, Guangdong Province.

DIMOCARPUS LONGAN  
(Longan)

1. INTRODUCTION

The longan is grown for the sweet, juicy aril around the seeds, which is somewhat similar in taste to that of litchi. The fruits can be eaten fresh, dried or canned and the fruits can be frozen and stored (Knight, 1969). It has no special nutritional value. The leaves and flowers have pharmaceutical uses (Anon., 1952), and the seeds contain a saponin used as a shampoo in China. The wood is useful in carpentry and as a fuel.

Rather few statistics on longan production are available. It is grown in Malaysia (Lum, 1975), southern China, Indo-China and Indonesia. Production in Thailand in 1978 was 116,000 ha, about one tenth of that of rambutan in the country (Vangnai, 1980). The longan is not grown commercially to any extent outside these areas.

2. TAXONOMY AND BOTANY

The longan (Dimocarpus longan Lour., syn. Euphoria longana Lam. and Nephelium longana (Lam.) Cam., family Sapindaceae, is one of 6 species of trees or shrubs in the genus Dimocarpus. Five of the species are found in Asia from Sri Lanka and India to eastern Malaysia; one is from Queensland, Australia. Descriptions of the genus and species are given in Leenhouts (1971, 1973).

The longan tree grows to a height of 40 m and has a trunk up to 1 m in diameter. Leaves 2-4(-6)-jugated with petioles up to 20 cm long. Inflorascence a panicle, usually terminal, rarely in the upper leaf axils, 8-40 cm long. Flowers unisexual, yellowish-brown; calyx lobes confluent at base, 2-5 x 1-3 mm; petals 5(-6); disc velutinous; stamens (6-)8(-10) pistil 2(-3)-merous, with sessile bilobed ovary. Usually only one of the lobes develops into a fruit. Fruit lobe(s) broad-ellipsoid to globular, 1-3 cm diameter, smooth to warty or sometimes up to 1 cm aculeate, sometimes granular, glabrescent (Leenhouts, 1971).

Leenhouts (1971) distinguishes 2 subspecies and 5 botanical varieties, and provides the following key:

- (i) (a) Midrib nearly always distinctly sunk above, nerves above nearly always grooved, veins and veinlets clearly different. Petals well-developed, outside hairy, inside fur-like woolly .....subsp. malesianus
- (ii) (a) Fruit smooth to warty.....var. malesianus
- (ii) (b) Fruit long-aculeate.....var. echinatus
- (i) (b) Midrib not sunk above, nerves above prominulous, veins and veinlets hardly different. Petals more or less reduced, outside mostly sub-glabrous, inside sparsely woolly.....subsp. longan
- (iii) (a) Apex of leaflets rounded, slightly emarginate.....var. obtusus
- (iii) (b) Apex of leaflets blunt to cuspidate.
- (iv) (a) Petiolules 2-10 mm; leaflets relatively narrow, base at least in upper leaflets distinctly oblique.....var. longan
- (iv) (b) Petiolules 8-10 mm; leaflets relatively broad, base equal-sided.....var. longepetiolulatus

The most commonly cultivated taxon is D. longan subsp. longan var. longan, mainly in continental Southeast Asia and Java. The variety obtusum is cultivated in Thailand; the others occur wild. Longan is self-incompatible, and cross-pollination may be effected by bees (Crane and Walker, 1984).

Chen et al. (1949) and Fang et al. (1949) described 25 cultivars from Putien and Foochow, Fukien Province, China, classifying them by maturity period (early, mid-season, late), quality (fleshiness), usage (dessert, drying, jam-making), yield etc. Vangnai (1980) distinguished 3 groups embracing 11 cultivars in Thailand, but did not give any descriptive characters. Soderholm (1981) mentioned 27 cultivars in Florida, one of them being 'Kohala', which is also grown in Hawaii (Campbell, 1970).

### 3. ORIGIN, DISTRIBUTION AND ECOLOGY

The origin of the longan is not clear. It grows in southwestern India in the forests of the Western Ghats, from Konkan southwards to the Tinnevely hills, at up to 1,500 m high. It is also very common in the evergreen forests of upper Assam and in the hill districts and may be native to these areas (Anon., 1952). The centre of diversity of the longan is known to be central and southern China; Leenhouts (1971) states that it is also Kalimantan (Indonesia). The longan became naturalized in India, and has been long cultivated in China, where numerous cultivars have been selected.

The longan is also cultivated in southern Florida (26°N), Java (7-8°S) and the island of La Réunion (21°S), but whether cultivars have become adapted to different latitudes is not clear. At higher latitudes the longan grows best near sea level, while in Java it may be found at 300-900 m (Terra, 1948).

### 4. AGRONOMY, DISEASES AND PESTS

The longan tree can be propagated by seed, but seedling progeny are variable. Of the possible methods of vegetative propagation, inarching was commonly used in southern China (Chandler, 1958), and budding has been recommended in India, using longan seedlings as a rootstock. Both air-layering and grafting have been tried in Florida, and though possible are considered difficult (Campbell and Malo, 1981).

The trees are usually planted at about 10 m x 10 m, depending on their vigour, soil fertility etc. In Florida spacings of 7 m or 8 m square are recommended with periodic topping and hedging to prevent trees from growing too large. The greatest obstacle to commercial development of the longan in Florida, Indonesia and elsewhere is the problem of irregular bearing (Campbell, 1970; Terra, 1948).

Little has been published on pests and diseases of longan. Witches' broom, a virus disease, has been described in Hong Kong (So and Zee, 1972). In southern China the longan (and litchi) are damaged by Tessaratomia papilionae (Hemiptera), a bug which attacks the fruit peduncles, while in Brazil, longan fruits are damaged by a coccid, Florinia nephelii (Leroy, 1944).

### 5. GENETICS AND IMPROVEMENT

Genetic improvement of longan has hitherto mainly consisted of selection of the best types among existing cultivars. In some cases selection has also been amongst the open-pollinated seedlings of superior cultivars. Some such seedlings selected in Florida bear excellent fruits, although none of them bear fruit regularly (Knight, 1969; Campbell, 1970). Crosses were made in 1965 by Watana in Thailand between several cultivars of the "Galoke" group, which is characterized by large fruits with a thick flesh. The aim was improved fruit quality and regularity of bearing, and one of the F<sub>1</sub> seedlings was promising (B. Silayol, Kasetsart Agricultural University, Bangkok, Thailand, 1981 pers. comm.).

6. GERMPLASM CONSERVATION

According to Sastrapradja (1975) there has been extensive genetic erosion of longan resulting from the use of a few clonally-propagated cultivars in southern Viet Nam and Thailand, some in Indonesia and Malaysia, but none in the Philippines. There is no data on germplasm loss in southern China, but outside the above areas, there is unlikely to be cause for concern.

Sastrapradja (1975) considered that there was moderate erosion of the related wild species D. longan subsp. longan. Some of the related subspecies and botanical varieties could conceivably be useful in future breeding work and should be represented in collections. Seed can be stored (Ellis, 1984).

The only collections with more than 10 accessions are at Hilo, Hawaii (14) and Miami, Florida (27), USA. A few accessions are available at institutes in Australia, Indonesia, Israel and Thailand. The longan is held in the collections of the Provincial Academy of Sciences, Fujien, China.

NEPHELIUM LAPPACEUM  
(Rambutan)

1. INTRODUCTION

Rambutan fruits have a sweet acid edible aril, which is consumed fresh, stewed or canned. The percentage by weight of the aril may vary widely; 32% (Anon., 1966), and 46% (average of 2 cultivars) (Ng and Thamboo, 1967) having been reported. An analysis of the aril in Sri Lanka gave 82% water and 16% carbohydrate, 8.8% of which was sugar (Anon., 1966). Pynaert (1955) reported a sugar content of 11.3%. The seeds can be eaten roasted and are a source of a tallow. The seed kernel contains 37-43% of an edible solid fat, similar to cacao butter, which can also be used for making soap and candles. The fruit skins, and leaves, roots and bark may have uses in local medicine (Heyno, 1950; Burkill, 1966).

In Indonesia and Malaysia rambutans are often grown in mixed fruit gardens, commercial orchards being infrequent. The crop in Thailand amounted to 1,222,000 tons in 1978, bringing it to third place after pineapple and coconut (Vangnai, 1980). 9,600 ha of rambutans were grown in Malaysia in 1972 (Lum, 1975), and the crop is also grown in Indonesia and the Philippines.

2. TAXONOMY AND BOTANY

Nephelium lappaceum L. (syn. N. glabrum Noronh.), rambutan, is commonly cultivated. A related species N. mutabilis Blume, pulasan, is also cultivated but less commonly. Both have edible fruits. There are numerous other related wild Nephelium species (some graft-compatible).

The rambutan is a large evergreen tree up to 20 m high. Leaves pinnate with 2-4 pairs of leaflets. Inflorescence an axillary panicle, superficially terminal. Flowers male, female or hermaphrodite, small greenish-white; calyx cupular, 4-6 lobed; petals absent; disc small, 4-6 angular. Male flowers with 5-8 stamens, placed within the disc; ovary rudimentary. Female flowers with 5-7 staminodes, ovary usually 2-lobed, 2-celled, densely clothed with dark brown hairs, later with small tubercles; one ovule in each cell. Fruit usually of one well-developed nutlet (the other rudimentary one is present on the fruit pedicel), globose or ovoid, 3.5-8.0 cm long, 2-5 cm in diameter, red or yellow covered with tubercles ending in soft spines; pericarp glabrous, 2-4 mm thick. Seed 2.5-3.5 cm long, 1.0-1.5 cm diameter; aril white, transparent, sweet, juicy.

Both monoecious and dioecious tree types occur, cultivated rambutans being mainly dioecious. Monoecious trees are normally, but not always, cross-pollinated, producing both male and female flowers sequentially on the same inflorescence. The seedling offspring of these trees may include some trees with male flowers only (Anon., 1962b). Seeds can be produced apomictically from female flowers when grown in isolation from male flowers (Yap, 1980). Insects such as bees and flies are the usual pollinating agents (Soepadmo, 1979).

There are numerous named cultivars of rambutan, many of which have been recognized since the end of the 19th century in Indonesia and Malaysia (Ramlie, 1973; Oehle and Bakhuizen van den Brink, 1931). Almeyda and Martin (1979) listed 30 important cultivars, their country of origin, main fruit characteristics and for half of them, whether grown for fresh consumption or canning. Whitehead (1959) described 14 Malayan cultivars, and Sastrapradja (1973) described 16 Indonesian cultivars. Many published descriptions are rather imprecise and a standardized descriptor list is needed.



### 3. ORIGIN, DISTRIBUTION AND ECOLOGY

The centre of diversity of the genus Nephelium is the Indo-Chinese - Indonesian region and the rambutan originated in the Malaysian archipelago. Early this century rambutan cultivation was limited to Indonesia and Malaysia, but since then it has been successfully introduced to India, the Philippines, Thailand and Honduras. Nonetheless, it is primarily a Southeast Asian fruit grown in gardens and small orchards.

The rambutan thrives in humid tropical climates, especially in lowland areas with high rainfall. Dry winds during flowering may result in defective fruit setting, while drought during fruit development results in poor fruits. The soil should be well-drained (Terra, 1948). The pulasan occurs in similar climates to the rambutan, but is especially popular in western Java.

### 4. AGRONOMY, DISEASES AND PESTS

Rambutans can be propagated from seed or vegetatively by bud-grafting; seedlings do not grow true-to-type. Freshly harvested seeds germinate rapidly producing 2-leaved seedlings within 14 days, providing the aril is removed and the seed is washed (Chin, 1975). Seedlings come into bearing 5-6 years after sowing, a year or 2 later than trees propagated vegetatively (Almeyda and Martin, 1979). Seedlings of rambutan are commonly used as rootstocks, but N. mutabile and N. intermedium are also graft-compatible with rambutan (Valmayor et al., 1970). The fruits, which are non-climacteric, take about 108 days to develop in the Philippines. They are picked when almost fully ripe and do not store well (Mendoza et al., 1972).

The rambutan appears to be rather free from serious diseases. Mildew occasionally causes large flower and fruit losses in Indonesia and Malaysia (Madiwidjaja, 1950), but may be controlled chemically. Fomes lignosus is reported as a potentially serious disease (Anon., 1962b). Vein necrosis, caused by the bacterium Xanthomonas nepheliae, is of minor significance in the Philippines (Pordesimo, 1969). Popenoe (1967) reported a disorder called rough-bark disease on rambutan and pulasan trees in Honduras, which caused extensive die-back. It may be caused by a virus, so the transfer of vegetative material to other areas should be avoided.

Various insects damage the fruits, foliage and bark of rambutan in Indonesia (Kalshoven and van der Vecht, 1950) and the Philippines (Anon., 1962b), but none are serious pests. The most damaging insect pest of rambutan in the American tropics is a beetle, the sugarcane root borer (Diaprepes abbreviatus). The adults feed on the leaves and the larvae on the roots (Almeyda and Martin, 1979). Insecticidal control has been recommended (Wolcott, 1955).

### 5. GENETICS AND IMPROVEMENT

The somatic chromosome number of rambutan is  $2n=22$ ; no other genetic data are available. The fruits of wild rambutan trees have probably been eaten for very many years. There may have been some early selection of the best-quality fruits for planting, but as the tree is cross-pollinated, this would have had limited effect in the seedling generation. It only became possible to multiply selected cultivars when methods of vegetative propagation were developed, and this is the current basis of rambutan improvement. The vegetative propagation of rootstocks is not yet commercially practiced, and the selection and breeding of new rootstocks has not yet been undertaken.

### 6. GERMPLASM CONSERVATION

Sastrapradja (1975) considered that genetic erosion of cultivated rambutan was extensive in Indonesia, Malaysia, southern Viet Nam and Thailand, and slight in the Philippines; in the wild rambutan it was slight in Indonesia and the Philippines, and not a problem in the other 3 countries. There has been some loss of pulasan germplasm in Indonesia. There has been slight erosion of the related species N. eriopetalum in

Indonesia and Malaysia, but not in the other Southeast Asian countries. The main cause of genetic erosion was the more widespread use of clonally-propagated cultivars.

Rambutan seeds can not be stored under normal conditions (Ellis, 1984), and at room temperature lose their viability within a matter of days. They can be kept for several weeks in moist sawdust or charcoal to which some aril juice has been added at 21-28°C (Chiu, 1975). Clearly seeds are of no use for germplasm conservation, and all the collections are of trees, mostly of clonally-propagated cultivars.

Table 26. Collections of rambutan

Country	Location	Number of accessions	
		<u>Nephellium lappaceum</u>	Other <u>Nephellium</u> spp.
Australia	Darwin, N.T.	20	
China <sup>1/</sup>	Yunnan	?	
Indonesia	Bogor (IPB)	70	
Indonesia	Lombok	23	
Malaysia	Kuala Lumpur		<u>Nephellium</u> spp. (68)
Mexico	Cozucapa, Oaxaca	51	
Philippines	Los Baños	108	<u>Nephellium</u> spp. (2)
Seychelles <sup>2/</sup>	Mahé	22	<u>N. mutabile</u> (2)
Thailand	Bangkok	11	
Thailand	Chantaburi	275	
USA	Miami, Florida	13	<u>N. mutabile</u> (6)

<sup>1/</sup> Xishuang Banna Tropical Botanical Garden, Yunnan Institute of Tropical Plants, Chinese Academy of Sciences, Mengla, Xishuang Banna, Yunnan Province.

<sup>2/</sup> Grand'Anse Experimental Centre, Mahé Island, Seychelles.

<sup>3/</sup> Some wild Nephellium spp. are held at LBN, Bogor.

IBPGR (1984) also lists the following small collections of rambutan, but these probably can probably not be regarded as genetic resources collections: Manaus, Amazonas, Brazil; Njombe, Cameroon; Bogor (LBN), Indonesia <sup>3/</sup>; Keravat, Papua New Guinea. Hilo, Hawaii, USA. There are also likely to be a few trees in collections in Honduras and Puerto Rico.

MANILKARA ACHRAS  
(Sapodilla)

1. INTRODUCTION

The flesh of the sapodilla fruit, when ripe, is soft, granular and very sweet. Fruits contain an unusual-tasting gelatinous material, which in the unripe fruits of certain cultivars, may be quite sticky (Chandler, 1958). Fruits may be eaten fresh or used as an ingredient in ice-cream, but are rather unsuitable for jam-making or canning. They are not particularly nutritious (Table 1). For many years wild trees were an important source of "chicle", a gum tapped from the trunk and used in the manufacture of chewing gum, but now largely replaced by synthetic gums (Dupaigne, 1979).

The total area of sapodilla production probably only amounts to about 12,000 ha, with major producers, in descending order being the Philippines (Anon., 1980), India, Mexico, Malaysia (Lum, 1975) and Venezuela (Rivas and de Martos, 1979). According to Lakshminarayana (1980), 4,000 ha of trees are still cultivated in Mexico for chicle production. They are also grown in Brazil, Cuba, Indonesia, Jamaica, Kampuchea, Netherlands Antilles, Sri Lanka, Surinam, Thailand and USA (Florida and Puerto Rico).

2. TAXONOMY AND BOTANY

The sapodilla (Manilkara achras (Mill.) Fosberg, syn. Achras sepota L., Sapota achras Mill.) also known as chicopote, nispero, chicku, sapote or naseberry, is a member of the Sapotaceae, a family of shrubs or trees widely distributed mostly in the tropics. Closely related species are M. glaberrima DC (Trinidad), M. bidentata (DC) Chev. (South America) and M. spectabilis (Pitt.) Standl. (Costa Rica).

The sapodilla is a lactiferous tree, 5-15 m high with a globose or pyramidal crown. Leaves alternate, oblong-lanceolate, tomentose when young, becoming glabrous, dark green above, shining, 3.5-15.0 cm x 1.5-7.0 cm, pinnatinerved; petiole rather thin, furrowed on anterior side, pubescent or glabrous, 1.0-3.5 cm long. Flowers solitary in leaf axils, usually pendulous, scentless, ruddy, tomentose, 1.0-1.5 cm in diameter; pedicel robust, terete or slightly angular, ruddy tomentose, warty 1-2 cm long; calyx deeply 6-partite, densely tomentose inside, densely grey or brown tomentose outside, segments usually in 2 whorls of 3, light green, inner ones paler than outer 2 or 3, ovate, obtuse or rounded, coriaceous; corolla gamopetalous, tubular or campanulate, somewhat longer than calyx, white, over one third of its length divided into 12 segments, only the outer series being the true corolla, the inner ones being petaloid staminodes; stamens 6, filaments short, obliquely erect, anthers ovoid-oblong, yellowish-brown; style distinctly exserted from the flower, subulate. Fruits pendulous berries, globose, ovoid or ellipsoid, 5-9 cm diameter, 75-200 g weight, reddish or yellowish-brown when ripe, densely lepidote with darker-coloured dots, dull, 3-8 cm long, 3-6 cm in diameter; pulp juicy, reddish-brown, sweet. Seeds 6 or fewer, laterally compressed, shiny, blackish-brown, hard (Ochse and Bakhuizen van den Brink, 1931).

Honey bees visit sapodilla flowers to collect nectar, and probably pollinate them (Crane and Walker, 1984). Stands of seed-grown trees are commonly quite variable, but selected sapodilla cultivars are propagated vegetatively in several countries. Ochse (1927) briefly described 10 Indonesian cultivars, while Gonzales (1932) gave a description of 'Ponderosa' in the Philippines. There are at least 14 named cultivars in India (Singh et al., 1967) and 12 in Florida (Campbell and Malo, 1973).

3. ORIGIN, DISTRIBUTION AND ECOLOGY

Although Pittier (1914) considered the sapodilla to be native to Mexico (south of

the Isthmus of Tehuantepec or a little further north), Guatemala and possibly also El Salvador, northern Honduras, Colombia and Venezuela, its exact area of origin is not clear. It is certainly wild in the forests of Venezuela and the Antilles. Wild sapodilla trees mainly grow in the tropical lowland rainforests of southern Yucatan in Mexico and adjoining areas in Belize and Guatemala. The trees often occur in gregarious stands. It was domesticated by Central American Indians and spread in pre-Columbian times to islands in the West Indies, and to Peru and Ecuador.

The sapodilla is now cultivated in many countries, with climates ranging from continuously moist and hot, to seasonal with long cool periods. They thrive best in tropical lowlands, but grow at altitudes up to 900 m. Prolonged dry periods may result in poor fruit production, unless there is irrigation or adequate groundwater, but some drought is tolerated. The distribution range in Java, Indonesia covers areas with over 100 mm of rainfall per month throughout the year, to drier places in which there may be less than 60 mm rainfall for half of the year, but a high water table (Torra, 1948).

Young sapodilla trees are very susceptible to frost damage (Campbell and Malo, 1977). The trees are, however, highly resistant to wind damage, and are fairly tolerant of salt spray when grown by the coast in Florida. They grow quite well on many soil types, including ones which are rocky, alkaline and shallow (Chandler, 1958; Torres Sepulveda, 1976). Production of sapodilla could probably be considerably extended, although Singh (1970) reported serious problems of fruit set in India, which may have resulted from self-incompatibility as observed in Florida (Piatos and Knight, 1975).

#### 4. AGRONOMY, DISEASES AND PESTS

Seed-propagation of sapodilla is easy and is still widely practised, but only by such vegetative methods as marcotting, layering and grafting can selected cultivars be reproduced. Sapodilla seedlings can be used as rootstocks, but grow relatively slowly, and other species have been tested, with varying success, including: Manilkara hexandra (Roxb.) Dubard, M. kauki (L.) Dubard, Madhuca latifolia Macbr. and Sideroxylon dulcificum. The influence of different rootstocks on tree growth, and fruit production and quality needs further study (Rowe-Dutton, 1976).

Planting distances used vary from 6-9 m depending on soil fertility and tree vigour. Fruits may be produced almost continuously as there may be several, sometimes overlapping, flowering periods per year, depending on climatic conditions, probably especially day-length. Fruits take about 4 months to develop to maturity in India and are picked when the brown scurf begins to drop from the skin (Singh et al., 1967). An average grafted 10 year-old tree yields 200 kg of fruit annually (Lakshminarayana, 1980).

A leafspot disease caused by Phaeophloeospora indica may cause serious fruit losses in India. Varietal differences in susceptibility have been identified (Prasad et al., 1979) and chemical methods of control can be effective (Sohi and Sridhar, 1980). Cook (1975) mentions a fruit rot (Phytophthora palmivora) and a leafspot (Phyllosticta sapoticola) in India and Pestalotia scirrociliens, which causes tumour and leafspot in Florida. Srivastava (1967) noted a post-harvest decay in India caused by Botryodiplodia theobromae and Pestalotia sapotae. Leaf spotting can be caused by Septoria batistae in Brazil (da Matta, 1955), and by Colletotrichum gloeosporioides in Cuba (Roseñada, 1973). The leaf rust caused by Uredo sapotae has been recorded in Florida (Campbell and Malo, 1977) and Cuba (Roseñada, 1973).

Sapodilla trees are usually grown as scattered individuals in mixed orchards, which may help to explain the relative unimportance of insect pests. Fruit-flies (Diptera) are very damaging in some places, Dacus spp. being noteworthy in India (Bhutani, 1975b), and Anastrepha spp. in Venezuela and Brazil (Rubio, 1969; Simão, 1971). Infestation usually results in damaged fruit and early fruit drop. Sapodilla trees may also be attacked by beetles, grubs and caterpillars which eat leaves, shoots and buds and bark, branch and trunk-borers (Coleoptera and Lepidoptera), leaf-sucking Homoptera and thrips which infest the flowers. Caterpillars eating leaves and buds are

the most destructive pests in India. Pest control, if attempted, may be by the use of chemicals and plant and orchard hygiene.

#### 5. GENETICS AND IMPROVEMENT

The sapodilla is a diploid with  $2n=26$  chromosomes. As with many other tree crops, progress in cultivar improvement has depended upon the development of methods of clonal propagation. A programme of selection and testing has been carried out in Florida since 1933. The main criteria were precocity, total yield, regularity of bearing and fruit quality. Other factors considered were season of maturity, fruit size and shape, resistance to handling damage, disease and insect resistance, flesh texture and colour and number and size of seeds. A number of selected trees have been clonally multiplied and compared, and 2 of them were released as 'Brown Sugar' and 'Prolific' (Campbell and Malo, 1973).

#### 6. GERMPLASM CONSERVATION

The extent of genetic erosion in the wider genepool is not known, although there is loss of old cultivars where this species is exotic, e.g. Sastrapradja (1975) concluded that there was a moderate amount of genetic erosion of cultivated sapodilla in Southeast Asia.

Several species closely related to the sapodilla and which are graft-compatible with it, should be conserved. There may be considerable genetic erosion in these species, as many of them are forest trees, a habitat which is seriously threatened. The following have been used as rootstocks with some success (Rowe-Dutton, 1976):

- (i) Manilkara hexandra (Roxb.) Dubard (syn. Mimusops hexandra Roxb.), a small to medium-sized tree, is common in the dry evergreen forests of the Deccan in India. Its sweet and astringent fruits are eaten, fresh or dried. The tree is also cultivated (Anon., 1962a).
- (ii) Manilkara kauki (L.) Dubard (syn. Mimusops kauki L.), the kauki, is a tree up to 24 m tall with edible fruits, but used largely for its wood. It occurs wild in Burma, Thailand and Indo-China, through Malaysia to northern Australia (Whitmore, 1973).
- (iii) Madhuca longifolia (Koenig) Mäch. (syn. Bassia longifolia Koenig), a large evergreen tree common in the monsoon forests of the western Ghats in India from Kankan southwards, usually along the banks of rivers and streams; it also extends into the Deccan and many parts of southern India. The seeds are collected and yield a fatty oil, called illipe butter (Anon., 1962a).
- (iv) Madhuca latifolia Macbr. (syn. Bassia latifolia Roxb.), is a species of northern India, also having seeds containing illipe butter (Burkill, 1966).
- (v) Madhuca betis (Blanco) Merrill. This medium tree (up to 30 m high) occurs wild from Luzon to Mindanao in the Philippines (Brown, 1954).
- (vi) Palaquium foxworthii Merrill, a forest tree with a trunk diameter of up to 60 cm or more, reported in the Philippines from the provinces and islands of Bataan, Laguna, Pangasinan, Tayabas and Zambales (Schneider, 1916).
- (vii) Palaquium merrillii Merrill, a forest tree up to 80 cm in trunk diameter, in the Philippines from the provinces Bataan, Camarines, Guimares, Laguna, Mindoro, Nueva Ecija and Tayabas (Schneider, 1916).
- (viii) Palaquium philippense (Perr.) C.B. Rob, a tree up to 25 m high, very common and widely distributed in primary forests at low and medium altitudes from northern Luzon to southern Mindanao in the Philippines (Brown, 1954). Its fruits have tasty edible pulp and the trees have occasionally been planted.

The collections listed mostly contain clonally-propagated trees or seedling selections of the cultivated sapodilla and little other material. The seeds are recalcitrant (Ellis, 1984). Conservation efforts should be centered on Central America and representative samples of wild and related material should be incorporated in collections.

Table 27. Collections of sapodilla

Country	Location	Number of accessions	
		<u>Manilkara achras</u>	Other <u>Manilkara</u> spp.
Australia	Darwin, N.T.	15	
Costa Rica	Turrialba	118 <sup>1/</sup>	
Cuba	Habana	20	
Philippines	Los Baños	77 <sup>1/</sup>	<u>Manilkara</u> spp. (2 species) 2 accessions
Philippines	Tiaong, Quuzon	33 <sup>1/</sup>	<u>M. keuki</u> <sup>3/</sup>
USA	Miami, Florida	31 <sup>1/</sup>	<u>M. hexandra</u> (1) <u>M. keuki</u> (1)
USA	Hilo, Hawaii	8	
USA	Mayaguez, Puerto Rico	30	
Venezuela	Maracay, Estado Aragua	27 <sup>2/</sup>	

<sup>1/</sup> Listed in Tropical Fruits Directory (IBPGR, 1984) as Manilkara zapota.

<sup>2/</sup> Listed in Tropical Fruits Directory (IBPGR, 1984) as Achras zapota.

<sup>3/</sup> Valmayor and Espino (1975).

IBPGR (1984) also lists the following small collections of sapodilla, but these can probably not be regarded as genetic resources collections: Alstonville, New South Wales, Australia; Manaus, Amazonas, Brazil; Guilaan, Oaxaca, Mexico; Keravat, Papua New Guinea; Wad Medani, Sudan. There may also be a few plants at the Wilson Populoc Botanical Garden, Lancafilia, Honduras.

POUTERIA spp.  
(Canistel, Lucmo and Abiu)

1. INTRODUCTION

The canistel, lucmo and abiu are all usually eaten as dessert fruits. The canistel is a rather dry fruit, which can be used in milkshakes, ice-creams, drinks, puddings, preserves etc. It is high in carbohydrate, fairly high in protein and carotene (provitamin A), and contains useful amounts of vitamins and minerals. The lucmo is similar in many respects to the canistel, including nutritional value (Table 1) but is moister. Carotene is lacking in the abiu (Martin and Malo, 1978).

All 3 are minor crops, only occasionally grown outside Central and South America. About 870 ha of canistel were recorded in the Philippines, producing 1,347 tons of fruits in 1979 (Anon., 1980), but Burkill (1966) noted the failure of an attempt to grow the crop in Singapore. The lucmo is only grown in Ecuador, Peru and Chile and the abiu in Brazil and Peru. There are in addition many other cultivated Pouteria species.

2. TAXONOMY AND BOTANY

Like much of the family Sapotaceae, the genus Pouteria has been difficult to delimit. There have been frequent changes in the numbers of species recognized, both because of the discovery of new species and because parts or all of other genera, such as Lucuma, have at times been included in it. They grow in areas which have often been only partially explored, and many of the herbarium specimens collected have been inadequate, lacking, for instance, fruits. Baehni (1965) recognized 318 species, while Aubréville (1964) allocated only 16 species to the genus. Both authors present a key. Fouqué (1972b) listed 10 Pouteria species with edible fruits in tropical America alone, 3 of which are considered here.

(a) Pouteria campechiana (HBK) Baehni, the canistel or egg fruit, may be known by the following synonyms: Lucuma salicifolia HBK, L. nervosa ADC, L. sphaerocarpa ADC, L. palmeri Fern, L. laeteviridis Pittier, Richardella nervosa Pierre, R. salicifolia Pierre, Pouteria campechiana var. nervosa Baehni, P. campechiana var. salicifolia Baehni.

The canistel is a small, evergreen tree, 3.0-7.5 m high, with spreading branches. Leaves oblong-obovate to oblanceolate, 10-20 cm long, glabrous, bright green, acute. Flowers small, in the leaf axils of young branches in clusters of 2-5; calyx 5-lobed, the inner ones rounded at the apex; corolla whitish with ovate lobes; stamens 5; staminodes 5; style columnar; stigma slightly dilated; ovary 5 (or 6)-celled. Fruit globose to ovoid, orange-yellow when ripe, 5-10 cm long, frequently pointed at the apex; flesh bright orange, soft and mealy, like the yolk of a hard-boiled egg. Seeds usually 2-3 (Bailey, 1949).

Seedling trees are very variable, but a few cultivars have been propagated vegetatively.

(b) Pouteria obovata HBK (syn. Achras lucuma Ruiz and Pavón, Lucuma obovata HBK, Pouteria lucuma O. Kuntze, Pouteria insignis Baehni, Richardella lucuma Aubréville) is the lucmo, lucuma or rucma, names of Quechua-Indian origin.

The lucmo is a semi-deciduous tree from 6-15 m tall. Leaves entire, often coriaceous, elliptic-ovate or obovate, 10-20 cm x 5-8 cm. Flowers solitary or 2-3 in leaf axils; sepals ovate, 8-12 mm long; corolla fleshy up to 15 mm long, yellowish-green with 5 lobes; stamens 5, implanted on the corolla throat; staminodes 5; pistil as long

as the corolla with an ovary up to 7-8 mm long, 5 (or 4)-celled; ovules attached to the upper parts of the locules. Fruit a berry, glabrous, round or ovate, about 7.5 cm long, apiculate or depressed; green but yellowing towards maturity; flesh yellow to deep orange. Seeds (1-)2(-5), ovoid or spherical; scar large, ovate, almost as long as the seed (Baehni and Bernardi, 1970).

Two botanical varieties of lucmo have been distinguished (Baehni, 1965). Martin and Malo (1978) described the cultivars B<sub>1</sub>, B<sub>2</sub> and B<sub>3</sub>, which were selected in Peru from a large population of seedling trees. The Peruvian cultivars yield well and have small seeds and other desirable attributes.

(c) Pouteria calmito (Ruiz and Pavón) Radlk. (syn. Achras calmito Ruiz and Pavón, Lucuma calmito Roem and Schultes, Labatia calmito Martius, Pouteria calmito Radlk., Guspeba calmito Pierre) is the abiu. Other names include calmito, calmo (in the Cauca valley, Colombia), asixe (in the now dead language of eastern Ecuador), anuncuetoa (in Siona) and jifigogue (in Huitoto) (Patiño, 1963). Some of these names may also apply to other species; for instance, calmito for Chrysephyllum calmito L., C. oliviforme L. and C. auratum Miq.

The abiu is an evergreen tree, 4.5-6.0(-35.0) m tall; branchlets blackish furrowed. Leaves entire, obovate to lanceolate but variable in shape, 10-20 cm x 3-6 cm. Flowers solitary or 2-5 in the leaf axils or above the leaf scars, practically sessile; sepals usually 4, ovate, small (4-6 mm); corolla cylindrical, white or greenish-white, 5-8 mm long with 4-5 lobes; stamens 4-5 on the throat of the corolla; stamencodes 4-5; pistil a little longer than the corolla, with a small globose ovary, 2 mm high, 4-celled with ovules attached to the bottom of the locules. Fruit a berry, bright yellow, globose to cylindrical, obtuse or apiculate, 4-5 cm in diameter, 5-10 cm long, tomentose when young; flesh whitish, translucent, jelly-like. Seeds 1-4, cylindrical-ovoid, slightly compressed on the sides (Baehni and Bernardi, 1970).

A botanical variety of the abiu, var. strigosa is reported from Venezuela (Monachiño, 1953). Little has been done on cultivar selection, but seedlings may be highly variable (Popenoe, 1920).

### 3. ORIGIN, DOMESTICATION AND ECOLOGY

The genus Pouteria as recognized by Aubréville (1964) has a tropical American distribution. The much larger genus of Baehni (1965) covers much of the world.

(a) The canistel probably originated in southern Mexico and northern Central America, where the Mayan names kaniste, huicomo and others indicate that it has been known since pre-Columbian times (Martin and Malo, 1978). It may have been introduced before the Conquest to some Caribbean islands, but was transported to other continents as shipping developed. It was introduced to the Philippines in the 1920's where it is known as 'tiessa' (Brown, 1958). Elsewhere it is rarely grown.

(b) The lucmo was cultivated on the lower slopes of the Andes and on the Pacific coast from the equator to northern Chile at the time of the Spanish Conquest. As this is also where wild lucmo grows, it is assumed to have originated there. Sauer (1950) noted that the fruit was one of the commonest motifs in Peruvian archaeology. Lucmo is now found in scattered locations from 100 to 3,000 m in altitude in Peru (Baehni and Bernardi, 1970) and is also grown in Chile and Ecuador, but its occurrence and frequency is poorly documented. The crop is unimportant outside these areas.

(c) The abiu was being cultivated by South American Indians before 1492 (Patiño, 1963). Two centuries ago wild trees grew in the Amazon lowlands from Peru to the state of Pará in Brazil (Cavalcante, 1974). According to Popenoe (1920), the abiu used to be extensively cultivated in Pará and elsewhere in the Amazon valley, and was common in Bahia and Rio de Janeiro, but was little known outside Brazil and Peru. The current area of abiu cultivation has changed little.



#### 4. AGRONOMY, DISEASES AND PESTS

Most of the following is based on Martin and Malo (1978).

(a) Canistel is usually seed-propagated, although vegetative methods, such as side-veneer grafting and chip budding, can also be used successfully. A reasonable yield is 500 fruits or more per tree at a spacing of 7-9 m. The fruits are yellow to orange even when immature and do not mature synchronously. In Florida the tree flowers from June to August and fruits from August to March.

Few pests and diseases of canistel have been recorded. A rust disease may cause loss of mature leaves at certain times of the year. In Cuba, the tree may be attacked by several species of scale insects and mealy bugs (Homoptera). A hairy caterpillar (Robinsonia formula - Lepidoptera), occurring in flushes during the summer and autumn, can completely destroy the foliage (Bruner et al., 1945). Canistel is reported to be tolerant of fruit flies of various species. Soft scale may be abundant in some years, and affected fruits are covered by a sooty mould.

(b) The lucmo is also usually seed-propagated. Seeds should be planted when fresh; germination can be enhanced by soaking them in a gibberellic acid solution. Successful propagation has also been achieved by side-veneer grafting, chip budding and mist-rooted cuttings (Duarte B. and Franciosi T., 1976). The recommended spacing of the lucmo is 8-10 m. As the fruits approach maturity, they change in colour from green to light green or to brownish orange, according to cultivar. They should be harvested at this stage and allowed to ripen on a shelf. About 500 fruits per tree is a reasonable yield.

There are few pest and disease problems; Martin and Malo (1978) only mention powdery mildew (Oidium spp.), and 5 insects, including the fruit fly Anastrepha serpentina.

(c) The abiu is usually grown from seeds, grafting being less successful than with canistel or lucmo. Trees are spaced at 8-10 m, and yields are not seriously limited by pests and diseases.

#### 5. GENETICS AND IMPROVEMENT

Nothing is known about the genetics or inheritance of any of the crops in the genus Pouteria. Early selections by Indians were of seedling trees, which may be quite variable, all 3 species being probably out-breeding and insect-pollinated. A few cultivars have been selected from open pollinated seedlings of canistel in Florida, and of lucmo in Peru and Chile.

#### 6. GERMPLASM CONSERVATION

Should trees grown as seedlings of all 3 crops be widely replaced with clonal cultivars, some loss of cultivated germplasm is inevitable. Wild populations still seem to contain considerable variability: canistel in northern Central America; lucmo on the lower slopes of the Andes and on the Pacific side of Ecuador; and abiu in the Amazonian lowlands of Brazil. The extent of genetic erosion in these areas in the wild species will depend on the rates of forest clearance.

Uniformity, good handling and storage qualities, and high and reliable yields may be required by plant breeders, but there is little indication of consumer interest, although all 3 crops could be more widely grown.

A few collections contain one or more of these species. The seeds of lucmo lose their viability rapidly (Duarte B. and Franciosi T., 1976); and probably all 3 species have recalcitrant seeds, although data is lacking. Germplasm conservation should be restricted to Central and South America.

Table 28. Collections of canistel, lucma and abiu

Country	Location	Number of accessions			Related genera and species
		<u>Pouteria campechiana</u>	<u>Pouteria obovata</u>	<u>Pouteria calmito</u>	
Brazil	Manaus, Amazonas		1 <u>1/</u>	24	<u>Pouteria mammosa</u> (3) <u>Pouteria pariry</u> (1) <u>Pouteria sapota</u> (242) <u>2/</u> <u>Pouteria</u> spp. (5)
Costa Rica	Turrialba				
Cuba	Habana				
Peru	Lima		36 <u>1/</u>		
Peru	Iquitos			19	
Philippines	Los Baños	19			<u>Chrysophyllum calmito</u> (31)
USA	Miami, Florida	16		4	<u>Chrysophyllum calmito</u> (12) <u>Chrysophyllum</u> spp. (2) <u>Pouteria sapota</u> (26) <u>Pouteria viridis</u> (4) <u>Pouteria</u> spp. (2)

1/ Listed in Tropical Fruits Directory (IBPGR, 1984) as Lucuma obovata.

2/ For details, see Morera Monge (1982).

IBPGR (1984) also lists the following small collections, but these can probably not be regarded as genetic resources collections: Njombe, Camaroon (listed in Tropical Fruits Directory (IBPGR, 1984) as Lucuma nervosa); Santiago, Chile; Palmira Valle Colombia; Keravat, Papua New Guinea (listed in Tropical Fruits Directory (IBPGR, 1984) as Lucuma nervosa). There are a few accessions at Institute of Tropical Agriculture, Mayagüez, Puerto Rico, USA.

CYPHOMANDRA BITACEA  
(Tree tomato)

1. INTRODUCTION

Tree tomato or tamarillo fruits resemble tomatoes, but may be red, orange or yellow in colour, and have a somewhat different flavour. They may be eaten fresh in salads or stewed, and there are also various processed products in New Zealand (Dawson, 1972). They are of unexceptional nutritional composition (Table 1) (Dawson and Callaghan, 1970), but are high in pectin, and therefore useful for jams and jellies. The seeds are hard and bitter, and the skin is tough and has an unpleasant taste.

The tree tomato is a minor crop, usually grown on a home-garden scale throughout the cooler tropics and sub-tropics. Only in New Zealand is there significant commercial production, which amounted to 2,200 tons in 1982, and is increasing. Other countries in which the tree tomato is important include Australia, Colombia, Costa Rica, Cuba, India, Indonesia, Malaysia, Mexico, Philippines, Thailand and USA (Florida). Morton (1982) has provided a review article on the tree tomato.

2. TAXONOMY AND BOTANY

The genus Cyphomandra Sendt. embraces 30 or more South American herbs, shrubs or small trees. All are erect, spineless plants with large, entire, 3-lobed or pinnatisect leaves. The pedicellate flowers, arranged in racemes or cymes, have a 5-lobed calyx and a 5-lobed, rotate or bell-shaped corolla. The anthers open at the apex or the side. The fruit is a 2-celled, many-seeded berry, and may be quite large (Bailey, 1949).

C. costaricensis, a tree-like shrub or large herb known as popinillo, has been recorded from Panama to Honduras. It was frequent in thickets and pastures below 1,000 m altitude in Costa Rica (Standley, 1938). Solanum mauritianum is a tree or shrub up to 6 m high. Probably native to Brazil, Paraguay and Uruguay, it has been introduced to many tropical and sub-tropical regions of the Old World (Hutchinson and Dalziel, 1963). S. aviculare Forst. occurs in Australia and New Zealand (Jackson, 1895). C. betacea Sendt. is a tree-like, somewhat woody shrub, 1.8-3.0 m high, mostly pubescent or puberulent. Leaves simple and entire, cordate, ovate, 20-30 cm long, short-pointed, prominently pinnately veined, soft-pubescent. Flowers about 13 mm diameter, pinkish, fragrant; corolla lobes long and narrow. Fruit oval, 5-8 cm long, smooth, with a long pedicel (Bailey, 1949).

Plants raised from seed may vary considerably in fruit characteristics (Sutton and Strachan, 1971). The skin colour may be purple, red, orange or yellow, while the pulp varies from red to yellow (Hume and Winters, 1948; Singh et al., 1967; IBPGR, 1980). Groups of plants sharing common fruit characteristics can be considered as cultivars, but named cultivars have to be clonally-propagated as cuttings. The cultivar 'Kaitiaki Yellow' for canning has recently been released in New Zealand (Patterson, 1980).

3. ORIGIN, DISTRIBUTION AND ECOLOGY

Peru is assumed to be the centre of origin of the tree tomato, because it has been grown by the Peruvian Indians since before the European discovery of South America. Popenoe (1920, 1924) noted that it was still extensively cultivated in the Andean valleys of South America, especially Peru and Ecuador, in the early part of this century. The plant now only survives in cultivation and is not known wild. The tree tomato has been introduced to many tropical and sub-tropical areas.

The crop is best adapted to the cooler conditions of higher altitudes, and may

hardly set any fruit in lowland areas (Poponoe, 1920). Typically it is grown at altitudes between 1,600 and 3,000 m in the Andes of Peru, whereas it is successfully cultivated at 300-900 m in Puerto Rico at a latitude of 18°N (Gregory, 1965). The tree tomato does not have specific requirements for soil type, but grows best in fertile soils well supplied with water. In Indonesia it grows well where at least 100 mm of rainfall occurs for each of 7 months annually (Terra, 1948). Occasionally it is grown with irrigation (Anon., 1950b), but waterlogged conditions should be avoided (Slack et al., 1978).

#### 4. AGRONOMY, DISEASES AND PESTS

The tree tomato is usually propagated from seeds. Seeds germinate easily and the seedlings grow rapidly into vigorous plants. Cuttings generally give weaker plants but produce fruits sooner. Tissue culture has been used for commercial propagation of tree tomato in New Zealand. In vitro propagation of uninfected material, e.g. lateral buds, is a way of obtaining virus-free plants which grow true-to-type (Cohen and Elliot, 1979).

Grafting has been tried with varying success. In Indonesia, Cyphomandra costaricensis (Donn.) Smith as a rootstock promoted longevity in the scion (IBPGR, 1980). In New Zealand, cultivars grafted on to Solanum oviculare and S. mauritianum Scopoll (syn. S. auriculatum Ait.) rootstocks had higher fruit yields and increased resistance to Phytophthora root rot, but similar work in New South Wales was unsuccessful (Slack et al., 1978; Endt, 1973). Recently Nicotiana glutinosa has been successfully used as a rootstock in New Zealand; it may confer some aphid resistance to the tree tomato, but longer-term effects on cropping and the vegetative growth of the plant have not been studied.

Recommended planting distances in commercial orchards in New Zealand are 1.0 to 1.5 m between plants within a row, and 4.5 to 5.0 m between rows. Seedlings enter into production about 2 years from sowing, cuttings about 6 months earlier. Trees remain productive for 6-10 years. In the tropics flowering and fruiting occurs throughout the year, albeit with heavier crops at certain times of year. Fruit production is more seasonal at higher altitudes. Annual yields are about 18 kg/tree (Anon., 1950b) and 20 tons/ha (Jaime, 1977), the latter figure from a population of 1,100 plants/ha. Commercial yields in New Zealand are typically 10-12 kg/plant (Bielecki, 1983 pers. comm).

The fruits can be transported successfully if carefully packed. Fungal rots in storage are controlled by hot water treatment followed by waxing of the fruit. Fruits thus treated in New Zealand and stored at 3-4°C remained in good condition for 12-14 weeks, and had a further shelf life of at least 7 days (Strachan and Dawes, 1970; Jaime, 1977). The tree tomato can doubtless be much more widely grown than at present, and recently has been promoted in several countries including India (Dadlani and Chandal, 1970) and Italy (Carnevali, 1974).

Tamarillos generally have few pest and disease problems (Gregory, 1965), but they may assume greater importance if the crop were to be grown more widely. The following fungal diseases have been reported: anthracnose, affecting fruits, branches and leaves, and mildew (Oidium spp.), both in Colombia (IBPGR, 1980); leaf spot (Ascochyta spp.) in Malaya (Singh, 1973); blight (Phytophthora palmivora) in India (Cook, 1975); and wilt (Fusarium oxysporum f. sp. lycopersici) in Brazil (da Silveira and de Mendonca, 1964). Sale (1982) reported that powdery mildew (Oidium spp.), sclerotinia disease (Sclerotinia sclerotiorum), tree tomato leaf spot (Phoma exiguum), bitter fruit rot (Colletotrichum acutatum) and root rot (Phytophthora cryptogea) occur in New Zealand, powdery mildew being the most serious but also fairly easy to control with fungicides.

In New Zealand, tree tomato is affected by at least 4 virus diseases, including cucumber mosaic (Chamberlain, 1948), potato virus Y (Chamberlain, 1954), and Arabis mosaic (Thomas and Proctor, 1972, 1977). All cause severe losses of yield, and all except Arabis mosaic virus are transmitted by insects (Sale, 1982). The first 2 have

also been reported from India (Cook, 1975). The tree tomato is also affected by a disorder known as "mal-azul", "bleu-ill" or "big-bud". Work in Portugal has shown that the causal agent, which may be a mycoplasma, is graft-transmissible between tomato and tree tomato plants (d'Oliveira, 1970). Bacterial blast disease (Pseudomonas syringae) and bacterial canker (Corynebacterium michiganense) are respectively fairly frequent and rare diseases of tree tomato in New Zealand (Salo, 1982).

Salo (1982) lists the following as pests of tree tomato in New Zealand: Myzus persicae and other species of aphids; the green vegetable bug (Nezara viridula) which attacks the fruit and foliage; the green looper caterpillar (Chrysodeixis eriasoma); the green-house whitefly (Trialeurodes vaporariorum); and several species of leaf rollers and thrips. In Colombia, a fruit-boring insect (Lepidoptera) can cause considerable fruit losses and fruit flies and aphids may also be a problem (Jaime, 1977). Fruit flies and aphids also occur in Queensland, Australia, although different species may be involved. These pests can be controlled with insecticides. The larvae of fruit flies in harvested fruits can be killed by fumigation, chilling or insecticide dips. (Rippon, 1979). The tree tomato is susceptible to the nematode Xiphinema diversicaudatum, the vector of Arabis mosaic virus, but no special control measures are taken (Salo, 1982).

#### 5. GENETICS AND IMPROVEMENT

The chromosome number of tree tomato is  $2n=24$  (Porter, 1967; Madhavadian, 1968; Whitaker, 1933; van der Mey et al., 1969). The chromosomes are unusually large, and do not show distinct chromatic/achromatic regions (Roe, 1967a and b). Tamarillo breeding work has only been reported from New Zealand (Dawes and Pringle, 1983; Patterson, 1980), but cultivars have been compared in trials in Malawi, New Zealand, New South Wales, Australia and Florida, USA.

#### 6. GERMPLASM CONSERVATION

While the tree tomato is propagated from seed and the plants are genetically heterogeneous, there is little danger of genetic erosion.

The ease with which Cyphomandra species naturalize lessens the risk of genetic erosion. Some species may yet be useful as rootstocks, while others may be significant in breeding. Tree tomato is represented only in the ICA collection at Bogotá, Colombia (31), and there are no collections of related species. Small non-genetic resources collections exist at Quito, Ecuador; Limbe, Malawi; Miami, Florida and Hilo, Hawaii, USA (IBPGR, 1984). No data on accessions stored in seed genebanks are available.

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