5

Loquat: Botany and Horticulture

*Shunquan Lin**
Institute of Subtropical Fruits,
Fujian Agriculture University, Fuzhou 350002 China

Ralph H. Sharpe
Horticulture Sciences Department,
University of Florida, Gainesville, Florida, 32611-0690

Jules Janick
Department of Horticulture and Landscape Architecture,
Purdue University,
West Lafayette, Indiana, 47907-1165

*I thank Prof. N. Nito of Saga University, Japan, for his encouragement and constructive comments.

Horticultural Reviews, Volume 23, Edited by Jules Janick
ISBN 0-471-25445-2

I. INTRODUCTION

Loquat (*Eriobotrya japonica* Lindl., Rosaceae, Maloideae) is a subtropical evergreen fruit tree that blooms in fall and early winter. The tree is cold-hardy to –10°C (12°F), but fruits are frozen by winter minimum temperatures of about –3°C (27°F). In the Gulf region of the southern United States, and in many other countries, the tree fruits irregularly but is grown for its handsome foliage (McConnell 1988). Loquat is now commercially produced in many countries (Table 5.1). Fruits can be consumed fresh or processed and can be used for jam, juice, wine, syrup, or as candied fruits (Liu 1982); seeds are rich in starch (20%) and have been used to make wine. Leaves and fruits of loquats traditionally have been considered to have high medicinal value (Duke and Ayensu 1985; Wee and Hsuan 1992) and there is evidence of pharmaceutically active compounds (Yang 1984; Shimizu et al. 1986; Morton 1987; Noreen et al. 1988; Chen et al. 1991; DeTommasi 1992b). Loquat is highly nectariforous, with a heavy fragrance and high honey potential (Yu 1979). Its wood is pink, hard, close-grained, and medium heavy (Morton 1987).

Since Popenoe (1920) wrote a chapter on the basic knowledge of loquat, there have been publications in several languages on various aspects of loquat, including chemical compositions (Shaw 1980) and cultivars in countries other than China (Morton 1987). There are popular books on loquat in Chinese (Chen 1988; Wang 1989) and in Japanese (Ichinose 1995). The objective of this chapter is to review the botany and horticulture of loquat and to summarize recent research, with emphasis on Chinese and Japanese investigations.

Table 5.1. Loquat production statistics in selected countries. Source: Fujisaki 1994; Monastra and Insero 1991.

Country[z] Location	Area (1,000 ha)	Production (1,000t)
China	25.9	102.0
Fujian	11.9	35
Zhejiang	9.1	35
Taiwan	2.5	13
Jiangsu	0.6	5
Anhui	0.5	4
Jiangxi	0.4	3
Sichuan	0.4	3
Other	0.5	4
Japan	2.8	13
Italy	NA[y]	7
Brazil	0.3 est	NA
Spain	3.9	NA

[z]Other countries with some commercial production include India, Turkey, and Israel. The United States has only home garden production.

[y]NA = not available.

A. Origin and History

Records on loquat in China span over 2,000 years (Sima 100 B.C.); there many loquat species occur in the wild state (Zeng 1937; Chen 1954; Zhang 1987; Zhang et al. 1990). The loquat cultivated in Japan was introduced from China in ancient times and loquat cultivation in Japan was described as early as 1180 (Ichinose 1995). Because Japan had been considered the original region of loquat by Thunberg (1784), the species was named as *Mespilis japonica*. Since some primitive types of *E. japonica* occur in several prefectures in Japan, some Japanese authors consider the origin to be both China and Japan (Fujisaki 1994; Ichinose 1995). Most authors around the world now believe loquat originated in China (Popenoe 1920; Shaw 1980; Morton 1987; Zhang 1987, 1990; Campbell and Malo 1986), but the definite region of origin is unknown. Morton (1987) described loquat as indigenous to southeastern China. In fact, various species of *Eriobotrya* are found in southwestern China. In the 1960s, a large group of previously unknown *Eriobotrya* plants were found in the Dadu River Valley, located on the southern slopes of the mountain Gongga in western Sichuan and named *E. prinoides* Rehd. & Wils var. *daduneensis* H. Z. Zhang (Zhang et al. 1990). The Dadu River Valley is now considered the center of origin for the genus *Eriobotrya* in China, and a great number of indigenous communities of *E. japonica, E. prinoides,* and *E. prinoides* var. *daduneensis* are distributed in the middle and lower reaches of the river valley (Zhang et al. 1990).

People beyond eastern Asia first learned of the loquat from Kaempfer, who observed it in Japan and described it in *Amoenites Exotica* in 1712, while the Swedish botanist, Thunberg, in *Flora Japonica* (1784), provided a more ample description of loquat under the name *Mespilus japonica.* In 1784, the loquat was introduced from Guangdong into the National Garden at Paris, and in 1787 was introduced into the Royal Botanical Gardens at Kew, England (Condit 1915; Liu 1982). From this beginning, loquat was distributed around the Mediterranean to various countries, including Algeria, Cyprus (Cyprus Agricultural Research Inst. 1987), Egypt, Greece, Israel, Italy, Spain, Tunisia, and Turkey (Demir 1983; Morton 1987).

Sometime between 1867 and 1870, loquat was introduced to Florida from Europe and to California from Japan. Chinese immigrants are assumed to have carried the loquat to Hawaii (Morton 1987). By 1915, it had become quite well established in Florida and southern California and several new cultivars had been named. In that year, Condit published 33 pages of information on the culture of loquat in *California Experiment Station Bulletin 240.*

Cultivation spread to India and southeastern Asia, the East Indies, Australia (Goubran and El-Zeftawi 1983), New Zealand (Burney 1980), Madagascar, and South Africa. Loquats are now distributed in many Asian countries, for example, Laos, Nepal, Pakistan, South Korea, and Vietnam; in Armenia, Azerbaijan, and Georgia (Safarov 1988); and in the Americas, including Argentina, Brazil, Chile, the mountains of Ecuador, Guatemala, Mexico, and Venezuela (Endt 1979). Generally, loquats are found between latitudes 20 and 35° North or South, but can be cultivated up to latitude 45° under maritime climates.

B. World Production

The major producing countries are China and Japan (Table 5.1). Loquats are grown in 19 provinces of China, ranging from the Yangtze River to Hainan Island (south of Hong Kong). Loquat is frequently sold at local markets in China during the fruiting season, from May to June, at a moderate price that is higher than that for citrus and banana, lower than for longan and litchi, and usually similar to that for apple and pear. In high producing areas such as Fujian and Zhejiang, fruits are shipped to Hong Kong and Shanghai, and are increasingly popular for canned products. In some areas, loquat is confined to home gardens. Loquat was cultivated on 1,700 ha in 1949 but production has increased dramatically in recent years due to the introduction of high-yielding and good-quality cultivars that ripen early enough for the fresh market.

Loquats are concentrated in Japan's warm districts, including Kyushu and Shikoku, and Chiba, Hyougo, Wakayama prefectures of Honshu. Loquat is often the most expensive fruit on the market, reflecting the high cost of production, and is now marketed over a very long season. Marketing begins in January with small amounts of the fruit and ends in July, but in exceptional years, a few fruits are marketed in November and December. More than 50% of the fruit is marketed in June. Marketing in April is increasing because of the increase in early cultivars growing under protected facilities (Fujisaki 1994). Japan was a leading producer of loquat from the beginning of this century to World War II. The crop area amounted to 4,162 ha in 1934, but declined during and after World War II, and was replaced by citrus. Protected culture has increased since the 1970s (Ichinose 1995).

Loquats are grown in northern areas of India. In Italy, loquat production is located in the central and southern coasts, and loquats are cultivated commercially in a small area near Palermo (Monastra and Insero 1991). Loquats are grown on a small scale in southeastern Spain (Galán Saúco 1986; Farré Massip 1993).

II. BOTANY

A. Taxonomy

Thunberg first described loquat in 1784 and placed it in the genus *Mespilus.* In 1822, the English botanist, John Lindley, revised the genus *Mespilus,* and established loquat in a new genus, *Eriobotrya* (from Greek, *erio-,* wool, and *botrys,* a cluster, referring to the woolly, clustered panicles) (Condit 1915; Huxley 1992). The specific epithet *japonica* was based on Thunberg's belief that the origin of loquat was Japan.

In Chinese, loquat has two common names, *luju* and *biba* (southern Chinese) or *pipa* (northern Chinese). The Japanese name of loquat, *biwa,* is undoubtedly derived from the southern Chinese name, *biba.* Loquats cultivated in Japan were called *Tang Biwa* after the Tang Dynasty, 618–907. Common names of loquat in various languages in the world are often derived from the China name or loquat's former scientific name, *mispilus*, or medlar. The English name, *loquat*, is derived from the Chinese *luju* , while the present names in French are *bibassier*, derived from *biba*, or *neflier du Japon*, literally medlar of Japan. The names in Spanish, German, and Italian are all derived from *mespilus*, e.g. *nispero japones, japanische mispel*, and *nespola giapponese*, respectively (Morton 1987). In Portugal, loquat is called *ameixa do Japao*, or plum of Japan, and in Florida it was once called Japan plum or Japanese medlar.

The number of loquat species is under dispute and the opinions of authors in different countries vary. In Japan, 20 species in the genus are estimated, but only 11 species have been well described (Ichinose 1995). *The New Royal Horticultural Society Dictionary of Gardening* lists some 10 species of evergreen shrub or trees (Huxley 1992). In several Chinese references, more than 30 species are listed, of which 14 species have originated in China and are fully described (Yu 1979; Chen 1988; Zhang et al. 1990). However, three species that have been thought to be distributed in China by non-Chinese authors were not included in Chinese publications. This situation can be attributed to the confusion involving genera of *Rosacese*. *Eriobotrya* is often confused with *Mespillus*, and sometimes with *Crataegus* and *Photinia*. For example, *E. grandiflorapy* has been placed in the genus *Mespillus*, *E. henryi* in *Crataegus*, and *E. prionphylla* in *Photinia*.

The 16 loquat species and three botanical varieties, which are clearly established, are listed in Table 5.2. Only *E. japonica* is cultivated for its fruits, but *E. deflexa* and *E. prinoides* had been used as rootstocks in China. Variegated forms of loquat have been sold as ornamentals in Europe and the United States (Morton 1987; McConnell 1988).

Peroxidase isozymes from shoot and root were clearly different among several species of loquat and can be used for *Eriobotrya* classification (Zhang et al. 1990). The loquat cultivars 'Akko 1' and 'Akko 13' were distinguished by isozyme patterns for shikimate dehydrogenase, peroxidase, and phosphoglucose isomerase. A third cultivar (whose characters are similar to 'Akko 13') grown at Zikim, Israel, was distinguished from both cultivars on the basis of its phosphoglucose isomerase banding pattern, and designated 'Zikim' (Degani and Blumenfeld 1986).

A number of widely planted cultivars had been classed as either "Chinese" or "Japanese" by some authors, based on distinguishing features that separate the two groups. For example, the Chinese group have nearly round fruits with orange flesh and small, numerous seeds, while the Japanese group have borne long-oval fruit with whitish (yellow-white) flesh and a few large seeds; however, these differences are no longer typical for each country's cultivars. Among 40 cultivars cataloged by T. Ikeda as more or less important in Japan, most were introduced from China, especially 'Mogi' and 'Tanaka', which account for 84 percent of the total area in Japan (Fujisaki 1994). Whitish flesh cultivars make up 30 percent of the number of total cultivars in China (Ding et al. 1995a), and some whitish flesh cultivars, such as 'Zhaozhong' and 'Baiyu', are the leading cultivars in Jiangsu province. There are several low-seeded cultivars, such as 'Duhe' (single seed) and 'Taicheng No. 4' (1 or 2 seeds).

Using data based on 100 characters, 50 cultivars collected from China and Japan clustered into three major groups (Liu et al. 1993). The first group was characterized by small, pale-color fruits, and consisted mainly of cultivars from Wuxian county, Jiangsu province, and from most areas of Zhejiang province. The second group consisted of cultivars with darker-colored, medium-sized fruits, mainly from Anhui province, some from Fujian province, and a few from Zhejiang province. The third group, with large, dark fruits, were cultivars from Fujian province. Japanese cultivars fell into the first two groups.

Loquats have formed different ecological types in various zones during the long course of their cultivation and climatization. Ecotypes in

Table 5.2. Loquat species and varieties.

Eriobotrya species	Representative area	References
E. japonica Lindley	Yangtze River valley	Yu 1979
E. bengalensis (Roxb) Hook.		
f. forma angustifolia	Yunnan	Yu 1979
E. cavaleriei Rehd.	Sichuan and Fujian	Yu 1979
E. deflexa Nakai	Guangdong and Taiwan	Yu 1979
var. buisanesis Kane & Sasaki	Taiwan	Huxley 1992
var. koshunesis Kane & Sasaki	Taiwan	Huxley 1992
E. elliptica Lindl.	Xizhang(Tibet)	Yu 1979
E. fragrans Champ	Guangxi	Yu 1979
E. grandiflora Rehd. & Wils	Sichuan	Huxley 1992
E. henryi Nakai	Yunnan	Yu 1979
E. hookeriana Decne	Xizhang and Sichuan	Huxley 1992
E. malipoensis Kuan	Yunnan	Yu 1979
E. obovate W. W. Smith	Yunnan	Yu 1979
E. prinoides Rehd. & Wils	Southeastern Yunnan	Yu 1979
var. *daduneensis* H. Z. Zhang	Western Sichuan	Zhang et al. 1990
E. salwineses Hand-Mazz	Northeastern Yunnan	Yu 1979
E. seguinii Card ex Guillaumin	Southeastern Yunnan	Yu 1979
E. serrata Vidal	Southern Yunnan	Yu 1979
E. tenyuehensis W. W. Smith	Western Yunnan	Yu 1979

China can be divided into two cultivar groups: the north subtropical cultivar group (NSCG) and the south subtropical cultivar group (SSCG) (Ding et al. 1995a). NSCG distributes in the mid- and north subtropical area, roughly in the provinces in the basin of the Yangtze River, located in the range of 27° to 33°, where its average annual temperature is 15°C to 18°C, with an absolute low temperature of –5° to –12°C, and 800 to 1,500 mm of annual rainfall. Snows and frost can occur. NSCG cultivars are characterized by strong cold-resistance; most of their fruits are late ripening and small but with high quality. Representative cultivars are 'Dahongpao' and 'Luoyangqing' in Zhejiang, 'Baiyu' and 'Zhaozhong' in Jiangsu, and 'Guangrong' in Anhui. In China, these cultivars have been successfully introduced to the south subtropical zones and margins of tropical zones. SSCG is located in the south subtropical zone and margins of the tropical zone, approximately in the area about 19° to 27°N, with only a few days of frost and snow or temperature lower than 0°C, and with more than 1,500 mm of annual rainfall. The SSCG cultivars have poor cold-resistance but are high yielding and early, while fruits are large but flavorless. Representative cultivars are 'Jiefangzhong' and 'Changhong No. 3' in Fujian. Flowers and fruits are injured by cold when they are introduced to the north subtropical zones. Introduction of 'Jiefangzhong' has been attempted in Zhejiang and Jiangsu several times since the 1970s, but it has not been accepted (Ding et al. 1995a).

It appears that both the first and the second groups classified by Liu belong to the north subtropical cultivar group of Ding. As the first group has the distinguishing feature of whitish flesh, cultivars in China can be divided into three groups, namely, whitish group, north subtropical group, and south subtropical group. Most cultivars cultivated in Japan belong to the north subtropical group. Several cultivars, such as 'Shiro Mogi', could be placed in the whitish-flesh group.

B. Morphology and Anatomy

The main characteristics of the genus *Eriobotrya* are as follows (Huxley 1992): leaves alternate, simple, coriaceous, coarsely dentate; petiole short; flowers small, white, in broad pyramidal, usually densely lanate-pubescent, terminal panicles; bracts deltoid-ovate, persistent; calyx 5-lobed, acute, persistent; petals 5, ovate to suborbicular, clawed; stamens 20–40; styles 2–5, basally connate; ovary inferior, each locule 2-ovulate. Fruit an obovoid to globular pome (Fig. 5.1), with persistent calyx lobes at apex; seeds (1–9) are large.

Yu (1979) described the main characteristics of *E. japonica* as follows: evergreen tree, occasionally up to 10 m; shoot density varies with culti-

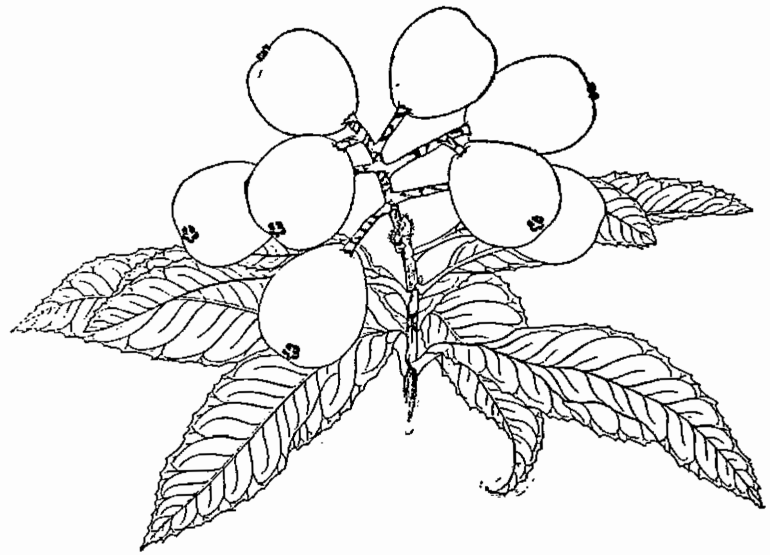

Fig. 5.1. Loquat cluster (×1/4). Source: F. W. Popenoe 1928.

var. Leaves on upper surface usually lustrous, lower surface often with pubescence; blades are narrow or broad, 12–30 cm long and 3–9 cm wide. Inflorescence 10–19 cm long, the main panicle axis bears 5–10 branched secondary axes, with 70–100 flowers, occasionally more than 100; hermaphrodite, flower size 12–20 mm. Fruit shape in longitudinal section as round, obovate, or elliptical; fruit size 2–5 cm; average weight usually about 30–40 g, some cultivars such as 'Jiefangzhong' average 70 g, the largest one 172 g, peel and flesh white or yellow; fruit apex concave, flat or convex, with calyx cavity closed or open; ease of fruit peeling depending on cultivars; thickness of flesh 0.5–0.8 cm, proportion of flesh usually 60–80%; Brix value 6.7–17°, some cultivars such as 'Huangyang No. 5' higher than 20°; number of seeds 1–8, often 3–4, each seed weight 1.1–3.6 g. The loquat has relatively large seeds, as the subfamily Amygdaloideae, but has multiple seeds as do the subfamiles Rosoideae and Maloideae.

Scanning electron microscopy of loquat revealed that the fruit skin was composed of only one layer of cells. The stomatal openings and base of trichome were surrounded by small, circular, cuticle ridges. Stomatal differentiation was completed before enlargement of young fruits, while trichomes developed up to the initial stages of fruit enlargement (Yin et al. 1994).

Trichome density and the capacity of leaf hairs to protect underlying tissues against ultraviolet-B radiation damage were assessed during leaf development (Karabourniotis et al. 1995). Trichomes density and the relative quantities of ultraviolet radiation-absorbing phenolic constituents declined considerably with leaf age.

C. Embryology

Embryogenesis of several loquat cultivars were observed in paraffin and semi-thin section with light microscopy, ultrathin section with transmission electron microscopy, and from enzymatic isolation of embryo sacs (Lin 1985, 1992; He et al. 1995). Embryo sac of loquat is the Polygonum type (Lin 1992; He et al. 1995). The first divisions of the endosperm are not accompanied by cell-wall formation, so endosperm remains free nuclear in the early stages. As the embryo develops to the globular stage, wall formation commences in the micropylar end of the embryo sac, and then the endosperm passes through an early and late dissociate nuclear stage, completely cellular-stage, followed by disintegration until elimination. When the young fruit is oblong and the peel is yellow (peel covered with yellowish trichomes), the embryo is in the globular stage and the endosperm is late dissociate nucleus cellular-stage; when the young fruit is rhomboid and the peel color is green (trichome abscission), the embryo is in the heart stage and the endosperm is completely cellular (Lin 1985, 1992).

Semi-thin sections were used to investigate the structure of female organs before and after fertilization, differentiation, and the distribution of transfer cells in the early developmental stage of the endosperm. There are papillose cells on the wet stigma and conducting tissue in the style, which contains transfer cells and annular tracheids (Lin 1992). Transfer cells are also found in locules (He et al. 1995). Some cells in the inner integument and nucellus had outstanding wall ingrowths; exo-layer cells of the endosperm were transfer cells; embryo sac and center cell all had some wall ingrowths or haustorial structures (He et al. 1995).

III. PHYSIOLOGY

A. Growth and Development

Vegetative growth is in the form of a series of flushes that occur once each season. Summer shoots are the most abundant; spring shoots, summer shoots, and sometimes autumn shoots will be flower branches; winter flushes depend on tree age and nutrition (Chen 1958). In China, flower bud differentiation occurs from July (warmer climate) to September (cooler climate). Flower differentiation in loquat is basically the same as in other Rosaceae, but the sequences of flowering in autumn and winter is of particular interest (Li 1982). In Zhejiang, China, the main axis of inflorescence panicles differentiate in the beginning of August, secondary axes in the middle or the end of August, sepals and petals in the beginning of September, stamens and pistils in the middle or end of September, and sperm nuclei and egg nuclei in October. The time span from flower bud differentiation to anthesis in November is three months. The summer lateral shoot begins to differentiate flower buds in September, one month later than the spring main shoot, but anthesis also takes place in November, the differential duration just spanning two months. Therefore, flower clusters of summer lateral shoots may be short and small, and should be thinned (Li 1982). Flowering in loquat may extend over 1.5 to 2.5 months, and fruits normally ripen about 150 to 200 days from flowering (Chen 1958). In Israel, the loquat flowers over a three-month period, which permits collection of fruit at all stages of development at a single date (Blumenfeld 1980).

Net photosynthetic rate (Pn) of loquat was low during winter, usually less than 1.5 mg CO_2 dm^{-2} h^{-1} (Ruan and Wu 1991). The highest Pn was measured in loquat during flowering; the presence of flowers increased the Pn in adjacent leaves but not basal ones. The optimum temperature for photosynthesis during winter was lower than 20°C and was depressed more after exposure to 0°C or –2°C. The light saturation point and light compensation point were 18 klx and 360 mmol $m^{-2}s^{-1}$, respectively. Photosynthetic induction of loquat leaves (45 min on a cloudy day) occurred more rapidly than that previously reported for 'Satsuma' mandarin.

The activity and abundance of flower-visiting insects of loquat were studied in Punjab, India. *Apis dorsata* (Fabr.) was the main flower visitor. Other species of insects found occasionally included syrphids, houseflies, *Myrmeleontidae, Bombinae,* and *Pieris rapae* (L.). Fruit set was 15% greater in unbagged than in bagged flowers (Mann and Sagar 1987).

The growth pattern of loquat fruit in Israel (Blumenfeld 1980) is neither sigmoidal, as in most small-seeded pome fruits, or double sigmoidal, as in stone fruits that have a large seed, but is exponential with a rapid growth toward the end of fruit development, in spring, until ripening. The maturation phase is characterized by decreasing acidity, color development, softening of the pulp tissue, sugar accumulation, and a rapid increase in the fresh weight of the pulp tissue. The fruit produces ethylene at the beginning of the maturation phase (Hirai 1980, 1982).

However, the loquat is a nonclimacteric fruit and shows no respiration climacteric rise and no peak of ethylene production either on the tree or after harvest (Blumenfeld 1980). The fruit does not abscise after ripening but shrinks on the tree.

Fruit weight was influenced by the number of days to ripening, heat summation from flowering to ripening, seed number and seed weight, but not number of leaves on bearing shoots. Seed weight was the most influential factor affecting fruit weight (Uchino et al. 1994a). Amitava and Chattopadhyay (1993) reported that fruit acidity increased up to 50 days after fruit set and then declined as maturity approached, resulting in a marked increase in total soluble solids (TSS) and sugar:acid ratios.

Leaf N, P, K, and Mg concentrations were lowest at flower initiation and highest at beginning of ripening (Ding et al. 1995b). Leaf Cu, Fe, and Mn concentration were highest at flower initiation and decreased at the beginning of fruiting. Leaf Na concentration was lowest at flowering and fruiting, and increased markedly before and after harvest ripening. Macroelement concentrations in fruits were in the order N > K > Ca > Mg > P; microelement concentrations were in the order Fe > Zn > Mn > Cu. Burló et al. (1988) proposed a method to predict total nutrient content in fruits at various stages based on fruit weight. In Taiwan, soluble carbohydrate in the leaves and soluble solids in the juice decreased as the N content of the leaves of non-fruiting shoots increased. Leaf Ca content of both shoot types was higher at the flower bud stage than at the young fruit stage. Fruit of loquat grown in some areas were larger, and had higher acid contents and lower ratios of solids to acids than fruits from other areas (Fan 1987a,b). In India, deficiency symptoms of 'Golden Yellow' grown in the greenhouse appeared after one year and increased in severity in succeeding growth flushes; characteristic symptoms of deficiency were described for C, P, K, Ca, Mg, and S (Singh and Lal 1990). Critical limits for C, P, K, Ca, and Mg have been suggested for loquat orchards in Italy (Crescimanno and Barone 1980).

B. Chemical Composition

Chemical composition of loquat fruit is presented in Table 5.3. In various cultivars, sucrose, sorbitol, glucose, and fructose varied almost 6-fold, but total sugars varied less than 2-fold (Kursanow 1932; Ito and Sakasegawa, 1952; Hirai 1980; Uchino et al. 1994b). Sucrose accumulated faster than any other sugars at the beginning of fruit maturation and became the predominant sugar in ripe fruit (Hirai 1980), while sorbitol, predominant during fruit development, was reduced to a minor component in ripe fruit. Glucose and fructose contents increased as color intensity increased (Hirai 1980).

Table 5.3. Chemical composition of loquat (Church et al. 1935).

Variable	Cultivar		
	Champagne	Advance	Thales
Moisture (%)	85.0	84.7	86.1
Total solids (%)	15.0	14.3	13.9
Insoluble solids (%)	2.3	2.7	2.4
Soluble solids (%)	12.7	11.6	11.5
Total acid (%)	0.4	0.5	0.7
Total malic acid (%)	0.3	0.3	0.5
Protein (%)	0.4	0.4	0.4
Ether extract (%)	0.2	0.2	0.2
Reducing sugars (%)	6.7	5.7	6.1
Sucrose (%)	3.4	3.4	2.4
Total sugars (%)	10.1	9.1	8.5
Alcohol ppt (%)	0.6	0.7	0.9
Pectic acid (%)	0.3	0.4	0.4
Total ash (%)	0.5	0.5	0.5
Soluble ash (%)	0.4	0.4	0.4
Insoluble ash (%)	0.1	0.1	0.1

Malic and citric acid levels increased with fruit maturation, and then decreased, with citric acid decreasing at a faster rate. Traces of tartaric acid that disappeared with maturation were found in green fruit (Kursanow 1932; Church and Sorber 1935; Rajput and Singh 1964).

Loquat flesh contained 0.42 g crude protein/100g fresh wt, 146 mg essential and 387 mg total amino acids (Hall et al. 1980). Ten essential amino acids were measured, with leucine the most abundant and cysteine-cystine the least abundant. Of the eight nonessential amino acids measured, glutamic and aspartic acids were the most abundant, with an unusually high level of proline (9.7 g per 100 g recovered amino acids).

The profiles of lipids, long-chain hydrocarbons, desmethyl sterols, and fatty acids were determined by gas-liquid chromatography (GLC). Long-chain hydrocarbons varied from C_{21} to C_{31}. Major sterols included β-sitosterol, campestol, isofucosterol, and cholesterol, in order of their prevalence. Fatty acids consisted of palmitic, oleic, linoleic, linolenic, and stearic (Nordby and Hall 1980). Loquat seeds yielded 0.1% lipids and consisted of 3.1% hydrocarbons, 5.3% wax esters, 78.6% triglycerides, and 13% (polar fraction) fatty acids, coloring matter, and other compounds. After saponification of the fat, the fatty acids C_{12}-C_{24} and fatty alcohols C_{12}-C_{26} were identified by GLC (Raie et al. 1983).

The carotenoids of loquat fruit are mainly responsible for flesh and skin color, which varied from yellowish white, yellow to deep orange (Sadana 1949; Gross et al. 1973; Lin and Li 1985; Godoy and Amaya 1995). Total carotenoid values, especially carotene, varies widely in fresh fruit peel and pulp. Total carotenoid values in the peel are several times higher than in the pulp (Gross et al. 1973; Lin and Li 1985). The content of carotene in yellow-orange fruit was 5–10 times higher than in the yellow-white fruits, while the contents of zeaxanthin, lutein, and violaxanthin in yellow-orange fruit were much lower (Lin and Li 1985). The carotenoid compositions in Brazil cultivars were identified by Godoy and Amaya (1995) as follows: β-carotene (7.8 mg/g), ζ-carotene (0.1 μg/g), neurosprence (1.1 μg/g), β-cryptoxanthin (4.8 μg/g), 5,6-monoepoxy-cryptoxanthin (0.6 μg/g), violaxanthin (1.6 μg/g), neoxanthin (0.8 μg/g),and auroxanthin (0.9 μg/g). Betacarotene and β-crytoxanthin were the principal pigments, being responsible for 44 and 27%, respectively, of the total carotenoid content (17.6 μg/g) and were also the principal contributors to the vitamin A value of 175 RE/100 g. Loquat fruits also contain a number of small carotenoids such as phytofluene, mutatochrome, carbonyl, and cryptoflavin (Gross et al. 1973).

Eighteen volatile compounds were identified in a methylene chloride extract of a distilled fraction from loquat fruit. The major components, phenylethyl alcohol, 3-hydroxy-2-butanone, phenylacetadehyde, and hexen-1-ols, and the minor components, ethyl acetate, methyl cinnamate, and β-ionone, contribute to the fruity-floral flavor of the fruit (Shaw and Wilson 1982).

Loquat is a cyanogenic plant and contains three cyanide metabolizing enzymes: β-cyanoalanine synthase, rhodanses, and formamide hydrolase (Miller and Conn 1980). Loquat tannin was a proanthocyanidin oligomer (Matsuo and Ito 1981). A few specific organic components, 4-methylene-D,L-proline and trans-4-hydroxymethyl-D-proline, have been identified in seeds (Gray 1972; Gray and Fowden 1972).

C. Plant Growth Regulation

In China, loquat fruit growth occurs in three stages and levels of phytohormones have been analyzed during each stage (Ding and Zhang 1988). In stage I, the stage of slow fruit growth, from December to the middle of February, indoleacetic acid (IAA), abscisic acid (ABA) and cytokinin are maximal. In stage II, the cell division stage from the end of February to the end of March, ABA decrease gradually to a minimum, while ethylene, which appears at the end of stage I, increases gradually to a maximum and then gradually decreases. IAA and cytokinin reach a second peak at the end of stage II. In stage III, the stage of rapid enlargement of fruits in the middle of April to fruit maturation, IAA and cytokinin are at a minimum, ABA increases again, and ethylene appears at a second peak (Ye 1988).

Endogenous gibberellins in the immature seed and pericap of loquat were first confirmed by Japanese scientists (Yuda 1987; Koshioka et al. 1988). Gibberellins, including GA_9, GA_{15}, GA_{19}, GA_{20}, GA_{29}, GA_{35}, GA_{44}, GA_{50}, and GA_{61}, were identified by capillary gas chromatography/selected ion monitoring in immature loquat seeds. Five unknown GA-like compounds with apparent parent ions of m/z 418, 504, or 506 (as methyl ester trimethylsilyl ether derivatives) were also found in the biologically active fractions. The m/z 418 and 504 compounds may have been C-11 β-hydroxylated GA_9, and dehydro-GA_{35}, respectively. The bioassay and GC/MS results suggest that the major gibberellins were GA_{50} and five unknown GA-like compounds. In the immature seeds, at least two GA metabolic pathways may thus exist, one being the non-hydroxylation pathway of $GA_{15} \rightarrow GA_{24} \rightarrow GA_9$, and the other C-13 hydroxylation pathway of $GA_{44} \rightarrow GA_{19} \rightarrow GA_{20} \rightarrow GA_{29}$. A late C-β-hydroxylation pathway is also possible (Koshioka et al. 1988). Besides GA_9, GA_{15}, GA_{35}, and GA_{50} mentioned above, GA_{24}, GA_{25}, GA_{48}, and GA_{80} were identified by Yuda et al. (1992). Two of them were determined to be new gibberellins: GA_{80} (11 β-hydroxy-GA_7), and GA_{48} (11 β-hydroxy-GA_9). Based on these results, an early 11-hydroxylation biosynthetic pathway is suggested in the loquat seeds (Yuda et al. 1992). Synthesis of the methyl ester was used to confirm the structure of the new 11 β-hydroxy, GA_{84}, which isolated together with another gibberellin, GA_{80}, from seeds of immature loquat fruits (Kraft-Klaunzer and Mander 1992).

1. Growth Control. Paclobutrazol (PP_{333}) was applied as foliar sprays to three-year-old 'Jiefangzhong' trees or direct to their soil (Pan et al. 1995). Four treatments were compared: soil application at 1.0 or 1.5 g m^{-2} of canopy, foliar application at 500 mg L^{-1} (three times at monthly intervals), and a control. Soil application was inferior to foliar application with regard to advancement of flowering. In the second year, the effect of soil treatment was significant; of the three PP_{333} treatments, percentage flowering was highest for the 1 g m^{-2} application rate. In the third year, fruit yields/tree were 23.5 kg (336%), 9.9 kg (84%) and 10.7 kg (90%), respectively, compared with 5.4 kg for the control. Results obtained in Italy showed that PP_{333} reduced fruit yields but increased fruit size, with no significant effect on juice pH and total soluble solids (TSS) (Pilone and Scaglione 1996).

2. Pollen Germination. The effects of naphthaleneacetic acid (NAA), GA_3, and IAA in combination with B, Ca, and Mn were analyzed on 8–10-year-old trees of several cultivars for three years. GA_3 and NAA at 1–100 ppm, boric acid and $MnSO_4$ at 1–100 ppm, and IAA at 0.1–1.0 ppm all had good effects on pollen germination (Ding et al. 1991). Eti et al. (1990a) reported that the germination rate of pollen was related to percent fruit set. Pollen germination was highest in 10% sucrose (Singh 1963; Singh et al. 1979).

3. Fruit Set. Fruit set was increased by 54 to 120% in various cultivars treated with plant growth regulators (Ding et al. 1991). Best results with regard to fruit set and fruit quality were obtained with GA at 60 ppm (Singh and Shukla 1978). Mature loquat trees sprayed when fruits were at the pea stage and again one week later with NAA, 2,4,5-T, or GA_3, each at 10, 20, or 40 ppm, ripened about 10 days earlier than with GA_3 at 10 ppm, gave the best fruit retention (88.5%) and greatest fruit volume (20.6 cm^3), weight (19.5 g), and pulp content (15.9 g/fruit), and lowest seed total weight (3.6 g/fruit). NAA at 40 ppm gave the highest TSS (13.5) and reducing sugars (8.6 mg/100 g), and lowest acidity (0.9%) (Chaudhary et al. 1990, 1993).

4. Fruit Thinning. NAA and NAAm (naphthaleneacetamide) applications (25, 50, or 100 ppm) effectively thinned loquat fruits. Optimum level of thinning was obtained with 25 ppm. The effects of thinning on fruit growth varied with cultivar. Fruits on thinned branches developed more rapidly than non-thinned controls in all cultivars. Thinning had no effect on fruit shape (Eti et al. 1990b; Kilavuz and Eti 1993).

5. Induction of Seedlessness. Several groups of scientists have applied GA to induce seedless fruits (Kumar 1976; Blumenfeld 1980; Kihara 1981; Muranishi 1982; El-Zeftawi and Goubran 1983a; Goubran and El-Zeftawi 1986; Fan 1989; Takagi et al. 1994). Goubran and El-Zeftawi (1986) reported that GA at 250 ppm applied after the emergence of floral buds or NAA at 20 ppm applied during full bloom produced seedless fruits. Seedless fruits were smaller, elongated, and matured four to five weeks earlier than seeded fruits. The reduced size was related to early maturity, as much of the fruit weight increase normally occurs just prior to maturation. It is suggested that seedless loquats need further treatment to increase fruit size. GA_3 applied at 250–500 ppm after emergence of the floral buds in mid-October resulted in the production of seedless fruits with a high flesh content. Seedless fruits were smaller, more elongated and matured about five weeks earlier than seeded fruits. TSS was increased in seedless fruits receiving a second growth regulator [GA_3 + benzyladenine (BA)] (Fan 1989). Spraying loquat clusters with an aqueous solution of 500 ppm GA_3 or 500 ppm GA_3 + 20 ppm kinetin greatly stimulated frost-induced seedless fruits to attain the same size as seeded control ones. The GA-treated seedless fruits were more slender but had a thicker pulp than seeded untreated fruits. Application of GA_3 + kinetin was more effective for enlargement than a single application of GA_3. If sprayed immediately after a frost, the enlargement response of the seedless fruits was significant. Although treated seedless fruits turned yellow earlier, the total soluble solid content in the juice at harvest was slightly lower than that of seeded fruits. No difference in titrable acidity was found between the treated and control fruits (Takagi et al. 1994).

D. Sorbitol Physiology

Loquat, like other rosaceous fruits, utilizes sorbitol as the main metabolite of photosynthesis (Hirai 1979, 1980, 1983; Nii 1993; Nii et al. 1994; Lin et al. 1995). Sorbitol and sorbitol-6-phosphate dehydrogenase (a sorbitol-utilizing enzyme) activity were surveyed in the leaves of mature loquat trees (Hirai 1983). The enzyme activity increased in late autumn and sorbitol content increased in early winter, both reaching maximums in winter and decreasing in spring. In seedlings, the increase in enzyme activity was induced by low temperature. Photoperiod did not affect enzyme activity. During the development of spring leaves, enzyme activity increased during the period in which a leaf had nearly reached its maximum size, the period during which young leaves depend on imported sorbitol from mature leaves. Enzyme activity was considered to be controlled mainly by the amount of enzyme in leaf tissue (Hirai 1983).

Although sorbitol content increased during fruit development (from 7 mg/per young fruit in March to about 50 mg/per mature fruit), its percentage relative to total sugar (sucrose, glucose, and fructose, which increased from 0 mg/per young fruit in March to about 500–1000 mg/per mature fruit) decreased during development and maturation (Hirai 1979). Sorbitol in globular, torpedo-shaped, and cotyledonary embryos were 5.7, 11.5, and 17.9 mg/g, respectively. Sorbitol increased gradually, while none of the other sugars increased, but D-galactose decreased from 29.7 to 10.7 mg/g (Lin et al. 1995b). In fruits, sorbitol accumulation paused in the middle of May and resumed after the color-change of the fruit. The regulatory mechanism of the accumulation is unknown, but interconversion between sugar alcohol in the fruit may be a factor in the carbohydrate accumulation.

Sorbitol may play an important role in morphogenesis in vitro. Protoplast cultures, cultured in the medium supplemented with a 3 percent or higher level of sorbitol, differentiated shoots (Lin and Chen 1996a). The relationship between sorbitol metabolism and morphogenesis requires further investigation.

Some related enzymes such as sorbitol-6-phosphate dehydrogenase have been surveyed. The activity of sorbitol-6-phosphate dehydrogenase both in leaf and in fruit increased before the increase of the sorbitol content (Hirai 1979, 1981, 1983), suggesting that sorbitol metabolism is regulated by sorbitol-6-phosphate dehydrogenase (Hirai 1983). Callus cultured in the medium added with sorbitol increased activity of D-sorbitol dehydrogenase and were richer in organelles (Lin and Chen 1997).

Some cells with distinct structural features may be related to the transport of sorbitol. Loquat, like other rosaceous fruit trees, show thickening of the sieve elements in vascular bundles of several organs. The ingrowth thickening, referred to as nacreous wall formation, was completely different from the apparatus of the transfer cell in other species (Nii 1993; Nii et al. 1994). In reproductive organs, not only outstanding wall ingrowths but transfer cells were found (Lin 1992; He et al. 1995). There may be a relationship between the degree of ingrowth of the nacreous cell and the transported soluble carbohydrate (Nii et al. 1994), and between distribution of the transfer cell and its role in the transport of sorbitol and other nutrients (He et al. 1995).

E. Temperature Response

Flowers and fruits of loquat show increasing injury from flower state to early fruit. Ovules in the early fruits are killed by brief exposure to –4°C (Yang 1963). Pollen could be stored at –23°C for 26 months (Singh 1963).

Loquats were undamaged in southern Florida during January 1977, when temperatures fell to –6.7°C for 12–14 h on three consecutive nights (Dawes 1980), and in the San Giuliano region of France when freezing temperatures occurred every night from January 2 to 12, 1985, with an absolute minimum of –6°C (Vogel 1986). In Mokpo, Republic of Korea, cold injury to fruits was 10% after exposure to –2°C, 40–49% at –3°C, and 95–100% at –4°C. At –3°C, smaller fruits (diameter < 9.5 mm) were more susceptible to cold injury than larger fruits. The conductivity rate of immature fruit exposed to cold temperatures increased as fruit diameter decreased. The freezing temperature of immature 'Mumok' ('Mogi')

fruits, with diameter of 7.5, 8.0, 9.0, 10.2, and 11.2 mm, were –1.4, –1.5, –1.7 and –1.8°C, respectively. High contents of reducing sugars and unsaturated fatty acids were associated with decreased freezing injury (Park and Park 1995).

Campbell and Malo (1986) reported –12°C as the critical temperature for wood hardiness and –3°C the killing temperature for young fruit. The latter is the limiting factor for regular cropping in Florida and much of California. In tropical regions, adaptation is obtained at altitudes from 900 to 2100 m.

F. Medicinal Value

Loquat has been considered to have health benefits in traditional medicine and there is now evidence of therapeutic effects. The ether-soluble fraction of the ethanolic extract of the leaves showed anti-inflammatory activity when applied topically to rats (Shimizu et al. 1986). Ursolic acid, maslinic acid, methl maslinate, and euscaphic acid were isolated from this fraction. Maslinic acid was shown to be at least partly responsible for the anti-inflammatory activity of the extract.

Loquat leaves have been used for the treatment of skin diseases and diabetes mellitus. The alcoholic extract of the leaves produced a significant hypoglycemic effect in normal, but not in alloxan-treat rabbits, but the effect was short-lived, lasting only for 3 h (Noreen et al. 1988). Comparison with the effect of tolbutamide indicated that the hypoglycemic effect of the extract was probably mediated through the release of insulin from pancreatic beta cells. Later, a new polyhydroxylated triterpene was isolated, as well as three known triterpenes. The new compound was identified as 3β,6α,19α-trihydroxyurs-12-en-28-oic acid (Liang et al. 1990). Seven glycosides, five of which are new natural products, were isolated from the methanol extract of leaves collected in Italy (De Tommasi 1992a). The three new sesquiterpene glycosides have nerolidol or isohumbertiol as aglycones, and two of these have branched oligosaccharidic chains made up of one β-L-glucopyranosyl and three α-L-rhamnopyranosyl units that link transferuloyl ester moieties. Analysis of the oligosaccharide structures was achieved by 2 D spectral analysis. The two new ionone-derived glycosides isolated from the extract were characterized by chemical and spectral methods. An alcoholic extract has been shown to exhibit anti-inflammatory and hypoglycemic effects. The $CHCl_3$ extract of leaves from an Italian source contained four new triterpene esters, namely, 23-trans-p-coumaroyltormrntic acid, 23-cis-p-coumaroyltormrntic acid, 3-o-trans-caffeoyltormentic acid, and 3-o-trans-p-coumaroyltormrntic acid, in addition to three common ursolic acid derivatives. Spectral data were used to elucidate their structures. An investigation of the antiviral properties of these compounds revealed that only 3-o-trans-caffeoyltormentic acid significantly reduced rhinovirus and was ineffective towards human immunodeficiency virus type I (HIV-I) and Sindbis virus replication (De Tommasi 1992b).

Loquat fruits contained low levels of B vitamins, including thiamine, riboflavin, and niacin (Shaw and Wilson 1981). For at least 40 years, Chinese food stores in the United States have sold a product imported from Hong Kong and recommended for chronic bronchitis, coughs, and lung congestion. Contents are listed as loquat leaves with other herbs (Duke and Ayensu 1985; Wee and Hsuan 1992).

IV. HORTICULTURE

A. Crop Improvement

1. Ploidy Manipulation. The number of chromosomes in loquat cultivars cultivated in China are all $2n = 2x = 34$ (Lu and Lin 1995). Tetraploidy was reported in India, and was also attained from colchicine treatment (Kihara 1981), and triploidy was derived from $2x \times 4x$ (Huang 1984, 1989) and by endosperm culture (Lin 1985; Chen and Lin 1991). Hybrids between *E. japonica* and *E. deflexa* were obtained and clearly resembled *E. deflexa*. Hybrids among cultivars are cross compatible. Most of the cultivars are self-fertile, but several cultivars in the United States are self-infertile (Morton 1987). A sterile plant that sets small fruits with no or few seed was found in Fujian (Lu 1984; Lu and Lin 1995).

2. Hybridization and Selection. Progenies between clones of loquat with round fruit and oblong fruit segregated ranging from round to oblong. Orange flesh appears incompletely dominant to white flesh fruit, indicating that the characteristics may be controlled by several pairs of genes (Zheng et al. 1993a).

Most major cultivars are derived from chance seedlings (Huang et al. 1990), but breeding programs based on hybridization have been initiated, and several cultivars have been released in China, such as 'Zaozhong No. 6', 'Zhongjing', '82-6-26', while 'Nakasakiwase', 'Obusa' (Fujisaki 1994), 'Suzukaze', and 'Yogyoku' (Y. Sato, pers. commun.) have been released in Japan. 'Jiefangzhong', bearing large fruits, has been a popular parent in China and is the parent of three cultivars (Huang et al. 1993; Ding et al. 1995a). Cross-pollination is most successful with flowers of the second flush. Early and late flushes have abnormal stamens, very little viable pollen, and result in poor setting and undersized fruits (Morton 1987).

There are many cultivars or selections in various provinces of China (Table 5.4). For example, there are 83 cultivars (or selections) in Zhejiang, 78 in Fujian, 57 in Jiangsu, 31 in Anhui, 18 in Hubei, 18 in Guangdong, 14 in Guangxi, 10 in Hunang, 10 in Jiangxi, and 9 in Sichuan (Zhang et al. 1990). The largest collection of germplasm, more than 250 cultivars, is located in Fuzhou, China. Most of the cultivars cultivated in Taiwan and the United States derived from materials introduced from Japan.

Although more than 10 cultivars are grown in Japan, three cultivars account for 95% of the total area: 'Mogi' (62%), 'Tanaka' (22%), and 'Nakasakiwase' (11%), followed by 'Obusa' (2%). 'Tanaka' was introduced prior to 1900 to the United States and Israel, and has now been introduced to Algeria (Lupescu et al. 1980), Brazil (Godoy and Amaya 1995), India (Testoni and Grassi 1995), Italy (Monastra and Insero 1991), Spain (López-Gálvez et al. 1990), and Turkey (Polat and Kaska 1992a–e), as well as China. The major cultivars of loquat in the world are presented in the Table 5.4.

3. Biotechnology

Endosperm Culture. Endosperm culture has been pursued in order to obtain triploids that might be seedless. The cellular-shaped endosperm inoculated into B5 medium supplemented with 2,4-D and LH medium for two weeks to one month produced callus but induction rate was low. Somatic embryos at various developmental stages appeared on the surface of some callus when the medium was supplemented with 0.1 mg/L 2,4-D. By ultra-thin sectioning, it was found that embryonic cells with much thicker walls, denser protoplasm, and smaller vacuoles from surrounding cells divided and differentiated into embryoids (Chen et al. 1983).

Somatic embryos developed similar to zygotic embryos, but cotyledons grew slowly. Normal shoots differentiated on MS supplemented with zeatin (0.25 mg/L) and NAA (0.1 mg/L). Roots were produced when new shoots were transferred into MS medium supplemented with IBA (0.4–0.5 mg/L). (Lin 1985, 1987). The chromosome number of these plants was close to triploid ($2n$ = 45–50) (Chen et al. 1991), but all triploids (100 plants) died before fruiting.

Embryo Culture. Mature embryos are easily cultured (Zhuan 1980). Two months after pollination, the embryos were 6–8 mm long and all organs

Table 5.4. Major cultivars in the main producing areas of the world.

Country	Area	Name of cultivar	Origin	Outstanding characteristics
Australia		Bessel Brown		Large fruit, acceptable taste, high flesh:seed ratio
		Enormity		Large fruit, acceptable taste
		Victory		White to cream-colored flesh, juicy, sweet
Brazil		Nectar de Cristal	Obtained by open pollination of Togoshi (Japan), 1970s	High yield, fruit uniformity
		Parmogi	Obtained by open pollination of the Mogi (Japan), 1970s	High yield, pleasant taste
		Mendes da Fonseca		Large fruit
		Precoce de Itaquera	Selected from Japanese seedling	Very productive
China	Zhejiang	82-6-26	From Jiefangzhong × Baozhu, 1982	Cold-resistance, large fruits, good eating quality
	Jiangsu	Baiyu	Selected from seedling of Baisha, 1980	Yellowish-white flesh, fruit uniformity, good keeping quality
	Fujian	Changhong No. 3	Selected from a natural hybrid seedling of Changhong, 1990	Elongate-obovate fruits, weighing 50 g, ripening in mid-April; high and stable yield
	Zhejiang	Dahongpao	An old seedling cultivar	Strong growth vigor, stable yield
	Jiangxi	Duhe (one seed)	Introduced from unknown cultivar, 1958	High yield, single seed, medium eating quality
	Anhui	Guangrong	Selected from seedling of Dahongpao	Vigorous growth, stable yield, quite large fruit, good keeping quality
	Hubei	Huaboa No. 2	Selected from Baisha	Cold-resistance, stable yield, good eating quality
	Fujian	Jiefangzhong	Selected from Dazhong seedling, 1950	Large fruits, average 70 g with some fruits as large as 172 g; high yield
	Zhejiang	Loyangqing	Selected from Dahongpao, 1980s	Strong disease resistance, high and stable yield, good keeping quality
	Hunang	Yuanjiang	An old seedling cultivar	Strong flavor, good eating quality
	Fujian	Zaozhong No. 6	Jiefangzhong × Moriowase, 1992	Ripening in the beginning of April, average 53 g, attractive, good quality
	Jiangsu	Zhaozhong	Selected from seedling of Baisha (white peel)	Yellowish-white flesh, juicy, Brix 12°, good eating quality
Egypt		Golden Ziad	Selected from seedling of Premier	High yield, early season seedling
		Moamora Golden Yellow	Selected from seedling of Premier	High yield
India		Pale Yellow		Fruit large, flesh white
		Safeda		Flesh cream-colored, early to midseason
		Thames Pride		Bears heavily, early in season, juicy, canned commercially
Israel		Akko 13	Japanese origin	Early in season (March), juicy, agreeable flavor, good keeping quality, needs cross-pollination
		Tsrifin		Bears regularly and abundantly, excellent quality, stores well
Italy		Nespola di Ferdinando	Released from breeding program, 1980s	
		Nespola di Francesco	Released from breeding program, 1980s	
		Nespolo di Palarmo		Superior in flavor

Table 5.4. Major cultivars in the main producing areas of the world.

Country	Area	Name of cultivar	Origin	Outstanding characteristics
Japan	Kyushu	Mogi	From a chance seedling of Chinese loquat introduced from China in 1840	Prone to cold damage, harvest in May, fruit 50–60 g, excellent quality
	Honshu	Tanaka Shikoku	From a seed brought to Tokyo from Nagasaki, 1888	Harvest in May, fruit weighing 60–70 g, good keeping quality
	Kyushu	Nakasaki-wase	From Mogi × Hondawase, 1976	Prone to cold damage, very early ripening, excellent quality
	?	Obusa	From Tanaka × Kushioki, 1967	Fruit 70 g, good keeping quality, resistant to insects and diseases
Turkey		Gold Nugget	A clone of Tanaka obtained in California, 1888–1890	Juicy, sweet flesh, apricot-like flavor, good keeping, ships well
		Hafif Cukurgobek		Sweet, juicy; pleasant in flavor
United States	California	Advance	A seedling selected, 1897	A good pollinator
	California	Champagne	Selected and introduced, 1908	Juicy, excellent flavor, good for preserving
	California	Eulalia	A seedling of Advance, 1905	Early in season, very juicy
	Florida	Fletcher	Parentage unknown, introduced 1957	Good keeping quality and flavor
	California	MacBeth	Chance seedling, 1966	Flavor pleasing, low acidity, small seed
	Florida	Oliver	? Tanaka hybrid	Best cultivar for southern Florida
	California	Premier	Originated in California, 1899	Flesh whitish, juicy, agreeable flavor
	Florida	Wolfe	A seedling of Advance, released 1965	Pale-yellow flesh, excellent flavor, stable yield, resistant to bruising

were differentiated. After three days of culture on MS medium in the dark, the embryo enlarged slowly, and then cotyledons opened. Cultures were transferred to light when plumules grew longer than cotyledons. Cotyledons and plumules rapidly turned dark green, after which plumules developed into a main shoot and two laterals and some radicles gradually developed and formed a root system. Cultured mature embryos can easily be subcultured from microcuttings after excising the shoot tip. This technique can be used to multiply genotypes obtained from hybridization (Lin et al. 1989; Lin 1991).

Several research groups have succeeded in producing embryogenic callus from immature zygotic embryo of *E. japonica* (Ho 1983; Ho et al. 1986; Teng and Chen 1986; Lin et al. 1989; Lin 1991) and *E. prinodes* (Lin and Lin 1993). The key step to establishing embryogenic callus is to balance BA and 2,4-D concentrations (Ho et al. 1986; Teng and Chen 1986; Lin et al. 1989; Lin 1991).

Protoplast Culture. Embryogenic callus derived from torpedo-shaped embryos was the optimum material for protoplast isolation (Lin et al. 1989; Lin 1991, 1995). A combination of 2% pectinase and 1% cellulase, combined with 12% mannitol as an osmotic agent, yielded 10^7 protoplasts/g of callus with 95% survival (Lin and Chen 1996a). Sorbitol was less efficient than mannitol as an osmotic agent. The first mitosis was observed four days after protoplasts were cultured in MS liquid medium supplemented with sucrose in several concentrations, and colonies were subsequently formed (Lin and Chen 1994). Protoplast of *E. prinodes* were also successfully isolated and cultured to form colonies (Lin et al. 1994). Colonies formed little callus in agarose medium. Shoots differentiated when callus was transferred into the medium supplemented with 3% or 5% sorbitol and developed when the shoot was cultured in MS salts (half strength macroelements) supplemented with 2 mg/L zeatin. At 4 mg/L IBA, 80% of shoots rooted with 5.7 roots per shoot and 90% rooting was achieved by another transfer to 1 mg/L IBA after 10–15 days (S. Q. Lin and F. X. Chen 1996a). In vitro-produced plants of two cultivars, 'Jiefangzhong' and 'Baili', derived from protoplast cultures, were successfully transplanted to soil (Lin 1995; Lin and Chen 1996a).

Genetic Transformation. Cotyledons were inoculated with *Agrobacterium*, *A. tumefaciens*, and *A. rhizogenes*, and octopine and nopaline were identified from the subcultured callus, indicating that Ti plasmid had been transferred into callus (Li et al. 1991). There has been no report on target gene transformation.

B. Propagation

1. Seed. Propagation by seed has been the traditional practice in many producing countries, and is still occasionally used in China and Japan. Although seedling plants are long lived, this method cannot be recommended because of genetic segregation. However, seedlings are often used as rootstock.

Loquat seeds remain viable for 6 months if stored in partly sealed glass jars under high humidity at room temperature; the best temperature for storage is 5°C. Seeds are washed and planted in flats or pots soon after removal from the fruit and seedlings are transplanted to nursery rows when 15–17.5 tall. Seedlings are ready to be topworked when the stem is 1.25 cm thick at the base (Morton 1987).

2. Vegetative

Graft. The rootstock generally is *E. japonica* itself, although *E. deflexa* and other species, even *Photinia serrulata,* have been used for rootstocks in China. Loquat seedlings are preferred over apple, pear, quince, or pyracantha rootstocks under most conditions in Turkey (Polat and Kaska 1992e). Quince and pyracantha may cause extreme dwarfing. Dwarfing on quince rootstocks has encouraged expansion of loquat cultivation in Israel since 1960. The growing of dwarf trees greatly reduces the labor of pruning and flower- and fruit-thinning, bagging, and later, harvesting. Quince rootstock, which tolerates heavier and wetter soils, is widely used in Egypt (Morton 1987).

Chip, patch, and T (shield) buddings performed at 15-day intervals from 15 January to 15 May were evaluated in Turkey (Polat and Kaska 1991, 1992d). March was the most suitable month for budding, with 95% bud take. Patch budding was more successful than T and chip budding, but the strongest scion shoots were obtained with chip budding.

The Chinese have used cleft grafting on large loquat trees for centuries and this method is still used in Japan for cultivar change. An improved method, called a *young stock cleft graft,* was developed in Fujian, China (Huang 1978) and more than one million plants per year were produced by this method in Putian county alone. Using 1-cm-diameter stock, cleft grafts are made and held tightly in place with parafilm strips. Because there were several leaves under the graft position, the scion grew quickly and the shoot reached 60–70 cm by autumn; survival rates were higher than 80%.

Veneer grafting is commonly practiced in Japan (Sato 1996) and in Jiangsu, China, and has proved to be a superior method in Pakistan.

Scion are usually grafted to two-year-old seedlings in spring prior to active sap flow. Scions begin budding out about one month after grafting. Whip and tongue and bridge grafting have been practiced in some producing areas of China.

Cutting. In Japan, January cuttings dipped in IBA solution were rooted under mist installation, but survival rate usually was lower than 50%. In Egypt, 65% of cuttings of 'El-Soukari' (25 cm long with 4 or 5 leaves) rooted when dipped for 10 s in 4,000 ppm IBA solutions, and placed in a 1 sand:peatmoss medium under mist. (El-Shazly et al. 1994). In China, 70% rooting was obtained when cuttings were placed in a 1 soil:1 sand mix (W. Lin 1996, pers. commun.).

Air Layering. In China, many farmers successfully propagate selected clones of loquat by air layering (Hu et al. 1988).

Micropropagation. Loquat has few buds and so rapid multiplication by conventional vegetative propagation is a problem. Chinese scientists have developed effective and successful micropropagation using shoot-tip culture (Yang et al. 1983; Yang 1984; Chen et al. 1991, 1995; Chen and Lin 1995; Lin and Chen 1996b). Most of propagules derived from shoot-tip cultures have performed better than grafted plants and a steady flow of plants has been supplied to farmers.

Successful micropropagation was achieved from axillary shoots derived from shoot-tip cultures (Yang et al. 1983). When the terminal bud was removed, lateral buds could be induced to develop by cytokinin. The optimum level of BA was 1.5–2 mg/L, producing multiplication rates of 4.25 per month. Rooting is achieved by transferred shoots to 1/2 MS basal medium after immersing the shoot in 100 mg/L IBA. The average survival rate of transplanted plants was 96%(Yang 1984).

There are reports of shoot formation from callus derived from shoot-tip culture (Ho et al. 1986; Higashi and Kuwahata 1989). Embryogenic callus was obtained from 1–2 mm shoot-tip dissected from late fall or winter buds on MS agar medium supplemented with 1 mg/L thiamine, 0.5–2.0 mg/L 2,4-D, and 0.05–1.0 mg/L BA. The differentiation of somatic embryo occurred on the surface of embryogenic callus that germinated on MS medium (Ho 1983). Embryos with secondary embryogenic callus were formed when embryogenic callus was transferred into induction medium (Ho et al. 1986).

C. Field Culture

1. Orchard Establishment. Loquat is a long-lived tree and orchards over 30 years old remain productive. Thus, location and site selection are important in planning orchards. In China and India, loquats are grown at elevations up to 2000 m. In Japan, loquats are grown on hillsides to obtain the benefit of good air flow (Kozaki et al. 1995). In more tropical regions, the tree thrives and fruits well at elevations between 900 and 1200 m, but bears little or not at all at lower levels (Campbell and Malo 1986; Morton 1987).

Winter temperature should be higher than −3°C, and summer temperature not over 35°C. The tree requires 1000–1200 mm of rainfall annually and a suitable level of humidity. Soil should be deep and well drained, with an adequate content of organic matter. Sand loams or clay loams with a pH of 5.0 to 8.0 are considered appropriate, with pH 6.0 being optimum.

Nursery plants must be transplanted before the growth of spring buds, depending on climate. In China, leaves on the base of nursery plants are removed and the root system is often dipped in mud. Before planting, well-fermented manure is added to planting holes.

Loquats are planted at a density of about 500–600 trees/ha, but some cultivars with vigorous and spreading character are established at about 450 trees/ha (about 5 m between rows and 4 m between trees). In Japan, standard plant distance is 5 to 7 m (Sato 1996). In Brazil, a spacing of 7 × 7 m is recommended on flat land, 8 × 5 (or 6) m on slopes. In Putian county, Fujian province of China, loquat is spaced 6 m between rows and 3 m between trees with longan, a tree with a long juvenile period, interplanted 6 × 6 m. Loquat produced the same yield as the normal orchard from the third to the tenth year and then was removed to encourage longan (K. Fan 1995, pers. commun.).

2. Training and Pruning. Loquat trees grow upright and too tall when proper training is neglected, often resulting in damage by strong winds and lower labor efficiency. In China, loquat trees had been traditionally trained as a modified central leader, but are recently trained into an open-center system, where branches are pulled down by string to allow light penetration into the crown to promote fruit set (Fujisaki 1994). Loquat may also be trained into a vase-shape.

Pruning is carried out in autumn or winter when flower buds become visible. Overgrown branches of the tree crown are removed with shears or handsaws, and sprouts are removed or cut back. Pruning is indispensable to reduce the number of bearing shoots and to secure sufficient flower buds.

Renovation pruning improved yields and profits of 'Luoyangqing' and was best carried out in summer, one week after harvest. Pruning should not be too heavy and trees are best trained to a modified leader system (Liu et al. 1994).

3. Flower and Fruit Thinning. Thinning of flowers and/or thinning of fruit is a basic cultural practice for loquat. Flower bud thinning is aimed at limiting the number of flowers within an inflorescence, encouraging the growth of fruitlets, and shaping the inflorescence for easier bagging. After flower thinning, one inflorescence contains a maximum of ten fruits. Fruit thinning by hand is necessary to reduce the number of fruits to one to four per inflorescence in Japan (Fujisaki 1994; Sato 1996) and four to six in some production areas in China.

Flower thinning is not widely practiced in China because small farmers feel anxious about reducing production, but is widely performed in Putian, Fujian. The whole inflorescence is often removed, often as many as 30% of the total. When the flowers on the remaining inflorescence are all blooming, further thinning of the clusters is practiced. This method is considered simple and effective by local growers.

In Japan, the usual procedure of flower thinning is to remove the lower two to three peduncles and some upper peduncles on the inflorescence, leaving the middle three to four peduncles on the inflorescence. As flower buds appear over a long period, successive thinning (up to three times) is required (Fujisaki 1994). The fruits to remain are selected by size, the larger the better. The thinning should be done as soon as possible after the danger of cold damage is over. The remaining large and healthy fruits are covered by paper bags in Japan. Bagging is indispensable to obtain fruit of excellent appearance, and particularly to protect pubescence on the peel from being rubbed off. Bagging is carried out simultaneously with fruit thinning. Selection of the paper material of the bag is important; translucent bags accelerate fruit maturity, but tend to increase the incidence of physiological disorder in the fruit (Fujisaki 1994). Old newspapers are used for bagging in Putian county, China.

4. Water and Soil Management and Fertilizers. Loquat, which can tolerate drought, is hardier than orange but not as hardy as the fig (Sawyer et al. 1985). In general, loquat does not require irrigation, but when the fruits are maturing, sprinkler irrigation is carried out to reduce sunburn.

Loquat is usually grown under sod culture in Asia. Orchards are mowed two to three times per year and mowed grass clippings are spread under the trees as mulch. Growers improve the soil by providing manure and other organic substrates (Sinkai et al. 1982). Film mulch was found to increase hardiness of loquat in Zhejiang, China. The soil temperature increased by 2°C in a 12-year-old loquat orchard mulched with brown-black or transparent polyethylene film from November to June. Soil moisture, nutrient status, and soil bulk density were improved by mulching and available soil N, P, and K, as well as yield also increased (Xia 1986).

The types of fertilizer used and application rates are related to plant age and soil nutrient content. For young juvenile trees, fertilizer is applied every two months. In the orchards with low fertility, 195 kg N, 165 kg P, and 210 kg K/ha were applied each year; while in orchards with higher fertility, 150 kg N, 94 kg P, and 112 kg K were applied. In Japan, standard applications are 170 kg N, 115 kg P, and 125 kg K/ha for 10-year-old trees of 'Mogi' (Sato 1996), and 240 kg N, 190 kg P, and 190 kg K when a yield of 10 t/ha is expected (Fujisaki 1994). Fertilizer schedules in China are shown in Table 5.5. A pit disorder (black fruit disease) was associated with low soil Ca and was corrected with soil applications of 100 kg/ha Ca (Huang and Lin 1996).

5. Tree Protection. In Japan, many insect pests and diseases damage loquat and, although only a few are serious enough to require prevention measures (Table 5.6), these can be difficult to control. Control is mainly by chemical pesticides, but every effort is devoted to keeping loquat trees vigorous by management practices (Fujisaki 1994; Sato 1996).

In China, the loquat suffers from few diseases (Table 5.6), compared with fruits such as citrus and apple (Chen et al. 1991). The most severe disease is caused by *Rosellinia necatrix*. Drenching the soil with a solution of Bavistin 50% WP, Benlate 50% WP, or Basamid 85% WP and then covering with transparent polyethylene were potential measures for effective control (Duan et al. 1990). Fumigation tests in Florida with methyl bromide at normal atmospheric pressure indicated that 16 g/m^3

Table 5.5. Fertilizer application timetable for loquat.

Stage of growth	Percentage of total	Function
After harvest	50	Resuming vigor
Prior to flowering	15	Increasing cold resistant
After fruit set	25	Lowering fruit drop
Growth of fruit	10 (foliar spray)	Increasing fruit growth

Table 5.6. Pests and pathogens in major producing areas (+ = minor, +++ = severe).

Pests and diseases	China	Japan	United States
INSECT			
Aprona japonica Thomson		+++	
Anastrepha suspensa Loew			+++
Grapholitha molesta Busck	+++	+++	
Nippolachnus piri Matsumura		+++	
Phalera flavescens Brem. et Grey		+++	
Rhynchites heros Roelofs		+++	
PATHOGEN			
Bacillus amylovorus (Burr.) Trev.			+++
Cercospora eriobotryae Sawada	+++	+++	
Coleopucciniella simplex Hara		+	
Entomosporium eriobotryae Prill	+		
Erwinia amylovora (Burr.) Winsl.			+++
Glomerella cingulata Spauld. & Schrenk	+	+++	+
Hemiberlesia lataniae Sign			+
Pestalotia funerea Desm.	+++	+++	+++
Phyllostica eriobotryae Thumen	+++	+++	+++
Pseudomonas eriobotryae Takimoto	+	+++	+++
Rosellinia necatrix (Hort.) Berl.	+++	+++	

for 2.5 h at 22.8°C or 32g/m^3 for 2.5 h at 18.3–22°C gave adequate protection to loquat and other horticultural crops grown in the greenhouse for latania scale [*Hemiberlesia lataniae*. (Signoret)] (Witherell 1984).

Loquat must be protected from cold, wind, and sunburn. Young fruitlet sets from autumn flowering are sensitive to cold temperature and suffer from damage that results in irregular production. Maintaining trees with vigorous and heavy flower bud thinning results in longer flowering periods, and this may avoid cold damage to some extent. In some districts, cold damage is successfully avoided by covering an inflorescence with about 20 g of wool (Fujisaki 1994). In windy areas, newly planted nursery plants must be supported by poles to protect trees from wind damage. Loquat trees, which have shallow root systems, must be protected by windbreaks (Sato 1996). Loquat fruits are usually protected from sunburn by covering the fruit with bags.

6. Harvest and Handling. Loquats reach maturity in about 150 days from full flower-opening in China and Japan (Chen 1958; Ichinose 1995). As each growing district grows only a few cultivars, the typical period of harvesting is only seven to ten days (Fujisaki 1994). Determination of ripeness is not easy, but is important because unripe fruits are excessively acid. Change of skin color to the original ripe color (orange-yellow or yellow-white) is a useful indicator for optimum harvest time. However, in case of yellow-white cultivars, determination of the ripe color is difficult (Sato 1996). There is a relationship between harvest date and skin color and fruit quality (Uchino et al. 1994b). Soluble solids content increased and the titratable acidity (TA) decreased with maturation. Thus, TA in fruits can be decreased with harvest delay. Malic acid content in the flesh decreased as the color increased, for each harvest date. Citric acid content was higher in immature fruits than mature fruits, whereas succinic and fumaric acid contents rose with maturation. Flesh firmness gradually decreased with maturity.

Since loquat fruits are easily injured, fruits should be handed carefully (Sato 1996). The fruits are difficult to harvest because of the thick, tough stalk on each fruit that does not separate readily from the cluster, and the fruits must be picked with stalk attached to avoid tearing the skin. Clusters are cut from the branch with a sharp knife or with clippers. Whole clusters are not considered attractive on the market, therefore the individual fruits are clipped from the cluster, and the fruits are graded for size and color to provide uniform packs. An exception is that whole clusters may be displayed in Spain. In India, usually two grades of fruit are considered, although three grades can be made, with the poorest fruits (undersized or misshapen) sold for manufacture of jams, jellies, and other by-products (Randhawa and Singh 1970). In Japan, fruits are separated into three to four grades according to quality and four to five grades by size, and packed in a 300-g or a 500-g bag, 1-kg or 2-kg carton box. Almost all of these procedures are performed manually. As harvesting and packing are highly labor-intensive operations, this limits the area of loquat production for each grower (Fujisaki 1994). In China, the fruit cluster is cut, packed in wood boxes or bamboo baskets, and shipped to market, where the fruits may be classified into two or three grades. In Putian Fujian, loquat fruits are carefully picked, classified into three grades and packed into various kinds of boxes, then shipped to Hong Kong.

D. Protected Culture

Growing loquat in plastic greenhouses first originated to protect the trees and fruits from falling volcanic ashes in Tarumizu, a major loquat growing area in Japan, and later to protect the tree from cold injury. This system proved to be profitable because of higher prices from earlier marketing, stable production, and the spreading of labor requirements. 'Mogi' and 'Nagasaki-wase' are the cultivars grown in protected cultivation (Fujisaki 1994). An ethylene vinyl acetate plastic film cover, supported on a framework commonly used for training grapes in Spain, was placed over an orchard of 'Argelino' and 'Tanaka' loquat on quince restocks from budbreak to ripening. The cover advanced the harvesting date by six days and increased market value. Yields, fruit diameter, and weight were unaffected by the plastic cover (López-Gálvez et al. 1990).

Most plastic houses are built of iron pipes and covered with polyvinyl chloride sheets. The plastic is covered from leafbreak to flowering and removed after harvest, but, in some cases, is removed in July after the rainy season is over. Because high humidity during flowering is conducive to the outbreak of gray mold (*Botrylis cinerea* Person) and lowers fruit setting, it is advisable to apply plastic cover after full bloom where gray mold is a problem.

Higher temperatures accelerate the growth of young fruitlets but increase fruit maturation, which results in small fruit. Therefore, minimum night temperature should not be higher than 15°C and maximum temperature not higher than 25°C. Higher temperatures just before fruit maturation may cause physiological disorders in the fruits. (Fujisaka 1994).

Losses of soil nutrients decreased during the time that the plastic is covered. Thus, fertilizers should be decreased, according to tree vigor. As higher soil water content promotes fruit growth, irrigation is applied during the fruit growing period, and reduced towards fruit maturation to enhance quality.

E. Storage and Processing

Data available on fruit storage and processing are quite limited. Loquat fruits are mostly consumed fresh and sold at high prices, especially in Japan. Fruit generally will keep for ten days at ordinary temperatures, and for four weeks to 60 days in cool storage. Sugar loss was minimal with slight decrease in acid, resulting in an overall improvement in taste for the mature fruit during storage (Ogata 1950; Shaw 1980). After removal from storage, the shelf-life may be only three to five days (Ogata 1950; Mukerjee 1958; Guelfat-Reich 1970; Shaw 1980; El-Zeftawi and Goubran 1983b). Treatment with the fungicide benomyl makes it possible to maintain loquats for one month at 16°C with a minimum of decay (Morton 1987). Cold storage of loquats in polyethylene promotes internal browning and fungal development and alters flavor (Guelfat-Reich 1970; Morton 1987). The 'Tanaka' cultivar had an unacceptable flavor after storage, but not 'Akko 13'. Quality aspects after storage depend on cultivar. In a storage experiment in Italy, good results were obtained with

'Argelino' and 'Tanaka', which were notable for resistance to mechanical damage. 'Marchetto' and 'Palermo' were superior in organoleptic traits (Testoni and Grassi 1995).

Controlled atmosphere (CA, low O_2) did not influence the quality of fruits stored at 25 ± 5°C. Low temperature (3 ± 1°C) prolonged storage life, especially when combined with CA; losses of soluble sugar, TSS, titratable acidity, and ascorbic acid slowed, enabling fruits to be stored for longer than 40 days. Furthermore, respiration rate, ethylene production, and fruit rots were kept low by low temperature and low O_2 (Q. Lin et al. 1994).

Loquat has been used for canning, jam, juice, syrup, candied fruits, and jellies. Dried fruit has good flavor (C. Campbell, per. commun.). A significant amount of canned loquats was produced in Japan in the 1970s and in Taiwan, China, in the 1980s. Yearly production of canned loquats in Japan was 2254 t in 1970 but gradually declined and is now near zero. In Fujian and Zhejiang, China, canning industries are increasing, but enterprises are usually small. Small amounts of loquats are used for jam.

Adam (1950) studied the final pH of loquats canned at 100°C and produced over a period of several years. A pH range of 4.0–5.4 was too high to prevent microbial growth during storage of the product (pH higher than 4.0 was considered unsafe). He recommended taking precautions to reduce the pH of the final canned product to increase storage stability.

V. FUTURE PROSPECTS

A. Crop Improvement

Research priorities have been listed by several authors (Condit 1915; Chandler 1958; Huang 1989; Chen et al. 1991). These include cultivar improvement such as development of seedless or low-seeded cultivars and whitish flesh, increased quality and size of fruit, and increased cold-resistance. Dwarf types would be of interest for both growers and homeowners.

Seedless or less-seeded cultivars would be a desirable feature. Loquat has ten ovules, and is potentially able to bear ten seeds, but generally no more than eight develop and most frequently only three to four. Both frost-induced seedless fruit (Condit 1915) and GA-induced seedless fruit have been reported (Fan 1989; Takagi et al. 1994), indicating that it is theoretically possible to produce seedless or less-seeded cultivars. However, the physiology and genetics of seedlessness remain to be determined. Seediness might be reduced by using low-seeded cultivars as parents in future crossing programs. Although autopolyploids have undesirable characteristics (Kihara 1981; Huang 1989), triploids should be further investigated for seedlessness. The extent of induced parthenocarpy in loquat is encouraging (Fan 1989; Takagi et al. 1994) and BA and other plant-growth regulators could be used as auxiliary measures for the production of seedless cultivars.

Whitish flesh, which combines fine and tender texture, high sugar content, and good flavor, has been emphasized by Japanese breeders. Breeders have released a whitish flesh cultivar, 'Shiro Mogi', which originated from an open-pollinated 'Mogi' seed irradiated with 20 KR gamma ray.

Fruit size is a quantitative trait. The large fruited cultivar, 'Jiefangzhong' crossed with 'Baozhu' (small, medium size fruit of good quality) produced a selection, 82-6-26, characterized by large fruit, high quality, and cold-resistance. 'Zaozhong No. 6' and 'Zhongjing 2', released in Fujian, are seedlings of 'Jiefangzhong' and possess large fruit and good quality (Huang et al. 1993; Ding et al. 1995a).

There are a number of reports that loquat trees are surprisingly hardy (Dawes 1980; Vogel 1993; Park and Park 1995), although reproductive organs, especially ovules, are cold sensitive. In general, cold injury is a limiting factor for commercial production of loquat. The survey of loquat resources in recent years in China are encouraging. The north part of Jiangsu province is a deciduous tree area, but farmers plant loquat trees around their houses and propagate the trees by seed. Many cold-resistant resources have apparently been developed. For example, some seedlings with cold resistance and large fruit, such as 'Bahong' and 'Shichen', have been selected in Zhenjiang City, Jiangsu. The yield of the original 'Bahong' tree reached 100 kg when the lowest temperature was −11.6°C in the winter of 1976, and in the winter of 1991, when the lowest air and ground temperature was −11.2°C and −20°C, respectively, yields were as high as in normal years. 'Bahong' obviously possesses very high cold resistance (Ding et al. 1995a). Cold-resistance breeding could focus on selection of seedlings in the marginal area of the north. In marginal areas, seedless fruits are sometimes formed when cold kills the very young embryos but is not severe enough to damage the flesh. The timing of fruit setting in fall and the timing of the cold are factors in fruiting and damage. If minimum night temperatures at bloom time are too high, fruit may not set. When the earliest flowers set in Florida, there can be ripe fruit in early January before the most damaging cold. Higher elevation could possibly affect the temperatures and time of fruit set. A study of the 'Bahong' in Jiangsu province is needed to determine if there is genetic resistance or avoidance factors in fruiting. The presence of resistance, if present, could extend the culture of loquat.

B. Culture and Utilization

Loquat areas of production are generally expanding. In China, loquat areas have increased 15-fold and yield increased 38-fold during the past 45 years. In Japan, there has been no increase in loquat cultivation area from the 1940s to the present for many reasons, but loquat production potential is high because the prices are the highest among all kinds of fruits year-round, and in the leading producing prefecture, Nakasaki, production has increased gradually. Loquats have become increasingly popular in Brazil.

The range of cultivated loquat is also changing. The leading producing areas of loquat in China are Zhejiang, Fujian, and Taiwan, ranging from 30° to 22° N latitudes. Two of the leading producing prefectures in Japan are Nakasaki and Chiba, 33° and 35° N latitudes, respectively. Commercial cultivated areas of loquat in Palermo, Italy, are located at 44°N. It is clear that loquat could be cultivated between 25° to 35° N and S latitudes, depending on altitude and climate. If some cultivars with cold resistance are introduced, the areas of production of loquat could be further expanded.

In India, a large area of adaptation appears to have a stable production, though specific figures are unavailable. Australia can produce loquat in both western and eastern areas. Adapted cultivars have large firm fruit, and if an export market could be developed, there would be increased commercial potential. Production of loquat in home gardens is high in Australia. Home production also occurs in the Mediterranean area, but with large urban markets there is an opportunity for commercial production (Mansour and Leaver 1995).

There was much early interest in loquat being grown in Florida (Krome 1936; Popenoe 1960), but the fruit is no longer grown commercially because of the fruit fly, *Anastrepha suspensa*. In the Gainesville area, where the fruit fly is not a problem, homeowners welcome the occasional crop (spared by frosts) but nurseries offer only seedlings that are inferior to 'Oliver' and 'Advance'. Interestingly, loquat is about the only fruit that does well in the shade of large trees such as hickory and oak, which can sometimes protect flowers and young fruit from freezing.

As in Florida, there was also a similar early interest in loquats in California (Condit 1915; Chandler 1958). Both states have a limited region of adaptation and have attracted rapid population growth to their mild

winter areas. Cultivars are still offered by California nurseries (Whealy 1989). Among them are 'Advance', 'Ben Lehr', 'Big Jim', 'Champagne', Gold Nugget', 'Mogi', 'Mrs. Cooksey' and 'Strawberry'.

In the United States, the introduction of loquat would have serious competition in the marketplace because of the presence of many kinds of citrus, apples, and pears from controlled atmosphere storage, peaches and nectarines from Chile, and strawberries from local production in Mexico and California in the early spring. Nevertheless, a limited commercial market for loquat exists among Asian populations in California.

Extensive studies have been carried out on harvesting, handling, and packaging of loquat, but the data on fruit storage and processing are limited (Zheng et al. 1993b; Lin and Chen 1994; Testoni and Grassi 1995). Some cultivars, such as 'Argelino' and 'Tanaka', are resistant to mechanical damage, and 'Palermo' is superior in organoleptic traits. Loquat fruits can be stored for longer than 40 days under CA without extensive diminution of quality. This suggests that loquat is a candidate for the export market provided fruit shelf-life can be extended with controlled atmosphere storage.

In Fujian and Zhejiang, China, the canning of loquat is increasing, and small amounts of loquat fruits have been used to make jam, wine, syrup, and candied fruits, but these are small-scale operations and large enterprises with better facilities must be established.

LITERATURE CITED

Adam, W. B. 1950. pH in fruit and vegetable canning. Food 19:4–7.

Amitava, G., and P. K. Chattopadhyay. 1993. Studies on the developmental physiology of loquat fruit. Hort. J. 6:29–33.

Blumenfeld, A. 1980. Fruit growth of loquat. J. Am. Soc. Hort. Sci. 105:747–750.

Burló, F., A. Vidal, I. Gómez, and J. Mataix. 1988. Changes in the mineral fraction in leaves and fruits of loquat (cv. Algeri). Anales Edafología Agrobiogía 47:1607–1618.

Burney, B. 1980. Exotics: A guide to some that may be grown in New Zealand. Part I. New Zealand J. Agr. 140:58–59, 62.

Campbell, C., and S. E. Malo. 1986. IFAS Fact Sheets 5. The loquat. Univ. Florida, Gainesville.

Chandler, W. H. 1958. Pome fruits. Evergreen orchards. Lea and Febiger, Philadelphia. p. 347–350.

Chaudhary, A. S., M. Singh, and C. N. Singh. 1990. Effect of plant growth regulators on maturity of loquat. Progress. Hort. 22:184–190.

Chaudhary, A. S., M. Singh, and C. N. Singh. 1993. Effect of NAA, 2,4,5-T and GA on loquat cultivar 'Safeda Batia'. India J. Agr. Res. 28:127–132.

Chen, Q. F. (ed.). 1988. Loquat (in Chinese). Fujian ScienTech. Press, Fuzhou, China.

Chen, W. X. 1954. The loquats in Putian, Fujian. Acta Agr. 5:199–214.

Chen, W. X. 1958. Observation of biological characteristics in loquat. J. Fujian Agr. Coll. 1958(7):29–49.
Chen, Z. G., and S. Q. Lin. 1991. Some research on micropropagation of horticultural crops. p. 28–32. In: R. Chen (ed.), Advances in biotechnology in China (in Chinese). China Scientech Press, Beijing.
Chen, Z. G., and S. Q. Lin. 1995. On research of micropropagation of horticultural crops in China. p. 143–146. In: Chinese Scientech. Committee (eds.), Advances in biotechnology in China (in Chinese). China Scientech Press, Beijing.
Chen, Z. G., S. Q. Lin, and Q. L. Lin. 1983. A brief report on the induction of plantlets from endosperm of loquat. J. Fujian Agr. Univ. 12:243–246.
Chen, Z. G., S. Q. Lin, and Q. L. Lin. 1991. Loquat. p. 62–75. In: Y. P. S. Bajaj (ed.), Biotechnology in agriculture and forestry. Vol. 16, Trees III. Springer-Verlag, Berlin/Heidelberg, Germany.
Chen, Z. G., B. K. Ma, S. Q. Lin, and J. J. Lei (eds.). 1995. In vitro biology in horticultural plants (in Chinese). China Agr. Press, Beijing.
Church, C. G., and D. G. Sorber. 1935. The chemical composition of the loquat. Fruit Prod. J. Am. Vinegar Ind. 14:335–340.
Condit, I. J. 1915. The loquat. California Agr. Expt. Sta. Bul. 250.
Crescimanno, F. G., and F. Barone. 1980. Variations in the N, P, K, Ca and Mg contents of loquat during one annual cycle. Tecnica Agriola 32:215–222.
Cyprus Agricultural Research Institute (eds.). 1987. Ministry of Agriculture and Natural Resources. Nicosia, Cyprus.
Dawes, H. 1980. Reevaluating cold hardiness of certain tropical fruit trees. California Rare Fruit Growers Yearb. 11:46–49.
Degani, C., and A. Blumenfeld. 1986. The use of isozyme analysis for differentiation between loquat cultivars. HortScience 21:1457–1458.
Demir, S. 1983. Promising loquat cultivars for the Antalya region. Bahce 12:5–16.
De Tommasi, N. 1992a. Plant metabolizes. New sesquiterpene and ionone glycosides from loquat. J. Nat. Prod. 55:1025–1032.
De Tommasi, N. 1992b. Constituents of *Eriobotyra japonica*: A study of their antiviral properties. J. Nat. Prod. 55:1067–1073.
Ding, C. K., Q. F. Chen, and T. L. Sun. 1995a. Seasonal variant in the contents of nutrient elements in the leaves and the fruits of *Eriobotrya japonica* Lindl. Acta Hort. 396:235–242.
Ding, C. K., Q. F. Chen, T. L. Sun, and Q. Z. Xia. 1995b. Germplasm resources and breeding of *Eriobotrya japonica* Lindl. in China. Acta Hort. 403:121–126.
Ding, C. K., Q. F. Chen, Q. Z. Xia, and T. L. Sun. 1991. The effects of mineral elements and growth regulators on the pollen germination and fruit set of loquat trees. China Fruits 1991(4):18–20, 40.
Ding, C. K., and H. Z. Zhang. 1988. Effects of hormones on growth and development of loquat fruits. Acta Hort. Sinica. 15:148–153.
Duan, C. H., H. W. Tsai, and C. C. Tu. 1990. Dissemination of white root rot disease of loquat and its control. J. Agr. Res. China 39:47–54.
Duke, J., and E. S. Ayensu. 1985. Medicinal plants of China. Vol. 2. Reference Publ., Algonac, MI. p. 544.
El-Shazly, S. M., M. B. EL-Safrout, and H. A. Kassem. 1994. Root formation on the stem cuttings of Eureka lemon and 'EL-Soukari' loquat as affected by root-promoting chemicals and mist. Alexandria J. Agr. Res. 39: 559–569.
El-Zeftawi, B. M., and F. H. Goubran. 1983a. Chemical induction of seedless loquat. Austral. Hort. Res. Newsl. 55:126.

El-Zeftawi, B. M., and F. H. Goubran. 1983b. Behavior of loquats in cool storage. Austral. Hort. Res. Newsl. 55:126–127.
Endt, R. 1979. Observations on fruit growing in Ecuador and Chile. Orchardist of New Zealand. 52:347, 349, 351, 353, 355.
Eti, S., N. Kaska, S. Kuranz, and M. Kilavuz. 1990a. The relationship between the production, viability and germination capacity of pollen and fruit set in some Turkish loquat varieties. Doğa, Türk, Tarim, Ormancilik, Dergisi 14:421–430.
Eti, S., M. Kilavuz, and N. Kaska. 1990b. The effect of flower thinning by chemicals and by hand on fruit set and fruit quality in some loquat cultivars. Bahce 19:3–9.
Fan, N. T. 1987a. Influence on fruit quality of nutritional status in loquat. J. Agr. Forestry 36:31–36.
Fan, N. T. 1987b. Investigation on nutrition status in the main Taiwan loquat growing area. J. Agr. Forestry 36:59–64.
Fan, N. T. 1989. Studies on the development of seedless loquat. J. Agr. Forestry 38:67–72.
Farré Massip, J. M. 1993. Tropical and subtropical fruits in mediterranean Spain. Informatore Agrario 49:23–28.
Flaccomio, E. 1967. It is possible to grow more loquats. Inf. Ortoflorofruttic 8:551–552.
Fujisaki, M. 1994. Loquat. p. 56–59. In: Organizing Committee, 24 Int. Hort. Congr. Publ. Committee (eds.), Horticulture in Japan. Chuo Printing Co., Japan.
Galán Saúco, V. 1986. Some tropical and subtropical fruits grown in Spain, mainly in the Canary Islands. Proc. Tropical Region, Am. Soc. Hort. Sci. 23:101–104.
Godoy, H. T., and D. B. Rodrigues Amaya. 1995. Carotenoid composition and vitamin A value of Brazilian loquat. Archivos Latinoamericanos Nutrición 45:336–339.
Goubran, F. H., and B. M. El-Zeftawi. 1983. Assessment of some loquat cultivars. Austral. Hort. Res. Newsl. 55:125.
Goubran, F. H., and B. M. El-Zeftawi. 1986. Induction of seedless loquat. Acta Hort. 179:381–384.
Gray, D. O. 1972. *trans*-4-Hydroxymethyl-D-proline from loquat. Phytochemistry 11:751–756.
Gray, D. O., and L. Fowden. 1972. Isolation of 4-methylene-proline from loquat. Phytochemistry 11:745–750.
Gross, J., M. Gabai, A. Lifshitz, and B. Sklarz. 1973. Carotenoids of loquat. Phytochemistry 12:1775–1782.
Guelfat-Reich, S. 1970. Storage of loquats. Fruits Outre Mer 25:169–173.
Hall, N. T., J. M. Smoot, R. J. Knight, and S. Nagy. 1980. Amino acid composition of ten tropical fruits by gas-lipid chromatography. J. Agr. Food Chem. 28:6–16.
He, K. Z., S. Q. Lin, and X. P. Wang. 1995. An application of three types of section to loquat embryology. J. Fujian Agr. Univ. 24:33–38.
Higashi, A., and R. Kuwahata. 1989. Plantlet formation from callus derived from shoot tips of 'Mogi' loquat. J. Japan. Soc. Hort. Sci. 58(Suppl. 2):50–51.
Hirai, M. 1979. Sorbitol-6-phosphate dehydrogenase from loquat fruit. Plant Physiol. 63:715–717.
Hirai, M. 1980. Sugar accumulation and development of loquat fruit. J. Japan. Soc. Hort. Sci. 49:347–353.
Hirai, M. 1981. Purification and characteristics of sorbitol-6-phosphate dehydrogenase from loquat leaves. Plant Physiol. 67:221–224.
Hirai, M. 1982. Accelerated sugar accumulation and ripening of loquat fruit. J. Japan. Soc. Hort. Sci. 51:159–164.
Hirai, M. 1983. Seasonal changes of sorbitol-6-phosphate dehydrogenase in loquat leaf. Plant Cell Physiol. 24:925–931.

Ho, W. J. 1983. The studies on induction of somatic embryogenesis from loquat young embryo and shoot tip. Hort. China 29:322–325.

Ho, W. J., C. S. Chang, and S. N. Huang. 1986. Plant regeneration via somatic embryogenesis in callus culture of loquat. Acta Hort. 175:243–247.

Hu, Y. L., X. Y. Zheng, and S. Q. Lin. 1988. Cutting propagation of some subtropical fruit crops. Bul. Chinese Agr. 4:24–27.

Huang, J. S. 1978. A report on young stock cleft graft of loquat. Chinese Fruits 1978(2): 24–29.

Huang, J. S. 1984. The culture of tetraploid loquat, Ming No. 13. Chinese Fruits 1984(2): 27–29.

Huang, J. S. 1989. The main achievements of scientific research on loquat forty years after liberation. Chinese Fruits 1989(2):5–8.

Huang, J. S., X. T. Xu, and J. Q. Fang. 1990. A new, stable, productive loquat variety, 'Changhong No. 3'. China Fruits 1990(2):26–27.

Huang, J. S., X. D. Xu, and S. Q. Zheng. 1993. New extra-large and early loquat cultivar: 'Zaozhong No. 6'. China Fruits 1993(4):4–6.

Huang, T. A., and S. Q. Lin. 1996. The relationship between black fruit disease and Ca nutrient deficiency. Proc. 7th Chinese Soc. Physiol. p. 32 (Abstr.).

Huxley, A. (ed.). 1992. The new Royal Horticultural Society dictionary of gardening. Macmillan, London. p. 196.

Ichinose, I. 1995. The origin and development of loquat (in Japanese). Series of Agr. Tech. 4 (Suppl.):1–5.

Ito, S., and H. Sakasegawa. 1952. Studies on the constituents of fruit juices by paper partition chromatography. I. Sugars and organic acids in several fruit juices. Bul. Hort. Div. Tokai-Kinki Agr. Expt. Sta. 1:225–235.

Karabourniotis, G., D. Kotsabassidis, and Y. Manetas. 1995. Trichome density and its protective potential against ultraviolet-B radiation damage during leaf development. Canadian. J. Bot. 73:376–383.

Kihara, H. 1981. Seedless fruit. Plant Breed. Abstr. 51:224.

Kilavuz, M., and S. Eti. 1993. The effects of flower thinning by hand, NAA and NAAm on the fruit set, growth rate and size of fruits of some loquat varieties. Doğa, Türk, Tarim, Ormancilik, Dergisi 17:537–550.

Koshioka, M., D. Pearce, R. P. Pharis, and Y. Murakami. 1988. Identification of endogenous gibberellins in immature seeds loquat. Agr. Biol. Chemistry. 52:1353–1360.

Kozaki, I., I. Ueno, S. Tsuchiya, and I. Kajiura (eds). 1995. The fruits in Japan. Yokendo, Tokyo. p. 385–396.

Kraft-Klaunzer, P., and L. N. Mander. 1992. Confirmation of structure for the new 11B-hydroxy gibberellin GA_{84}. Phytochemistry 31:2519–2521.

Krome, Isabell. 1936. Loquats. Fla State Hort. Sci. 49:143–145.

Kumar, R. 1976. Induction of seedlessness in loquat. Indian J. Hort. 33:26–32.

Kursanow, A. L. 1932. Biochemistry of the ripening of fruits of the loquats. Planta 15: 752–766.

Li, M. Y., J. G. Jian, and J. Luo. 1991. Transfer and expression of *Agrobacterium tumefaciens* harboured T-DNA in cultured cotyledon explants of loquat. J. Southwest Agr. Univ. 13:442–445.

Li, N. Y. 1982. Observation on differentiation of flower bud in loquat. China Fruits 1982(3):12–16.

Liang, Z. Z., R. Aquino, V. De Feo, F. De Simone, and C. Pizza. 1990. Polyhydroxylated triterpenes from loquat. Planta Medica 56:330–332.

Lin, D. Y., and Y. S. Li. 1985. A study on pigments in loquat. Acta Hort. Sinica 12:207–209.

Lin, Q., B. G. Yu, and X. X. Wang. 1994. The effects of storage conditions on the quality and physiological changes in loquat. J. Nanjing Agr. Univ. 17:27–31.

Lin, Q. L., and S. Q. Lin. 1993. Embryo culture of *Eriobotrya prinodes*. Fujian Fruit Trees 1993(1):1–2.

Lin, Q. L., S. Q. Lin, and Z. G. Chen. 1994. Isolation and culture of protoplasts in *Eriobotrya prinodes*. J. Fujian Agr. Univ. 23:72–74.

Lin, S. Q. 1985. A study on the forming of the plantlets from loquat endosperm in vitro. J. Fujian Agr. Univ. 14:117–125.

Lin, S. Q. 1987. An application of in vitro technology to research of fruit breeding. J. Fujian Agr. Univ. 16(1):73–82.

Lin, S. Q. 1991. Callus establishment from embryo callus protoplast in loquat. J. Fujian Agr. Univ. 20:179–184.

Lin, S. Q. 1992. Some observations on embryogenesis in loquat. J. Fujian Agr. Univ. 21:67–71.

Lin, S. Q. 1995. Plant regeneration from protoplast in loquat and some basic research. Ph. D. diss. Fujian Agr. Univ., China.

Lin, S. Q., and F. X. Chen. 1996. A study on raising rooting rate of shoot derived from protoplast. J. Fujian Agr. Univ. 25:410–416.

Lin, S. Q., and Z. G. Chen. 1994. Plant regeneration from protoplast in loquat (Short Commun.). J. Fujian Agr. Univ. 23:125.

Lin, S. Q., and Z. G. Chen. 1996a. Plant regeneration from protoplast in loquat. Acta Hort. Sinica. 23:313–318.

Lin, S. Q., and Z. G. Chen. 1996b. Decision support system in vitro propagation in horticultural crops in factory scale. J. Fujian Agr. Univ. 25:150–153.

Lin, S. Q., and Z. G. Chen. 1997. Effect of sorbitol on isolation and culture of protoplasts in loquat. J. Fjuian Agr. Univ. 26:411–417.

Lin, S. Q., Z. G. Chen, and Q. L. Lin. 1995b. A study on the culture of embryo and protoplast in loquat and their carbon sources. Acta Hort. 403:320–323.

Lin, S. Q., J. T. Ling, N. Nito, and M. Iwamasa. 1989. Isolation and culture of protoplast in loquat. J. Hort. Soc. Japan 58 (Suppl. 2):48–49.

Liu, Q. 1982. A review on loquat research since 1949. Datum Sci. Tech. Loquat (in Chinese) 1:7–11.

Liu, Q., J. L. Lu, Z. X. Yin, and S. X. Shi. 1994. Study on renovation pruning in loquat. J. Zhejiang Agr. Univ. 20:33–37.

Liu, Q., G. R. Wang, J. R. Lu, and D. X. Shen. 1993. Numerical taxonomy of loquat variety germplasm. J. Fruit Sci. 10:137–141.

Liu, T. T. 1993. Control and prevention of diseases and physiological disorder in loquat. p. 20–21. In: Lin, J. H. and L. R. Chang (eds.), Proc. Symp. Tech. Loquat Production, Taiwan.

López-Gálvez, J., J. Gallego, J. López-Hernandez, and M. M. Tellez. 1990. Influence of plastic cover in the ripening of loquat in south eastern Spain. p. 141–148. In: A. A. Balkema (ed.), Proc. 11th Int. Congr. Use of Plastics in Agr. Rotterdam, Netherlands.

Lu, L. X. 1984. A cytological observation on a sterile plant of loquat. J. Fujian Agr. Univ. 13:141–146.

Lu, L. X., and S. Q. Lin (eds.). 1995. An introduction on reproductive biology in fruit trees (in Chinese). China Agr. Press, Beijing.

Lupescu, F., T. Lupescu, A. Khelil, and G. Tanislav. 1980. Agro-biological performance of some loquat varieties grown at the horticultural station of the National Agronomic Institute of Algiers. Fruits 35:251–261.

Mann, G. S., and P. Sagar. 1987. Activity and abundance of flower visiting insects of loquat. Indian J. Hort. 44:123–125.

Mansour, K. M., and G. Leaver (eds.). 1995. Proc. First Cooperative Working Group on Underutilized Fruits of the Mediterranean Region. Zaragosa, Spain.
Matsuo, T., and S. Ito. 1981. Comparative studies of condensed tannins from several young fruits. J. Japanese Soc. Hort. Sci. 50:262–269.
McConnell, D. B. 1988. Container size and potting medium affect growth rate of weeping fig and loquat. Proc. Florida State Hort. Soc. 100:337–339.
Miller, J. M., and E. E. Conn. 1980. Metabolism of hydrogen cyanide by higher plants. Plant Physiol. 65:1199–1202.
Monastra, F., and O. Insero. 1991. Loquat industry in Italy: Varieties investigation. Annali dell'Istituto Sperimentale Frutticoltura 19:87–91.
Morton, J. F. (ed.). 1987. Loquat. p. 103–108. In: Fruits of warm climates. Creative Resource Systems, Winterville, FL.
Mukerjee, P. K. 1958. Storage of loquat. Hort. Adv. 2:64–67.
Muranishi, S. 1982. Effects of GA on the seedless fruiting of artificial polypoloids in loquats. XXI Int. Hort. Congr., Hamburg, Germany. Vol. I (Abstr. 1371).
Nii, N. 1993. Anatomical features of the sieve elements in vascular bundles of Rosaceae fruit trees. J. Japan Soc. Hort. Sci. 62:55–61.
Nii, N., K. Hase, and H. Uchida. 1994. Anatomical features on the sieve elements and sorbitol content in various organs of Rosaceae fruit trees. J. Japan Soc. Hort. Sci. 62:739–747.
Nordby, H. E., and N. T. Hall. 1980. Lipid markers in chemotaxonomy of tropical fruits: preliminary studies with carambola and loquat. Proc. Florida State Hort. Soc. 92:298–300.
Noreen, W., A. Wadood, H. K. Hidayat, and S. A. M. Wahid. 1988. Effect of loquat on blood glucose levels of normal and alloxan-diabetic rabbits. Planta Medica 54:196–199.
Ogata, Y. 1950. Physiological study on the fruit of loquat during storage. Tech. Bul. Kagawa Agr. Coll. 1:42–55.
Pan, J. P., J. G. Li, B. M. Yang, and J. S. Li. 1995. Influence of PP_{333} on growth of loquat trees. Guangdong Agr. Sci. 1995(1):28–29.
Park, Y. S., and H. S. Park. 1995. Changes in cold injury and contents of chemical compounds as related to the different growth stages of immature loquat fruit. J. Korean Soc. Hort. Sci. 36:522–534.
Pilone, N., and G. Scaglione. 1996. Effects of paclobutrazol on growth of loquats. Riv. Frutticoltura Ortofloricoltura 58:69–71.
Polat, A. A., and N. Kaska. 1991. Investigation on the determination of most suitable budding time and method for the loquat under Adana ecological conditions. Doğa, Türk Tarim Ormancilik Dergisi 15:975–986.
Polat, A. A., and N. Kaska. 1992a. Investigations on the propagation of loquat by various methods. 1. Propagation by air layering. Doğa, Türk Tarim Ormancilik Dergisi 16: 433–443.
Polat, A. A., and N. Kaska. 1992b. Investigations on the propagation of loquat by various methods. 2. Propagation by cutting. Doğa, Türk Tarim Ormancilik Dergisi 16:444–449.
Polat, A. A., and N. Kaska. 1992c. Effects of stratification on the germination of loquat seeds and embryos. Doğa, Türk Tarim Ormancilik Dergisi 16:450–459.
Polat, A. A., and N. Kaska. 1992d. Anatomical and histological studies on "T", patch and chip buddings in loquat. Doğa, Türk Tarim Ormancilik Dergisi 16:529–541.
Polat, A. A., and N. Kaska. 1992e. Studies on bud compatibility and bud union formation for some loquat cultivars on Quince a rootstock. Doğa, Türk Tarim Ormancilik Dergisi 16:773–788.
Popenoe, F. W. 1928. Loquat. p. 1915–1916. In: L. H. Bailey. The standard cyclopedia of horticulture. Macmillan, New York.
Popenoe, J. 1960. Evaluation of loquats at the sub-tropical expt. sta. Fla. State Hort. Soc. 73: 315–316.

Popenoe, W. 1920. Manual of tropical and subtropical fruits. Macmillan, New York.
Raie, M. Y., S. Zaka, and M. Saleem. 1983. Chromatographic analysis of loquat fat. Fette Seifen Anstrichmittel. 85:325–326.
Rajput, C. B. S., and J. P. Singh. 1964. Chemical analysis of loquat fruits. Indian J. Hort. 21:204–205.
Randhawa, G. S., and R. K. N. Singh. 1970. The loquat in India. Indian Counc. Agr. Res. Bul. 24, Swan Press of Lahore, New Delhi.
Ruan, Y. L., and L. M. Wu. 1991. A study of photosynthetics of wintering loquat and bayberry. Acta Hort. Sinica. 18:309–312.
Sadana, J. C. 1949. Carotenoids of loquat. Biochemistry 44:401–402.
Safarov, I. S. 1988. The present state and prospects for the development of subtropical fruit growing in the Azerbaijan SSR. Rastitel'nye Resursy 24:161–167.
Sato, Y. 1996. Loquat. p. 121–129. In: Japan Int. Coop. Agency (eds.), Cultivation and evaluation of fruit tree PGR. JICA, Tokyo.
Sawyer, P., P. Houghton, and L. Manuel. 1985. Loquats: a literature search. Calif. Rare Fruit Growers Yearb. 17:23–33.
Shaw, P. E. 1980. Loquat. p. 479–491. In: S. Nagy and P. E. Shaw (eds.), Tropical and subtropical fruits. Avi, Westport, CT.
Shaw, P. E., and C. W. Wilson. 1981. Determination of organic acids and sugars in loquat by high-pressure liquid chromatography. J. Sci. Food Agr. 32:1242–1246.
Shaw, P. E., and C. W. Wilson. 1982. Volatile constituents of loquat fruit. J. Food Sci. 47:1743–1744.
Shimizu, M., H. Fukumura, H. Tsuji, S. Tanaami, T. Hayashi, and N. Morita. 1986. Anti-inflammatory constituents of topically applied crude drugs. I. Constituents and anti-inflammatory effect of loquat. Chem. Pharm. Bul. 34:2614–2617.
Sima, Q. (100 B.C.). Record of history (in Chinese). Vol. 117:3028–3029.
Singh, M., B. D. Verma, M. L. Rawat, and L. Dhar. 1979. Studies on the morphology and viability of the pollen. Progress. Hort. 10:45–51.
Singh, N., and H. S. Shukla. 1978. Response of loquat fruits to GA and urea. Plant Sci. 10: 77–83.
Singh, S. N. 1963. Studies on longevity of loquat pollen. Trop. Agr. 19:31–42.
Singh, U. S., and R. K. Lal. 1990. Investigation of hunger signs in loquat. Narendra Deva J. Agr. Res. 5:101–109.
Sinkai, K., M. Sakibara, and M. Fukaya. 1982. Effects of watering and organic fertilizer application on the growth of loquat trees in shale soil. Res. Bul. Aichiken Agr. Res. Center. 14:262–266.
Takagi, T., H. Mukai., R. Ikeda, and T. Suzuki. 1994. Effect of application of GA and KT on the enlargement of frost-induced seedless fruit of loquat. J. Japan Soc. Hort. Sci. 62:733–738.
Teng, S. Y., and H. M. Chen. 1986. Plant regeneration via somatic embryogenesis of immature loquat embryo. Acta Hort. Sinica. 13:245–249.
Testoni, A., and M. Grassi. 1995. Quality aspects and storage life of some cultivars of loquats. Riv. Frutticoltura Ortofloricoltura 57:33–38.
Thunberg, C. P. 1784. Flora japonica. Leipzig.
Uchino, K., A. Kono., Y. Tatsuda, and K. Sakoda. 1994a. Some factors affecting fruit weight of loquat. Japanese J. Trop. Agr. 38:286–292.
Uchino, K., Y. Tatsuda, and K. Sakoda. 1994b. Relation of harvest date and skin color to fruit quality of loquat 'Mogi' during maturation. J. Japan Soc. Hort. Sci. 63:479–484.
Vogel, R. 1986. The reaction of exotic fruit trees grown at the Corsican Agricultural Research Station to frost in January 1985. Fruits 41:43–47.

Vogel, R. 1993. Adaption of exotic fruit species in Corsica in the last thirty years. Informatore Agrario 49:29–31.
Wang, P. L. (ed.). 1989. Culture and processing of loquat (in Chinese). Agriculture Press. Beijing.
Wee, Y. C., and K. Hsuan. 1992. An illustrated dictionary of Chinese Medicinal Herbs. CRC5 Pub., Box 1460, Sebastopol, CA.
Whealy, K. 1989. Fruit, berry, and nut inventory. Seed Saver Publ. Decorah, IA.
Witherell, P. C. 1984. Methyl bromide fumigation as a quarantine treatment for latania scale, *Hemiberlesis lataniae* Homoptera: Diaspididae. Florida Entomologist 67:254–262.
Xia, Q. Z. 1986. Film mulch for increasing hardiness of loquat. Zhejiang Agr. Sci. 3:136–138.
Yang, J. Y. 1963. The relationship between flower biology in cultivars with cold resistance and their overwintering in loquat. Acta Hort. Sinica 2:83–84.
Yang, Y. Q. 1984. The culture of loquat shoot tip culture. p. 420–431. In: Z. H. Chen, (ed.), The tissue culture and its application of woody plants (in Chinese). Higher Education Press, Beijing.
Yang, Y. Q., G. L. Chen, and D. Y. Tang. 1983. A study on the culture of shoot tip and its in vitro propagation of loquat. Acta Hort. Sinica 10:79–86.
Ye, S. Q. 1988. Relationship between ethylene and growth and development of loquat fruits. China Fruits 1988(2):15–18.
Yin, T. J., Y. F. Xi, Q. J. Bian, D. M. Qian, and Y. H. Zheng. 1994. The ultra structures of fruit surface and their development in loquat and grape. J. Zhejiang Agr. Univ. 20:173–177.
Yu, D. J. (ed.) 1979. The taxonomy of Chinese fruit trees (in Chinese). Agri. Press, Beijing. p. 309–316.
Yuda, E. 1987. New gibberellins in developing loquat fruit and hypothetical metabolic pathway. Proc. Plant Growth Regulator Soc. Am. (1987):167–173.
Yuda, E., S. Nakagawa, N. Mourfushi, T. Yokota, N. Takahashi, M. Koshioka, Y. Murakami, D. Pearce, R. P. Pharis, G. L. Patrick, L. N. Mander, and P. Kraft-Klaunzer. 1992. Endogenous gibberellins in the immature seed and pericarp of loquat. Bioscience, Biotech. Biochem. 56:17–20.
Zeng, M. 1937. The loquats in Suzhou, Jiangsu province and in Hangzhou, Zhejiang province. Horticulture 3:406–407.
Zhang, H. Z. 1987. History of loquat cultivation (in Chinese). World Agr. 1987(6):54–56.
Zhang, H. Z., S. A. Peng, L. H. Cai, and D. Q. Fang. 1990. The germplasm resources of the genus *Eriobotrya* with special reference on the origin of *E. japonica* Lindl. Acta Hort. Sinica 17:5–12.
Zheng, S. Q., X. D. Xu, J. S. Huang, and J. Q. Zhou. 1993a. Study on heredity of several characters in loquat, I. Genetic tendency of fruit agronomic characters. J. Fujian Acad. Agr. Sci. 8:19–26.
Zheng, Y. H., Y. F. Xi, and T. J. Ying. 1993b. Studies on post-harvest respiration and ethylene production of loquat fruit. Acta Hort. Sinica 20:111–115.
Zhuan, F. C. 1980. The culture of loquat young embryo. Subtrop. Plant Commun. 2:3–7.