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The Fig: Botany, Horticulture, and Breeding

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I. INTRODUCTION

The common fig (*Ficus carica* L.) belongs to the Eusyce section of the Moraceae, with over 1,400 species classified into about 40 genera (Watson and Dallwitz 2004). The genus *Ficus*, comprised of about 700 species, is found mainly in the tropics and is currently classified into six subgenera, which are characterized by a particular reproductive system (Berg 2003). The fig is an aggregate fruit composed of individual small drupes; each is

termed a drupelet. The drupelets develop from the ovaries in a closed inflorescence, known as a syconium (the fig), which encloses many unisexual flowers that can be accessed via the ostiole (Fig. 2.1) by pollinating wasps. The fig tree bears the succulent fruit, which in its fresh and dried state has been valued for millennia. The fig tree is indigenous to Persia, Asia Minor, and Syria and currently grows wild or feral in most of the Mediterranean countries (Condit 1947; Ramírez 1974; Storey 1975; Aksoy 1998; Weiblen 2000; Zohary and Hopf 2000; Datwyler and Weiblen 2004). The tree is known almost universally simply as fig, common fig, or edible fig. The name is very similar in French (*figue*), German (*feige*), and Italian and Portuguese (*figo*). In Spanish it is *higo* or *brevo*. Haitians coined the name *figue France*, to distinguish it from the small, dried bananas called "figs" (Condit 1947).

Fig has been recently proposed to be the first domesticated plant (Kislev et al. 2006), based on archaeobotanical evidence that shows the use of partenocarpic fruit during the 12th millennium BP. Such

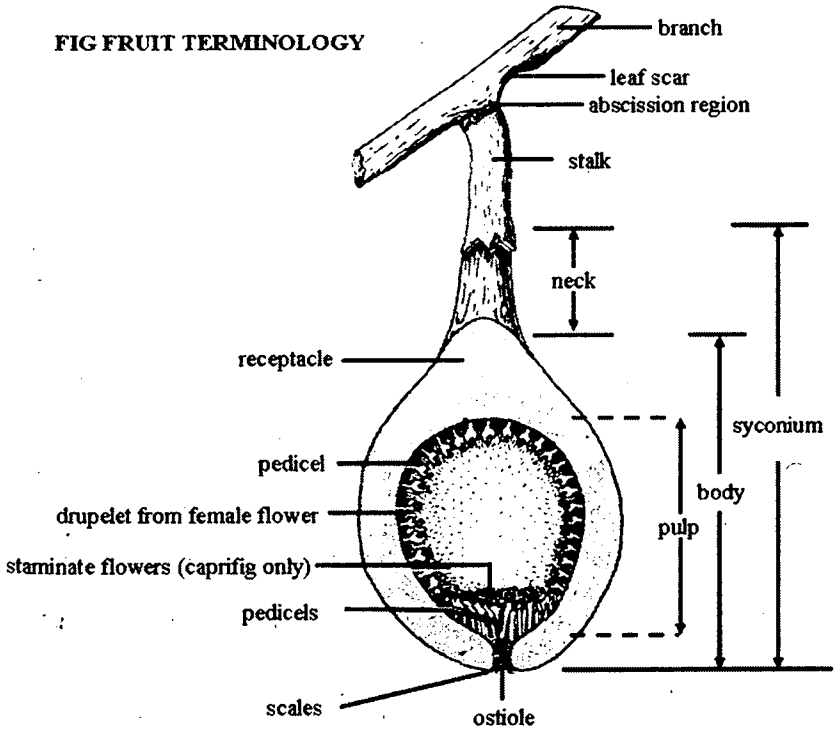

Fig. 2.1. Diagram of *Ficus carica* syconium explaining the fruit terminology. Source: Adapted from Storey (1975).

early cultivation likely resulted from the simplicity of fig tree propagation, which is achieved by merely cutting and planting branches (Condit 1947). The fig is cultivated in most warm and temperate climates and has been celebrated from the earliest times for the beauty of its foliage and for its *"sweetness and good fruit"* (Judges 9:11), with frequent allusions to it in the Hebrew and Christian Bibles and the Koran. There was a fig tree in the Garden of Eden, and the fig is the most mentioned fruit in the Bible. In the Book of Genesis, Adam and Eve clad themselves with fig leaves after eating the "Forbidden Fruit" from the Tree of Knowledge of Good and Evil. Likewise, fig leaves, or depictions of fig leaves, have long been used to cover the genitals of nude figures in painting and sculpture. The use of the fig leaf as a protector of modesty or shield of some kind has entered the language. The biblical quote *"each man under his own vine and fig tree"* (1 Kings 4:25) has been used to denote peace and prosperity. The fig is one of the two sacred trees in Islam and plays an important part in Greek mythology. It was dedicated to Bacchus and employed in religious ceremonies. In the Olympic Games, winning athletes were crownded with fig wreaths and given figs to eat. The wolf that suckled Romulus and Remus rested under a fig tree, which was therefore held sacred by the Romans. Ovid, the Roman poet, states that figs were offered as presents in the Roman celebration of the new year. In several great cultures and religions, the fig tree is used as a symbol (Ferguson et al. 1990).

The fig tree has been distributed from Persia, Asia Minor, and Syria by people throughout the Mediterranean area. It has been an important food crop for thousands of years and is thought to be highly beneficial in the diet. Thousands of cultivars, mostly unnamed, have been developed or came into existence as human migration brought the fig to many places outside its natural range. Figs were introduced into Italy before recorded history. Pliny gives details of no less than 29 kinds of figs (Condit 1947). Figs were introduced into England sometime between 1525 and 1548. Later on, European types were taken to China, Japan, India, South Africa, and Australia. In 1550 it was reliably reported to be in Chinese gardens. The first figs in the New World were planted in Mexico in 1560. Figs reached Virginia in the eastern United States by 1669 and were introduced into California when the San Diego Mission was established in 1769. Subsequently, many distinctive cultivars were received from Europe. The 'Smyrna' fig was brought to California in 1881–82, but it was not cultivated until 1900, when the pollinating wasp was introduced to make commercial production possible. It became a familiar dooryard plant in the West Indies, and at medium and low altitudes in Central America and northern South America.

There are fair-size plantations on mountainsides of Honduras and at low elevations on the Pacific side of Costa Rica. From Florida to northern South America and in India only the common fig is grown. Chile and Argentina grow the types suited to cooler zones (Condit 1947).

Figs can be eaten fresh or dried and are often used as jam. Some fruit is made into paste for use in making fig bars and other pastries, and a tiny portion is canned. Today most commercial fig production is as dried or otherwise processed forms, since the ripe fruit does not transport well. For dry consumption and processed uses, figs are often cultivated using traditional methods. Trees are planted at large distances (100–150 trees/hectare [ha]), often grow quite tall (more than 5 meters) and require no irrigation. Fruits are picked from the ground and, without mechanization, the harvest requires intensive hand labor. Such traditional fig growing has low productivity and is often no longer profitable. In many areas, fig producers are transitioning to more profitable fresh fig production. Fresh fig production, however, requires more sophisticated cultural practices. For the production of fresh figs, new cultivars with high productivity are often planted.

The Food and Agriculture Organization (FAO) (2005) estimates that figs are harvested from 427,000 hectares worldwide (Table 2.1), producing yearly over 1 million metric tonnes (t) of figs around the world, with Turkey, Egypt, Iran, Greece, Algeria, Morocco, the United States, Syria, and Spain producing 70% of the crop and Turkey alone producing nearly 25% of the total (FAOSTAT 2005). The top three exporters of dried figs in the world are Turkey, Iran, and Greece. Turkey, the largest producer, supplies more than half of world export volume while Iran accounts for 12% and Greece for 6%. While fig production by Italy and Spain has decreased over the last decade, it has increased in Turkey, Syria, Algeria, and Brazil. The economic importance of fig production is likely to continue into the future. In the world market, there is an increasing demand for fresh figs and a stable demand for dried figs. The most critical trade concern for fresh fruit is the short shelf life, while for dried fruit most producers struggle to compete with countries with very low production costs. At present, evaluation of fresh cultivars in Europe and the United States combined with improved cultivation practices and better fresh fruit postharvest practices have opened new prospects for fresh and dry fig production (Aksoy 2005).

The aim of this review of figs is to outline the variability and genetic resources and to integrate the current scientific information on morphology and development, horticultural requirements, fresh and dry handling, fig breeding, and neutraceutical and medical properties. Other reviews on figs have described in detail the nature of orchard

Table 2.1. Summary of total world fig production with breakdown of the major producers between the years 1998 and 2005.

	Production (Metric tonne)							
Fig	1998	1999	2000	2001	2002	2003	2004	2005
Algeria	42,209	50,609	54,326	40,864	60,694	63,266	63,000	63,000
Brazil	15,687	16,570	17,207	25,981	23,921	25,586	25,000	25,000
Egypt	220,849	203,005	187,698	150,200	194,631	135,834	160,124	170,000
Greece	80,000	80,000	80,000	80,000	80,000	80,000	80,000	80,000
Iran	78,555	70,100	78,163	71,228	81,000	89,000	90,000	90,000
Italy	30,000	45,200	25,000	21,803	13,020	19,349	21,255	20,000
Morocco	55,700	82,000	68,400	75,600	97,500	67,000	60,000	60,000
Spain	60,250	63,570	56,014	43,163	41,130	43,533	41,278	38,000
Syrian Arab Republic	47,049	41,815	44,071	40,019	43,400	43,400	43,400	43,400
Turkey	255,000	275,000	240,000	235,000	250,000	280,000	275,000	280,000
USA	46,390	42,910	50,712	37,195	48,260	43,999	46,085	43,000
Total	1,083,740	1,126,762	1,047,073	956,904	1,065,686	1,023,076	1,034,644	1,043,676

Source: FAOSTAT, 2005.

fig diseases, insect pests, and their interactions (Ferguson et al. 1990; Michailides 2003) as well as life cycle and caprification (Condit 1947; Janzen 1979; Valdeyron and Lloyd 1979; Weiblen 2002; van Noort 2004). These aspects, which have attracted the attention of many investigators, are only briefly reviewed here.

II. VARIABILITY AND GENETIC RESOURCES

A. Botanical and Horticultural Classification

The genus *Ficus* comprises about 700 species, most of which are native to the tropics or subtropics, and a few have fruits that are considered edible (Condit 1969). Cultivated fig, *F. carica*, clearly had an important role in the human diet throughout history. Wild or nearly wild figs are reported throughout much of the Middle East and Mediterranean region and are distinguished from edible figs by two important features: first, a mutation in the wild fig gave rise to the long-styled pistils and succulent fruitlets of the edible fig and, second, as a consquence of either a pleiotropic effect or a mutation in a tightly linked gene, the edible fig also displays a suppression of the androecium (Storey 1975). Due to suppression of the androecium, all "edible" figs are functionally female. Chromosome number and morphology in the genus *Ficus* have been studied mainly by Condit (1928, 1934, 1964), who states that the chromosomes of the various fig species are similar to each other in appearance, and $2n = 26$ is the basic chromosome number in all figs. The genome size of fig is small, less than three times that of *Arabidopsis* (Ohri and Khoshoo 1987).

Four types of figs are described based on cropping and pollination characteristics (Fig. 2.2). The type known as common fig (e.g., 'Brown Turkey', 'Mission', and 'Adriatic' requires no pollination to set a commercial crop. These types are referred to as "persistent" rather than parthenocarpic since the fig is not a true fruit. The allele for persistence is dominant but is lethal in the ovule, and can only be conferred by the pollen parent (Saleeb and Storey 1975). The flowers in the common fig are all long-styled pistillate flowers and need no pollination for continued growth and maturity. Common fig produces one to two crops each year. Pollination (called caprification in figs) common-type figs sometimes markedly increases fig size, changes the color of both skin and pulp, increases the tendency to split, and enhances fruit taste (Condit 1947). The other two types of edible figs require pollination by the wasp to set the main crop of figs. Botanically, these nonpersistent types are classified as "cauducous" and are classified as Smyrna types

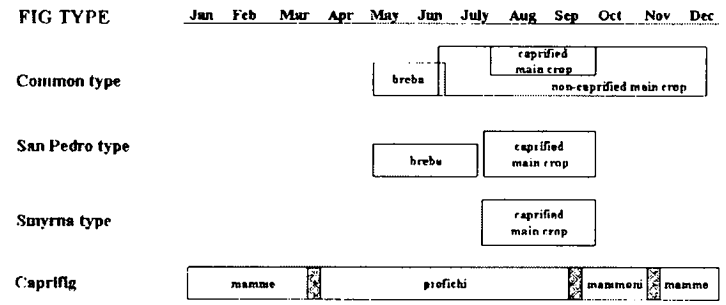

Fig. 2.2. Fig fruit production in Israel as affected by different fig type, caprification, and cropping.

(e.g., 'Sarilop', 'Marabout', and 'Zidi', and San Pedro types (e.g., 'Dauphine', 'King', and 'San Pedro'). The San Pedro types are distinguished by setting a persistent early crop, known as breba fruit, but require caprification to set the main crop. This is a unique combination in which on the same branch persistent and nonpersistent fruits develop in the same season. While San Pedro types are in part defined by the setting of a breba crop, some common figs also produce brebas.

The fourth type serves as a source of pollen for commercial plantings of the cauducous types and is known as caprifig. The caprifig is generally termed male or goat fig, reflecting lack of value as human food and, with a few exceptions, is inedible. However, the caprifig is not only male, and the syconium usually contains both staminate and short-styled pistillate flowers. The staminate flowers are located in a limited area surrounding the ostiole, while the short-styled pistillate flowers occupy most of the interior surface of the syconium. The short-style pistillate flowers are adapted to oviposition by the symbiotic fig wasp *Blastophaga psenes*, which has coevolved with the fig (Galil and Eisikowitch 1968; Galil and Neeman 1977; Kjellberg et al. 1987).

The caprifig tree typically produces three crops of fruit annually, each harboring the larvae, pupae, and temporarily the adult *Blastophaga* wasps. The spring crop *profichi*, the pollen source for the edible fig, are produced in large numbers on wood from the previous season. Summer crop *mammoni* are produced as single or double fruits in the axils of leaves on branches of the current season. They mature during October when the *Blastophaga* wasps leave them and enter young *mamme* that develop on current growth. Cool temperatures in October and November retard development of *mamme* fruit and their attendant wasp larvae, which overwinter and develop into pupae in March.

Regarding the wasp life cycle, in early April, the adult male wasp emerges through the ovary wall. When free in the fig cavity, the male

searches for female wasps and copulates with them. The females emerge from the *mamme* fruit and search for developing *profichi* fruitlets. The females then lay eggs in ovaries of the short-styled pistillate flowers of the *profichi* spring crop. An important botanical component of this coevolution is the protogynous nature of the caprifig so that pistillate flowers are receptive six to eight weeks before anthers mature in the same syconium (Condit 1932). Through this feature, wasps enter, pollinate, and oviposit a syconium, which later has mature pollen as the next wasp generation emerges.

B. Cultivars

Genetic variability in fig is enhanced by the obligatory outcrossing in this species, resulting in the production of new individuals with potentially favorable characteristics from seeds. Because fig is easily propagated through cuttings and is repeatedly repropagated to maintain desirable cultivars, there is also considerable opportunity for phenotypic variability from natural mutations within a cultivar. Naming of desirable fig cultivars is recorded as early as the fourth century BCE. In the first century CE, Pliny lists 29 cultivars of fig. De Candolle (1886) noted that the "cultivated forms [of figs] are numberless." Even after eliminating suspected synonyms, the most complete fig monograph (Condit 1955) describes 607 named fruit-producing cultivars. However, most commercial production is based on only a few cultivars. For example, the California fig industry is essentially based on five cultivars: 'Calimyrna' ('Sarilop'), 'Adriatic', 'Mission', 'Brown Turkey' and 'Kadota' (California Fig Advisory Board 2006; California Fresh Fig Growers Association 2006).

Of the cultivars described by Condit (1955), 78% are common types, less than 4% are San Pedro types, and the remaining 18% are Smyrna types. Cultivars also vary in such traits as leaf morphology, plant vigor, fruit external and internal color, fruit flavor, percentage soluble solids, titratable acidity, seed characteristics, fruit shape, skin thickness, ostiole diameter, and duration of fruit production. A selection of the amazing diversity in fig cultivars, focusing primarily on commercial cultivars, is described in Table 2.2.

Traditionally, characteristics of the fruit and tree have been used to categorize different cultivars. This approach is useful and sensible especially in marketing fruit or selecting material for planting. However, there are numerous cultivars with similar descriptions and in some cases dozens of names are believed to be associated with a single genotype (Condit 1955). More detailed data on leaves and fruit of brebas

Table 2.2. Characteristics of selected and major commercial fig cultivars.

Cultivar	Pollination Type	Major Synonym	Region	Breba Crop				Main Crop				Flavor
				Size	Skin Color	Pulp Color	Use	Size	Skin Color	Pulp Color	Use	
Abicou	Common		France	Med.	Black	Red	Fresh	Med.	Black	Red	Dried, fresh	Caramel, rich
Adriatic	Common	Verdone	California	na[z]	na	na	na	Small to med.	Green to yellow green	Light pink to pink	Dried, fresh	Mild berry, rich
Allomi	Smyrna		Iran	na	na	na	na	Med.	Purplish to black	Yellow	Fresh	Cherry-like
Alma	Common		Texas (home)	na	na	na	na	Small	Yellow	Amber to pink	Fresh, preserves	Caramel
Bardacik	Smyrna		Turkey	na-	na-	na	na	Small	Light green	Dark pink	Fresh	
Beall	Common		USA (home)	Med.	Violet	Light pink	Fresh	Med.	Violet	Light pink	Fresh	
Beyaz orak	San Pedro		Turkey	Med.	Light green	Light pink	Fresh	Small	Light green	Light pink	Fresh?	Mild
Brawswic	Common		China	na	na	na	na	Large	Violet bronze	Amber	Fresh	
Brown Turkey	Common		California, Israel, Global	Very large	Violet brown	Pink	Fresh	Very large	Violet brown	Amber	Fresh	Mild caramel
Bursa siyâhi	Smyrna	Black Bursa	Turkey	na	na	na	na	Large to very large	Striped violet-brown-green to purplish black	Pink to dark red	Dried, fresh	Berry-like, rich
Celeste	Common	Malta	SE USA (home)	na	na	na	na	Small to med.	Violet bronze	Amber to pink	Fresh, preserves	Caramel

Chichek	Common		Turkey	Med.	Black	Red	Fresh	Med.	Black	Red	Dried, fresh	Rich
Conadria	Common		California	Large	Green + purplish tint	Light pink	Fresh	Med.	Light yellow green	Light pink	Dried	Honey
Cuella dama blanco	Common	Col de Dame	Spain, Chile	na	na	na	na	Med.	Green	Red	Fresh	Berry-like
Dalmatic	Common		France	Very large	Green	Red	Fresh	Large	Green	Red	Fresh	Berry-like, rich
Dauphine	San Pedro		France	Very large	Green violet	Pink	Fresh	Med.	Green Violet	Dark pink to red	Fresh	Rich
Dottato	Common	Kadota	Italy, California, Chile	Med.	Green to yellowish green	Amber to pink	Fresh	Med.	Green to yellow	Green to yellow amber	Fresh canned, dried	Honey
Göklop	Smyrna		Turkey	na	na	na	na	Very large	Green	Pink to light red	Dried, fresh	Aromatic
Kalomon	Smyrna	Kalamata	Greece	na	na	na	na	Large	Light yellow to golden yellow	Amber to light pink	Dried, fresh	Caramel, rich
Kashky	Smyrna		Iran	na	na	na	na	Med. to large	Chimera, black and yellow	Red	Fresh	Strawberry-like
Keshany	Common		Iran	Large	Red to orange	Red to yellow	Fresh	Large	Red to orange	Red to yellow	Fresh	Sweet orange like
King	San Pedro	Desert King	California	Large	Green	Pink	Fresh	Med. to large	Greenish purple	Amber to light pink	Fresh, dried	Honey
Lampa preta	San Pedro	Tiberio	Spain, Italy	Med.	Violet	Amber	Fresh	Med.	Light violet	Amber to light pink	Fresh	
Lampiera	San Pedro		Portugal	Large	Greenish brown	Rose	Fresh	-	-	-	-	
Mangefy	Common		Iran	Large	Yellow	Yellow	Dried	Large	Yellow	Yellow	Dried	Sweet
Masui dauphine	Common?	Masui Dolphin	Japan	Very large	Violet-Brown	Pink	Fresh	Vary large	Violet brown to purple	Pink	Fresh	Mild caramel

(Continues)

Table 2.2. Characteristics of selected and major commercial fig cultivars. *(Continued)*

Cultivar	Pollination Type	Major Synonym	Region	Breba Crop				Main Crop				Flavor
				Size	Skin Color	Pulp Color	Use	Size	Skin Color	Pulp Color	Use	
Meshky	Common		Iran	Large	Black	Red	Fresh	Large	Black	Red	Fresh	Berry-like
Mission	Common	Franciscana Brebal	California Spain	Large	Purplish black	Light pink	Fresh	Med.	Purplish black	Amber to light pink	Dried, Fresh	Berry-like, rich
Neri	Common		Italy	Med.	Black	Red	Fresh	Med.	Black	Red	Dried, Fresh	Caramel, rich
Panache	Common	Striped tiger	USA (home)	na	na	na	na	Med.	Yellow with green stripes	Dark pink to red	Fresh	Intense raspberry, rich
Ponte de gada	San Pedro		Italy		Green Violet	Pink	Fresh	Med.	Green Violet	Pink	Fresh	Rich
Roshnik	Common	-	Albania					Small	Yellow	Brown	Dried	Berry-like
Sabz	Smyrna		Iran	na	na	na	na	Med.	Green to yellow	Yellow to pink	Dried	Honey
Sari Lop	Smyrna	Calimyrna, Lob Injir, Sarilop, Lop Incir	Turkey California	na	na	na	na	Large	Light yellow to golden yellow	Amber to light pink	Dried, Fresh	Caramel, rich, aromatic
Shah-anjer	Smyrna		Iran	na	na	na	na	Large	Yellow	Yellow	Fresh	Honey
Sierra	Common		California	na	na	na	na	Med. large	Green to yellow	Amber to light pink	Dried, Fresh	Caramel, rich

Siyah	Smyrna		Iran	na	na	na	na	Med.	Violet	Red	Fresh	Berry-like
Siyah incir	Common		Turkey	na	na	na	na	Very large	Purple	Dark pink	Fresh?	Aromatic
Siyah orak	Common		Turkey	Med.	Purplish black	Amber to red	Fresh	Small to med.	Purplish black	Red	Fresh?	Mild
Sultani	Common	Fayoumi, Ramadi	Egypt, Tunisia	Med. Large	Green and brown	Pink	Fresh	Med. large	Violet brown	Light pink	Dried, Fresh	
Yesilguz	Smyrna		Turkey	na-	na-	na	na	Large	Light green, white sectors	Dark red	Fresh	Aromatic
Zard-peazy	Common		Iran	Large	Yellow	Yellow	Fresh	Large	Yellow	Yellow	Fresh	Sweet
Zidi	Smyrna		Morocco, Tunisia	na	na	na	na	Very large	Purplish black	Amber to red	Dried, fresh	Berry-like, rich

*Nonapplicable, brebas are rare or nonexistent.

and main-crop figs have been shown to uniquely characterize almost all cultivars in the Extremadura collection in Spain (Giraldo et al. 2007). This type of description has the advantage of requiring little specialized equipment but is more likely to be influenced by environmental variability than molecular markers.

Among molecular methods, isozyme analysis has been used for many years to sort genotypes. While there are multiple studies involving the use of isozymes to distinguish fig cultivars, in practice only a few cultivars were examined. Chessa and Nieddu (2005) employed six enzyme systems to distinguish a larger number of cultivars but found that isozyme banding from only the three most useful enzyme systems were needed to provide unique patterns for each of the 31 genotypes assessed. These authors found similar discrimination using 25 primers to produce random amplified polymorphic DNA (RAPDs).

In many species, DNA microsatellites, also known as simple sequence repeats (SSRs), have proven very useful in fingerprinting genotypes. Khadari and colleagues (2003) compared RAPDs, inter simple sequence repeats (ISSR) and microsatellite markers for the molecular characterization of 30 cultivars and found that RAPDs were the least efficient system for identifying fig genotypes. When five SSR loci were used to analyze 70 fig accessions in the Conservatoire Botanique National Méditerranéen de Porquerolles in France (Khadari et al. 2003), 52 distinct genotypes were identified. While the authors suggested that these were likely to represent 52 distinct genotypes with several duplicates under different names, they also indicated that use of more markers is needed.

Use of six SSR loci in analysis of 75 fig accessions allowed identification of 72 distinct genotypes (Khadari et al. 2004). Giraldo et al. (2005) developed 25 polymorphic SSR loci and used them to characterize 15 accessions. The SSRs averaged 3 alleles per locus and revealed 11 unique genotypes among the 15 accessions, which were interpreted as demonstrating a narrow genetic base in cultivated figs. More recently, 16 SSR loci have been used to assess 181 fig accessions in the Germplasm Repository in Davis, California, which revealed 128 unique genotypes (Aradhya and Stover, personal comm.). Ideally, fig researchers worldwide should agree on a uniform set of markers, so that identity of figs can be verified across different collections.

C. Genetic Resources

For several decades, the land area devoted to village traditional fig production has significantly decreased in many Mediterranean countries, and severe genetic erosion is threatening the local fig germplasm.

Therefore, it is imperative to establish programs to preserve and characterize Mediterranean fig genetic diversity, a challenge that is being met by several countries. Collections listed in Table 2.3 have at least 25 different accessions.

Proper cultivar identification is a key concern in many fig collections, largely because individual cultivars have been widely distributed with many synonyms, and often the same name is being used for different cultivars. The Institute of Kalamata, Greece, has 64 different fig cultivars collected from Cyprus, Italy, Greece, Turkey, France, the United States, and Spain. The collection was characterized by the use of RAPD markers, and results were evaluated in conjunction with morphological and agronomical characters in order to determine the genetic relatedness of genotypes originating from diverse geographic origin. The results indicate that fig cultivars have a rather narrow genetic base. No wasteful duplications were found in the collection. Cluster analysis allowed the identification of groups in accordance with geographic origin, phenotypic data, and pedigree (Papadopoulou et al. 2002). The U.S. National Clonal Germplasm Repository (NCGR) in Davis, California, houses most of the Mediterranean-adapted fruit and nut crop collections in the United States, including fig. The NCGR fig collection currently contains 190 different accessions: 78 named fruiting cultivars, 44 regional selections from diverse locations, 40 advanced selections from plant breeders, 28 caprifigs, and a small number of species and hybrids (www.ars-grin.gov/dav/). Recently the NCGR has completed DNA microsatellite fingerprinting of its fig accessions (Stover and Aradhya 2007).

To finalize identification of fig cultivars from different collections around the world, it will be necessary to compare fingerprints to "typed" material from several collections. The microsatellite information and AFLP data will make it possible to assess affiliation among fig genotypes and will facilitate understanding of evolutionary relationship within the genus *Ficus* and will help conservation of fig plant material.

III. PLANT MORPHOLOGY AND DEVELOPMENT

The morphology and anatomy of figs have been described by many authors. These reports have been summarized by Condit (1947, 1955), Crane (1986), and Ruth (1975). The fig is an unusual tree as it may produce multiple crops of fruits each year, and certain fig types need pollen from their pollinator caprifigs. The breba crop, which is not produced in all cultivars, is borne laterally on the growth of the previous season from buds produced in leaf axils. These buds develop in the

Table 2.3. Compilation of fig germplasm collections published with 25 or more accessions.

Location	Name	No. Accessions	Focus of Collection	Reference
Castel Ste. Claire, France	Conservatoire Botanique National Méditerranéen de Porquerolles	277		Roger and Khadari 2003
Winters, CA, USA	National Clonal Germplasm Repository	275		
Rome, Italy	Istituto Sperimentale per la Frutticoltura	250	Italy	IPGRI 2006
Guadajira, Spain	Junta de Extremadura. Servicio de Inv. y Desarrollo Tecnológico Finca la Orden	202		IPGRI 2006
St. Petersburg, Russian Federation	N.I. Vavilov All-Russian Scientific Research Institute of Plant Industry	187	Many from Ukraine	IPGRI 2006
Moncada-Valencia, Spain	Instituto Valenciano de Investigaciones Agrarias	171	Spain	Bellini and Giordani 2006
Bet Dagan, Israel	Agricultural Research Organization, The Volcani Center	105		Bellini and Giordani 2006
Tarragona, Spain	Centre de Mas Bove, Inst. Recerca i Tecnologia Agroalimen. (IRTA)	92		IPGRI 2006
Meknes, Morroco	Aïn Taoujdate Experimental Station	72	Morocco and Algeria	Khadari et al. 2004
Kalamata, Greece	Olive, Fruit and Vegetables Institute of Kalamata	66	Greece and Cyprus	Papadopoulou et al. 2002
Tavira, Portugal	Direccao Regional de Agricultura do Algarve	60		IPGRI 2006
Boufarik, Algeria	Arboricult. Fruit.et de la Vigne	52	North Africa, S. Europe	IPGRI 2006
Palma de Mallorca, Spain	Conselleria d'Agricultura i Pesca	52		IPGRI 2006
Alcobaca, Portugal	Estacao Nacional de Fruticultura Vieira Natividade	50		IPGRI 2006
Caserta, Italy	Istituto Sperimentale per la Futticoltura	50	Italy	Bellini and Giordani 2006
Nicosia, Cyprus	National (CYPARI) Genebank, Agricultural Research Institute	39		IPGRI 2006
Sassari, Italy	Istituto di Coltivazioni Arboree (now Dipartimento di, Università di Sassari	31	Italy	Bellini and Giordani 2006
Neve-Yaar, Israel	Agricultural Research Organization, The Volcani Center	28	Israel	Bellini and Giordani 2006
Potenza, Italy	Dipartimento di Produzione Vegetale, Università degli Studi della Basilicata	25	Italy	Bellini and Giordani 2006

following spring, and the fruit matures between June and July. The main crop of figs is produced laterally in the axils of leaves on shoots of the current season. Fruit maturation starts at July and may last until temperature drops between October and December. At the end of the growth period, the leaves fall and the tree enters the dormancy period. Reproductive buds that do not produce fruit during the growing season remain dormant over the winter to give rise to the first spring breba crop. In some cultivars and in appropriate environments, largely developed main crop figs may remain on the tree over the winter and complete development in early spring.

Environmental factors such as temperature, photoperiod, and humidity affect the development and yield of the fig tree. Growing figs in unsuitable conditions may cause crop loss and various types of fruit damage.

A. Vegetative Morphology and Development

1. Root System. The fig tree has a system of fibrous roots that spreads up to three times the diameter of the canopy and is typically very shallow and without a taproot (Condit 1947). Fig plants are fairly tolerant of poor soil and moderate salinity (Golombek and Lüdders 1990). Once plants are established, they are relatively drought tolerant, probably due to their very extensive and wide-ranging root system. The extreme ease of rooting figs has facilitated cultivation for thousands of years and is routinely used to establish new orchards from cuttings. A recent study evaluated the establishment performance of *F. carica* trees three years after planting. The study employed two types of soil beds, alluvium or terra-rossa, and each tree was planted in 6 cubic meters of soil ($2 \times 2 \times 1.5$ m). Results showed efficient and fast establishment of the root system. In addition, roots were affected by changing the type of soil in the rhizosphere, further documenting the highly effective root system in fig (Atzmon and Henkin 1998).

Fig roots are sensitive to the root knot nematode *Meloidogyne incognita*, especially when trees are planted on light, sandy soils (Condit 1947). Some *F. carica* cultivars and many other *Ficus* species display tolerance or even immunity to some nematodes that compromise commercial fig plantings (Storey 1975). Nematode-resistant rootstocks have been investigated as a solution to this problem. Several species of *Ficus* have displayed graft compatibility and resistance to root-knot nematodes (Krezdon and Glasgow 1970). Other species were reported to be nematode-resistant but were not practical as rootstocks because of their low graft compatibility or poor tolerance of low temperatures (Condit

1947). When commercial fig cultivars were tested for nematode resistance, some were identified as being semiresistant (Kawase 1990). Recently Hosomi et al. (2002) tested 20 commercial fig cultivars for nematode resistance. Trees grafted on 'Zidi' cultivar were vigorous under different field conditions and usefully nematode-tolerant. 'Masui Dauphine' grafted on 'Zidi' was vigorous, and the 'Zidi' rootstock had no negative influence on fruit quality.

2. Shoot and Leaf Systems. Histological examination of the terminal bud in the spring shows that the apical meristem has elongated to produce lateral outgrowths—the meristems of scales, leaves, inflorescence, and lateral vegetative buds (Crane 1986). Each terminal bud generally contains four or five primordial leaves flanked on either side by a scale. Toward the base of the bud one vegetative and two inflorescences primordia are present. A primordium destined to become vegetative has three or four scales that are laid down to cover the bud axis. The vegetative primordia continue during tree growth to initiate scales and leave. As the bud elongates, the cover scales abscise, and the apical meristem develops into a shoot that produces leaves and new inflorescences. Fig trees vary in their growth habits, ranging from open and drooping to upright and compact (Feguson et al. 1990). Fig growth habit is characteristic of the cultivar. Thus, 'Brown Turkey' has a weeping willow type of growth with compact, down-spreading branches, while the cultivars 'Sierra' and 'Autumn Honey' have a vigorous growth habit with upright-rising branches. Individual trees in a favorable environment often reach large size, while fig trees in orchards are usually more compact. Fig has typical bright green, single, alternate and large leaves. Leaf characters are quite stable and serve as an important parameter in cultivar identification (Ferguson et al. 1990). They start to develop in the early spring and will continue to form of new leaves until temperature drops in autumn. Toward the end of the growing season, environmental conditions such as low temperature, photoperiod, wind, and rain cause leaf fall.

3. Latex Cells. Fig trees and fruit contain typical latex secreting cells, producing milky exudates characteristic to all fig cultivars (Condit 1947). Latex is the cytoplasmic fluid of laticiferous tissues that contain the usual organelles of plant cells such as nucleus, mitochondria, vacuoles, ribosomes, and Golgi apparatus. Rubber (cis-1,4-polyisoprene) is produced in latex at the expense of high-energy cost and is considered a secondary metabolite (Kang et al. 2000). Although it is not fully understood why plants produce rubber, it has been suggested that latex secretion is a

defense against mechanical wounding and/or herbivores such as insects, vertebrates, microorganisms, and fungi (John 1993). This view of latex as a defense system is based on the observations that latex contains a variety of defense-related proteins. Recently King et al. (2000) isolated two major rubber particle proteins in *F. carica*. Kim et al. (2003) identified three rubber particles and latex genes from *F. carica*: a trypsin inhibitor, chitinase, and peroxidase. Peroxidase is widely known to participate in a variety of plant defense mechanisms in which hydrogen peroxide is often supplied by an oxidative burst (Lamb and Dixon 1997; Shigeoka et al. 2002). The transcript level of peroxidase in *F. carica* was increased following treatment with various types of abiotic stresses or hormones, including wounding, drought, jasmonic acid, and abscisic acid. Also, the transcript level of the trypsin inhibitor was increased remarkably by wounding treatment and slightly by jasmonic acid treatment. In *F. carica* leaves, the expression of chitinase was remarkably induced by wounding or jasmonic acid treatment. The presence and expression of stress-related genes on the surface of rubber particles and latex in *F. carica* further support a possible role of rubber particles and latex in defense mechanisms in this species. The identification and characterization of the three latex fig genes could be further used to investigate the physiological and biochemical traits of the fig tree cultivated in temperate zones.

B. Reproductive Development

Primordia destined to develop into reproductive or vegetative organs are identical at their initial stage of development. Generally, there are four scales laid down, which cover the bud axis. Following this stage, the vegetative meristem continues to initiate scales and leaves, unlike the reproductive meristem, which broadens and elongates and then begins the initiation of ostiolar scales. Hence, the first visual microscopic evidence of inflorescence differentiation is the elongation of the axis and the initiation of scales that eventually surround the ostiole of the syconium. Further development of the inflorescence primordia consists of continued broadening of the apex and cell division around the periphery, giving rise to many ostiolar scales forming a cup-shaped structure lined with floral primordia. The formation of the syconium is complete when the apical portion of the cup-shaped structure grows toward the center and forms an ostiole, which is partly closed with numerous scales (Crane and Brown 1950; Crane and Baker 1953; Crane 1986). *Ficus carica* is gynodioecious, bearing either hermaphroditic or "female" figs on separate plants.

C. Fruit Growth and Development

Fruit growth and development were described in detail by Crane (1986). As the terminal bud unfolds and growth occurs in the spring, the fig fruits are borne in the axils of the leaves. Two inflorescences and one vegetative bud are present at the same lateral position in the leaf axils. In cultivars such as 'Mission' and 'Brown Turkey,' usually only one inflorescence develops into a syconium, while in 'Kadota' and 'Calimyrna' cultivars, often both inflorescences at a node may develop. Similar to other fruits, fig syconium development has three defined growth periods represented by a double sigmoid curve (Crane and Brown 1950; Crane and Baker 1953). The first period of growth—Stage I—is characterized by a very rapid diameter increase and slower rate of fresh and dry weight, with almost no change in sugar accumulation. The second period—Stage II—is a quiescence stage that is marked with almost no change in fruit diameter, dry and fresh weights, and sugar content. Stage III is characterized by accelerated rate of increase in diameter, in fresh and dry weights, in water as well as in sugar content. During this phase of growth, over 70% of the total dry weight and 90% of the total sugar content is accumulated in the fruit. Dramatic pigment changes occur during this period in many dark cultivars as chlorophyll content in the fruit skin decreases rapidly and the fruit skin turns from green to bluish black (Crane 1986). In addition, fruit size increases and tissue softening occurs during the last stage of fig fruit development (Chessa 1997). Since the inflorescence buds begin developing as associated leaves emerge along the branch, fruit maturation is sequential, beginning with the basal fruit and progressing toward the branch apex, and harvest can last for a long period. Where *B. psenes* wasps are present, both caprified and noncaprified fruit may develop on the same branch in common-type fig fruits. In most cultivars, within a given fruit, the first period of growth lasts 5 to 6 weeks and the third period 3 to 5 weeks. However, there are great differences between fig cultivars in the duration of the second, quiescence period of development. In cultivars such as 'Mission'. the second period lasts 3 to 4 weeks, while in the autumn-producing cultivars 'Sierra' or 'Autumn Honey', the second period lasts 6 to 8 weeks. Using 'Masui Daufine' fig cultivar grown in a greenhouse, Matsuura et al. (2001) studied the distribution of ^{13}C at the lower nodes when administered to a leaf of a bearing shoot during fruit enlargement and maturation stages. The ^{13}C accumulation data revealed that fruit at Stage I had a greater sink strength than fruit at Stage II. When the Stage II fruit was treated with drop of oil on the ostiole to induce early maturity (a practice known as oleification), it became a highly active sink,

importing ^{13}C labeled photosynthates primarily from leaves positioned near the fruit.

Breba figs have a different pattern of growth and development from the main crop syconia that develop on the same branch in the same season. Shortly after initiation, the breba syconium enters winter dormancy. At spring, the breba syconium resumes growth, which continues for 7 to 8 weeks with a short quiescence stage for 2 weeks and a fast maturation stage, for 2 weeks, in June-July. About 2 weeks before maturation of the breba fruit, growth rate and sugar accumulation significantly increase. Since all breba fig syconia on the same branch are at similar developmental stages, the fruit harvest is shorter and lasts only 2 to 3 weeks.

Different fig cultivars can set fruit with or without pollination. A consistent difference in nitrate levels has been detected in persistent versus nonpersistent fig cultivars (Crane 1986). The average nitrate content of persistent figs is triple that of nonpersistent ones during Stages I and II of summer main crop figs. By Stage III nitrate is not found in non persistent fruit. Crane (1986) showed that indoleacetic acid (IAA) is inhibited as nitrate levels rise and suggested that the reason nitrate levels differ so greatly in persistent versus nonpersistent figs has to do with the regulation of indoleacetic acid oxidase. Therefore, persistent cultivars are expected to have higher auxin levels. Indeeed, auxin application was found to stimulate fruit set in nonpersistent Smyrna-type figs (Crane and Overbeek 1965; Crane 1986). Various applied growth regulators, including auxins, gibberellins, and cytokinins can induce persistence in the Smyrna-type 'Calimyrna' cultivar (Crane 1986). The maturation process of auxin-induced persistent fruits is somewhat longer than that of caprified ones, but their morphology is similar.

Common fig cultivars are facultatively persistent and may produce both persistent and pollinated main-crop figs. Morphologically, the pollinated fig syconium creates true fruits, while the nonpollinated fig syconium presents an enlarged inflorescence with multiple long- styled pistillate flowers. 'Autumn Honey' and the 'Brown Turkey' are two cultivars that produce caprified and nonpollinated figs on current year's wood. The caprified 'Autumn Honey' fruits have darker purple skin color and red pulp, compared with the white pink color pulp of the noncaprified fruit. Usually caprifed fruits are bigger and have longer storageability (Rodov et al. 2005; Yablowicz et al. 2005).

The number of crops produced by fig trees directly influences its carbohydrate balance. Smyrna-type figs, producing a single main crop, have maximum starch concentration at early spring, midsummer, and late fall (Crane 1986). The spring decrease in sugar and simultaneous increase in starch concentration occur when shoot and breba fruit

initiate in March. Shortage in available carbohydrates and competition between the new foliage and the breba syconium can cause syconium drop and elimination of the breba crop. Yablowitz et al. (1998) found that application of gibberellins to the San Pedro–type 'Nazareth' cultivar, or nipping of the terminal bud, will temporarily stop new foliage development and will allow breba growth and reduce competition and syconium drop.

D. Fruit Maturation

The fig is a highly perishable climacteric fruit subject to rapid physiological breakdown. The postharvest life of the fruit is considered to range from 7 to 10 days even when stored at low temperatures (Chessa 1997). Profound cell wall modification processes occur within the tissues during maturation (Chessa 1997). Basic studies on processes that occur during ripening are essential for studying systems in which the biological and physiological processes linked to maturation are involved in postharvest deterioration. Application of ethylene to fig fruits during late Stage II of their development stimulates growth and ripening. In mature and ripe fig fruit, the receptacle tissue and the pulpy tissue of the drupelets within it are clearly distinct. Therefore, analysis of both tissues as a single mixture may obscure some cell wall changes that are crucial in understanding the cell wall modification processes during ripening.

Owino et al. (2004) characterized the changes in cell wall polysaccharides taking place within the distinct and separate tissues of the receptacle and the pulpy drupelets during sequential ripening in fig fruit. The pectic extracts had high uronic acid contents in addition to high amounts of neutral sugars. At the fig-ripening onset, the amounts of both uronic acid and total sugars were more pronounced in the drupelets than in the receptacle. The data suggest that even though quantitative and qualitative changes in cell wall polysaccharides occur during ripening in both tissues, qualitative variations between tissues occur only in the pectic polymers, not in the hemicellulosic polymers. In an effort to understand the molecular basis of softening in figs, the cDNAs responsible for cell wall expansion and disassembly were isolated (Owino et al. 2004). The cDNAs isolated from ripe 'Masui Dauphine' fig cultivar encode two divergent Endo-1,4-β-glucanases (*FC-Ce-l1* and *FC-Cel-2*) and three xyloglucan endotransglycosylases (*FC-XET1, FC-XET2, FC-XET3*). Southern blot analyses indicate that the isolated XETs and EGases exist as single-copy genes in the fig fruit genome. Propylene stimulated the accumulation of *FC-Cel-1* mRNA while 1-Methylcyclo-

propane (1-MCP) inhibited its accumulation, indicating that this gene is up-regulated by ethylene. *FC-XET1* mRNA accumulation was detected only in the 1-MCP-treated fruit, indicating that this gene is down-regulated by ethylene. *FC-Cel-1* and *FC-XET2* mRNAs showed a more or less constitutive expression in both treatments, indicating that these genes are ethylene independent and are developmentally regulated. These results suggest that fig fruit XETs and EGases comprise gene families with divergent members showing differential regulation during fig fruit ripening. A combination of ethylene and other developmental factors influence the expression of these genes, suggesting that multiple activities are required for the cooperative modification of the hemicellulose network during softening of fig fruit. The authors (Owino et al. 2004) concluded that, similar to most studied fruit species, the gene products of the isolated 11 cDNAs, putatively encoding cell wall– related enzymes, are coordinated both in time and in amount during fig fruit development and ripening and act concertedly to achieve softening.

E. Climatic Effects

1. Vegetative Growth and Development. Fig growth and production are strongly dependent on climatic conditions. Generally, fig will grow best and produce high-quality fruit in Mediterranean and dryer warm-temperate climates. The decrease of temperature in autumn, the cold winter conditions, and the growth temperature and rain all affect tree growth and crop production. When fig grows in hot desert areas, where winter temperature is above 6° to 10°C, leaf defoliation and dormancy are eliminated. In Israel, around the Dead Sea area, where the winter temperatures are 5° to 17°C, 'Brown Turkey' cultivar, grown in nethouses, never defoliates and continues to produce fruit from November to May. The lower winter temperatures between February and mid-March (5°–13°C) slow down fruit maturation at this period, while the rise of temperature at the end of March (10°–22°C) leads to resumed growth and fruit maturation (Flaishman and Al Hadi 2002).

Fig tree has limited requirements for chilling units, and the length of the dormant period depends on the local climatic conditions (Erez and Shulman 1982). Under hot climatic conditions, in several areas in South America such as Brazil, the tree can continuously grow and be evergreen. In colder weather, however, the tree stops growth, becomes defoliated, develops a typical terminal bud, and enters a dormancy period. Kawamata et al. (2002a) estimated the intensity of bud dormancy in 'Masui Dauphine'. The endodormancy of the fig buds was classified into three phases: introductory, deepest, and awaking phases. They found that fig

shoots will sprout shortly after being heated even when they were in the deepest phase of dormancy. It was concluded that these treatments could be used to induce double cropping or year-round production. In figs that are not completely dormant, early cold weather (temperatures down to –6°C) may cause severe shoot and bud damage and sometimes may cause mortality. Some cultivars are hardier and can tolerate lower temperatures and produce new shoots from underground protected buds. In spring, the terminal buds unfold and growth is resumed.

2. Reproductive Growth and Development. The drop of temperatures in autumn will arrest shoot growth, and, as a result, a typical terminal bud will develop. This process will affect the late autumn crop production. In areas with night temperatures above 12°C, such as the Imperial Valley in California and in the coastal area in Israel, fig trees produce fruits in November and December and fruit maturation will continue until leaf fall (Flaishman and Al Hadi 2002). During winter dormancy, most fig syconia at Stage II will drop, while fig syconia at Stage I will form scales that protect the developing fruit from low winter temperature. In this case, the fruits stay quiescent and produce breba crop in spring. Generally, autumn production will reduce the number of dormant buds and, therefore, next year's breba crop production. Breba crop production can be successful in relatively moderate winters. When grown in cooler areas, fig tree are often injured by early or late frosts that kill back the younger branches and can damage the syconia buds of both breba fruit and caprifigs. To prevent frost damage, growers in California use wind machines that create air movement in the orchard (Freguson et al. 1990). Climate markedly affects the size, shape, and skin and pulp color of figs (Condit 1947). Cooler climates produce greener, as opposed to yellow skins, more vivid pulp colors, and larger, more elongated fruits. Crane (1986) has suggested that the larger individual size of first breba crop, which competes with shoot growth and second crop for available carbohydrates, is due to its development during a cooler period. In addition, Crane (1986) suggested that climate may also affect pollination requirement.

Other environmental conditions such as rain, hail, and wind can reduce fruit quality and production. Rain may cause fruit splits. Splitting is the result of sudden changes in the internal fruit pressure brought on by cool temperatures and/or high humidity as the fruit matures (Freguson et al. 1990). Splitting in 'Calimyrna' and other varieties may also result from excessive pollination and the growth of too many developing seeds during fruit ripening. Strong winds at the season of ripening whip the foliage and cause scarring of fruits such as of 'Kadota' and 'Brown Turkey'.

Fig genotypes vary widely in their response to environmental factors. Several selection and adaptation studies have been reported on fig cultivars. In Turkey, a major source of domesticated figs in the world, different fig cultivars can be found growing in different climatic conditions. Adaptation and selection studies have been used to identify fig cultivars best suited to these climates (Küden and Tanriver 1998). Similarly, a study in Chile was conducted to evaluate the effect of climatic conditions on the cultivars 'Kadota', 'Kennedy' and 'Larga de Burdeos' (Botti et al. 2003). The study demonstrated strong effects of climatic conditions on yield, type of production (breba and main crop), timing of production, and fruit quality. Comparison of the role of climatic conditions in production of dry and fresh fig revealed that dry fig production is strongly dependent on climatic conditions and is successful mostly under dry and warm-temperate climates. Fresh figs, however, can be cultivated under a wider range of ecological conditions (Sahin 1998).

IV. HORTICULTURE

Figs are deciduous subtropical trees whose growth is more limited by winter low temperatures than by summer heat. The typical fig-producing regions are characterized by hot dry summers, low relative humidity, and mild winters. The fig tree has a low chilling requirement. Winter temperatures are a limiting factor particularly with young trees that may be damaged by frosts at temperatures between -5° and -10°C (Ferguson et al. 1990).

Fig trees adapt to marginal conditions easily, as they are tolerant to high soil calcium content, salinity, and drought (Aksoy 1998; Golombek and Ludder 1990). Horticultural requirements for fig production have been described by many authors and were summarized by Condit (1947), Obenauf et al. (1978) and Ferguson et al. (1990). Here we provide a brief review on fig production, emphasizing the effect of different growing areas.

A. Site Selection

Figs can be grown on a wide range of soils, including heavy clays, loams, and light sands, but ideally the soil should be well drained at least in the top 1.0 meter (m). The plant is moderately tolerant of high salinity (Golombek and Ludder 1990). Fig trees display little salt stress until EC = 6 mS cm^{-1}, while for most fruit trees irrigation water should not

exceed 2 mS cm ^{1} (Maas 1993). In addition, figs tolerate soils with pH ranging from 5.5 to 8.0. Caprifig orchards have the same site requirements as edible fig orchards. Caprifig orchards should be isolated from commercial fig orchards to avoid overcaprification leading to excessive fruit splitting. In California, caprifig orchards used for pollination of Smyrna type 'Calimyrna' and other cultivars are located in warmer sites to ensure that early caprifigs are available to pollinate the earliest 'Calimyrna' fruit (Ferguson et al. 1990).

B. Propagation and Planting

Figs can be propagated by seeds, cuttings, air layering, or grafting. Figs grown from seeds are not true to type and are used only in breeding programs. Rapid mass multiplication by tissue culture has been achieved (Muriithi et al. 1982; Pontikis and Melas 1986; Hepaksoy and Aksoy 2006), but in horticultural practice the tree is commonly propagated by cuttings of mature two- to three-year-old wood. Cuttings can be taken in late autumn or early winter. In common practice, they should be 20 to 30 centimeters (cm) long and contain several nodes. The base should be cut just below a node. Cuttings can be planted in pots and grown in a glasshouse over winter, or may be rooted by complete immersion in damp (but not wet) sawdust or other medium. They should be planted out into a well-drained propagation mix to develop roots. The upper, slanting end of the cutting should be treated with a sealant to protect it from disease, and the lower, flat end with a root-promoting hormone, usually auxins such as Indole-3-butyric acid (IBA) (Antunes et al. 2003b). When rooting of hardwood apical 'Sarilop' cuttings was tested in three media, sand + perlite mixture (1:1 v:v) proved to be the most successful (Aksoy et al. 2003). In the cost analysis, propagation in soil gave higher plant vigor (Aksoy et al. 2003). Cuttings placed under mist in the nursery develop roots within three or four weeks.

Young trees are usually planted at the end of the winter when they are dormant. In new orchards they may be spaced 1.8 to 7.5 m apart, depending on the cultivar and the fertility of the soil. In older orchards, trees were planted 9 to 12 m apart. In California, trees are spaced 3 to 4.5 m apart. A denser planting of 2 to 3 m apart is successful in Israel. Care must be taken to ensure that the roots do not dry out during the establishment phase. Young trees are susceptible to sunburn until the canopy fills. Water-based white acrylic paint can be used to protect bark from the sun. Orchards come into full production in about 3 to 5 years, often bearing some fruit in the second year, and remain productive for

15 to 20 years, when fruiting declines. Fig trees of unsatisfactory cultivars can be replaced by field topwork with other scions.

Cultivar selection is usually based on profitability and suitability for the local climate. In California, most of the production is of dry figs with limited new plantations (Ferguson et al. 1990). There are, however, new plantations for fresh fig production of 'Brown Turkey', 'Mission' and 'Sierra', a recent cultivar. Similarly, new plantations for fresh fig production of 'Brown Turkey', 'Mission'. and other cultivars were developed in Israel, Chile, Argentina, South Africa, Australia and New Zeeland.

C. Training and Pruning

Training trees into an open-vase shape is the usual practice in most orchards. The open vase has usually four or five main structural limbs. In some countries, a spur pruning method is used and the young tree is trained to produce four main branches. These are tied down so that they grow almost horizontally. Each year, shoots are allowed to grow vertically from these branches. At the end of the year they are all cut off to small spurs, similar to the way in which grapevines are managed (Plate 2.1). When left to grow naturally, the tree canopy can reach 15 m in height. This size is suitable for the production of dry figs that are picked from the ground. In new orchards producing figs for fresh consumption, the trees are kept at 3 m height by pruning to allow easy access during fruit picking.

Pruning in figs is cultivar dependent and varies between fresh and dry fruit production. In dried fig production, pruning is essential only during the initial years. With fresh fig production, trees should be trained according to the type of fig. With breba and main crop producing cultivars, the breba crop is formed on the previous season's wood. Therefore, winter pruning will cause loss of the breba crop; and it is better to prune immediately after the main crop is harvested. Recently, Puebla et al. (2003) studied pruning dates and intensities in a San Pedro–fig–type cultivar grown primarily for commercial breba production. They found significant differences in yield and productivity depending on the dates and the type of cut. The highest yields were obtained when pruning was carried out in the earliest date after the main crop harvest. Early main-crop-pruning increased the length of new breba-producing shoots (Caetano et al. 2005; Puebla et al. 2003). With main-summer-crop-producing cultivars, such as 'Kadota' and 'Brown Turkey, winter pruning is performed. Winter pruning will affect productivity by stimulation of new wood growth that increases the main

crop. Mature trees need light winter pruning to remove any diseased, broken, or overlapping branches and heavier winter pruning approximately every three years to encourage enough new wood for good maintenance.

D. Irrigation and Fertilization

Fig trees tolerate drier conditions than most fruit trees and are an attractive fruit crop for arid zones. However, there is little information about water requirements under these conditions. Regarding water quality, the fig tree is less demanding compared with other fruit trees, tolerating an electric conductivity of irrigation water of up to 5.5 mS cm^{-1} (Flores 1990). The frequency of irrigation depends on tree size, vigor, soil type, and rainfall. Fig trees may become stressed in dry periods because of their shallow root systems. However, most fig cultivars do not cope well under increased moisture conditions. In such areas and during the rainy season, fruit cracking usually occurs, and fungicide sprays may be necessary to control surface rot (*Alternaria alternata*), smut (*Aspergillus niger*), and mold (*Botrytis* spp., *Penicillium* spp.). Studying productivity and vegetative growth of fig trees at different irrigations rates showed that irrigation equivalent to 50% of pan evaporation results in a good vegetative growth (d'Andria et al. 1992). Tapia el al. (2003) examined the effect of four irrigation rates on growth of six fig cultivars. They found that three-year-old trees of most the cultivars performed adequately when irrigated at 17% of pan evaporation.

Change in water status during fruit development can decrease fruit quality and affect fruit cracking. A sudden increase in water supply during the ripening period will cause fruit to split (Melgarejo 1996). Excess water in midsummer will cause excessive vegetative growth at the expense of fruit quality. A wet soil causes fruit to be large and watery and prone to rot and shriveling.

Literature concerning fig-tree fertilization is scarce. From a practical viewpoint, the fertilization requirements of figs depend on soil type, organic matter content, and pH, as well as on the nutritional demands of the crop. Figs prefer alkaline soils, so lime has to be applied if the pH is lower than 6.0. The optimal pH ranges between 6.0 and 8.0. Proebsting and Tate (1952) observed that foliar concentration of net and total nitrogen decreased during the growing season. Similar results were obtained by Proebsting and Warner (1954), who noted decrease of nitrogen and phosphorus content as the season progressed, while potassium content increased up to the middle of the growth season

and calcium and magnesium contents increased gradually from the beginning to the end of the growth season. Bataglia et al. (1985) reported that nitrogen fertilization may play an important role not only because it provides for the proper concentration of nitrogen metabolites but also because it affects the incorporation of assimilates through the increase of the photosynthetic capacity of the tree. In Israel, excess nitrogen encouraged vegetative growth in 'Brown Turkey' at the expense of fruit production (M. Flaishman, unpubl.). In drying-fruit types such as 'Sarilop', excess nitrogen, with leaf nitrogen higher than 1.75%, enhanced tree vigor and thus increased the number of fruits per shoot but exerts a negative effect on fruit size and color (Aksoy and Akyüz 1993). In both fresh and dried figs, fruit quality is highly correlated with the nutritional status of the tree. High levels of leaf magnesium, iron, and boron were found to affect fruit color negatively. Potassium/calcium + magnesium ratio affected the split (ostiole-end crack) ratio whereas the impact of potassium/calcium was pronounced on percentage of sun-scalded fruit. As the potassium level increased, the incidence of split was enhanced and sun-scalded fruit number decreased (Aksoy and Akyüz 1993). Soil zinc content was positively correlated with dried fruit color (Aksoy and Anac 1993). Soil or foliage applied zinc increased fruit yield in 'Sarilop' orchards. Increasing zinc levels enriched fruit sugar components such as fructose and glucose, but negatively affected the fruit texture and color (Hakerlerler et al. 1999). Hakerlerler et al. (1998) found that manganese content had a marked effect on total fig fruit sugars, possibly by its role in carbohydrate metabolism. Irget et al. (1998) found that dried fruit color was darker in trees treated with calcium nitrate. Water-soluble fertilizers can be applied in the irrigation system throughout the growing season. Complete fertilizers with a nitrogen-potassium-phosphorus ratio of approximately 20:5:20 are commonly used. With dry fig production in California, nitrogen is the only nutrient applied with average application rate of 22 to 45 kilogram (kg) of nitrogen/ha, depending on soil quality (Perguson et al. 1990).

E. Cultivation Practices

Extensive fig culture is traditional in many regions around the world, mainly for dry consumption and industry. Recently, new fig cultivars with high productivity have been planted for production of fresh fig fruit. For commercially successful production, these cultivars have to be well adapted to the climatic region and appreciated by the consumers.

In those new orchards, tree spacing is more compact and trees are pruned to allow easy picking without ladders.

1. Controlled Growing Conditions. Use of improved growing conditions and sophisticated horticultural practices are practiced to increase revenue from growing fresh figs. For example, growth under net (Plate 2.1b) or using hydroponics in greenhouses increases fruit production, fruit quality, and allows better control over the the time of fruit production. Growth in the nethouse protects the trees from wind, hail, pests, and diseases. Growing fig trees in a nethouse, under a 17 mesh white polyethylene net, provides total protection against various insects attacking fig fruit, especially the fig fly (*Silba adipata*), which causes severe damage in warm growing locations (Yablowitz et al. 1998). In Israel, growing figs under net extended the season for fig production. The 'Nazareth' breba is the first-producing cultivar in May followed by 'Brown Turkey' main crop, which continued production until the end of December (Flaishman and Al Hadi 2002). However, when grown under net, color of dark-fruited figs is often signficiantly reduced. Erez et al. (2003) evaluated the best training system for high breba fig production in 'Nazareth'. They found that to maximize yield of figs grown in an intensive system under net, an increase in light interception and uniform light distribution in the canopy are required. This was achieved by training the trees in perpendicular V system and pruning after harvest to prevent heavy shade.

In Japan, multiple crops per year of high-quality fruit was obtained in four-year-old trees of 'Masui Dauphine' when grown hydroponically in a greenhouse (Kawamata et al. 2002b). Trees were headed back in mid-January, producing main crop figs that were harvested from primary shoots between June to the end of September at 1.5 kg per primary shoot, a mean fruit size of 104 grams (g) and soluble solids of 14%. To induce a second crop, all shoots were pinched at their 30th nodes in mid- June, and half were headed back to their 3rd nodes at the end of July. Fruit from secondary shoots were harvested from the end of November to mid-February at 1.3 kg per shoot, a mean fruit size of 80 g, and soluble solids at 16%. The percentage of fruit set at node 12 to 20 on the secondary shoots of the pinched tree was smaller than that on other nodes. It was concluded that figs tree grown hydroponically in greenhouses could be forced to yield double crops of high-quality fruit and can produce all year round (Kawamata et al. 2002b).

2. Organic Fig Production. Organic production of dried fig has been recently started in Turkey and shows steady and marked yearly increases

in acreage. In general, there are no significant differences between organic and conventional fig growing. Organic and convention production are primarily distinguished by different pest management practices in the orchard and during storage (Aksoy et al. 1994; Altindisili and Ertem 1998). Recently, organic production of fresh 'Brown Turkey' figs has been demonstrated in Israel (M. Flaishman, unpubl.). The organic figs are grown in nethouses and different practices, mainly new pest management programs, were developed.

3. Caprification. Some of the best dry and fresh fig cultivars, such as 'Sarilop' ('Calimyrna') and 'Bursa Black' are Smyrna- type figs that require pollination for fruit set. Commercial Smyrna-type figs are pollinated in early summer with pollen from the *profichi* caprifig. Generally, one caprifig tree is needed for every 15 to 20 Smyrna-type fig trees. Planting the caprifig trees within the block is not recommended. The trees closest to the caprifigs can be overfertilized and their figs may split, and more distant trees may not be pollinated. Caprifig trees should be planted in a separate block. The *profichi* caprifigs (with wasps) are picked and placed in wire baskets around the orchard when the first wasps start to emerge. Each basket should contain six or seven figs. The profichi needs to be replaced every three days for about three weeks since not all the synconia of the Smyrna figs are receptive at the same time. It is useful to have more than one cultivar of caprifig so that the pollination period is extended. In 'Sarilop', the effect of the pollen source on fruit characteristics was studied. The caprifig cultivar providing pollen had a significant effect on fruit size of 'Sarilop' (Aksoy et al. 2003).

4. Dormancy Bud Break. Fig grows and produces the best-quality fruit under dry and warm-temperate climates. Quality figs can be produced in regions with little winter chilling, but bud break may be erratic in such climates and may compromise production. To enhance flower bud break and productivity of orchards in such hot climate areas, trees are often sprayed with the bud breaker cyanamide (Erez and Yablowitz 2000).

5. Fruit Size. In general, fruits developing along the shoot are larger at the lower nodes and become smaller toward the top of the shoot. Selected cultural practices may exert a positive impact on fruit size. In 'Black Mission' cultivar, girdling was demonstrated to increase fruit size, although late girdling produced less marked effects (Ferguson et al. 2003).

6. Fruit Yield. Fig yield is influenced by a number of factors including cultivar, growth conditions, and harvest. Typical mature fig yield varies between 5 and 12 t/ha. The combination of careful practices under optimal growing conditions and sophisticated growing facilities could increase and even double regular yield. Yablowitz et al. (1998) describe 12 t/ha production of breba fruit plus an additional 5 to 7 t/ha production for the main summer crop of the 'Nazareth' cultivar grown in nethouse in Israel. Main crop of 'Brown Turkey' cultivar, grown in nethouse, produces between July and December up to 25 t/ha of high-quality fruit crop (Flaishman and Oren 2005).

F. Harvest

In California, where most figs are grown for drying and are allowed to fully ripen and partially dry on the tree, fruits will fall to the ground, where they continue to dry. They will be mechanically collected by sweepers from the ground during September and October (Obenauf et al. 1978) and then continue to dry in storage. Harvest is repeated weekly for 4 to 6 weeks (Ferguson et al. 1990). After harvest, the dried figs are washed and may be stored for a few days at 0 to 1°C. Fruit is dried in the sun or by using an electric dryer at a temperature of 60 to 70°C before final processing as dried figs. Fresh figs are picked when they begin to soften, and the color change indicates maturity. Since fresh figs ripen irregularly, picking should be done daily or weekly during the long harvest period (4 to 6 weeks).

Figs must be allowed to ripen fully on the tree before they are harvested; they will not ripen if picked immature. Applications of ethylene as 2-chloroethylphosphonic acid (ethephon) are known to enhance fruit development, resulting in early and compact ripening. The application of ethephon to 'Mission' dry fruits during the late second period of fruit development stimulates growth and ripening within 8 days (Crane 1986). Dramatic pigment changes occur during this period as the fruit skins turn from green to bluish black (Crane 1986). The chlorophylls and various caratenoids decrease for an additional 4 days, at which time the fruits attain their maximal size and are considered to be ripe. The application of ethephon accelerates ripening, thus shortening the harvest period by as much as 10 days (Ito and Sato 1987). Proper timing of application of the growth regulator is crucial for fruit quality. Ethephon applications at the end of the second fruit growth period on 'Bursa Black' fruits advanced fruit ripening in 5 days relative to untreated control (Celikel et al. 1997).

V. POSTHARVEST PHYSIOLOGY AND HANDLING

A. Fresh Fruit

Figs may be consumed either in fresh or in processed form. For centuries the processed (mainly dried) product has been the major form of fig available at the market because of the extreme perishability of fresh fruit. However, the current market trend is characterized by an increasing demand of fresh figs (Aksoy 1995; Tous and Ferguson 1996). The worldwide trade in fresh figs became possible mainly due to the accumulation of knowledge and technological developments in the area of postharvest fruit preservation.

1. Postharvest Physiology. Fig is classified as a climacteric fruit with moderate respiratory activity (10–20 mg CO_2/kg hr at 5°C), moderate ethylene production rate (1–10 μL/kg hr at 20°C), and sensitivity to ethylene (Kader 2003; Crisosto and Kader 2004).

The early work of Claypool and Ozbek (1952) did not reveal a respiratory climacteric peak in the fruits of 'Mission' cultivar. Ryall and Pentzer (1982) classified figs as nonclimacteric fruit referring to Biale (1960; cited by Ryall and Pentzer 1982). However, a series of studies carried out in the 1960s and the 1970s (Maxie and Crane 1968; Ben-Yehoshua et al. 1970; Marei and Crane 1971) clarified the role of ethylene in the development and ripening of figs and in particular their climacteric character. It was shown that the fruit reaction to ethylene changes while it follows the typical double sigmoid growth pattern, comprising two periods of rapid growth (Stage I and III) separated by a quiescence period (Stage II). Ethylene was found to inhibit fig growth at Stage I (the stage of cell division), to stimulate growth at early Stage II, and to stimulate both growth and ripening at late Stage II and Stage III (Marei and Crane 1971). These findings provided a scientific explanation for practices of stimulating fig growth and ripening by inducing ethylene production, known from antiquity (fruit gashing, oleification), as well as for using an ethylene-releasing agent (ethephon) for the same purpose.

The onset of Stage III was accompanied or slightly preceded by a sharp increase in ethylene production and by respiratory climacteric peak (Fig. 2.3). New aspects of ethylene biosynthesis and action in fig fruit have been recently summarized using modern methodologies. It was found that blocking ethylene sensitivity by 1-methyl cyclopropene (1-MCP) markedly increased ethylene production in harvested figs (Kubo et al. 2003; Sozzi et al. 2005; Owino et al. 2006), which is opposite

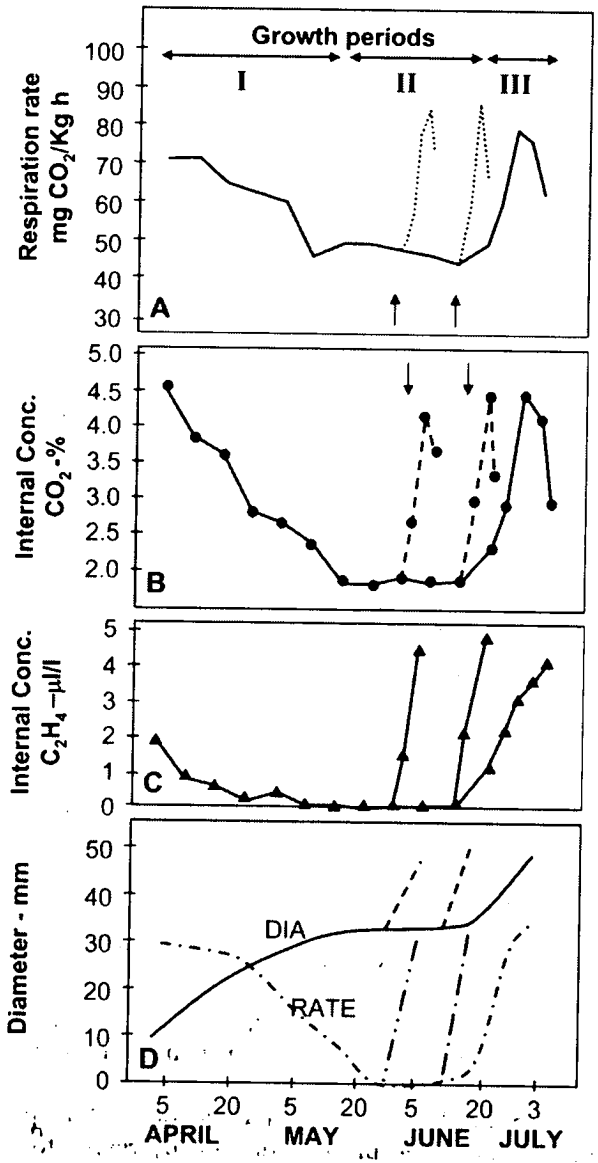

Fig. 2.3. Autocatalytic ethylene production and climacteric respiration in figs. Respiration rate (A), concentrations of carbon dioxide (B), and of ethylene (C) in the internal atmosphere of 'Mission figs' in relation to their growth (D) and development and to ethylene treatment. Arrows indicate time of ethylene application. Note the autocatalytic upsurge of ethylene production in preclimacteric fruit in response to exogenous ethylene treatments. Source: Adapted from Marei and Crane (1971).

to the characteristic response in climacteric fruit and resembling that of nonclimacteric ones (Watkins and Miller 2004). This phenomenon indicated autoinhibitory regulation of ethylene biosynthesis and the absence of climacteric autocatalytic ethylene production.

Owino et al. (2006) analyzed the expression of ethylene biosynthesis genes in figs at Stage II and III in response to ripening-stimulating factors (propylene, auxin, and olive oil) and 1-MCP. Three 1-aminocyclopropane-1-carboxylic acid (ACC) synthase genes and one ACC oxidase gene were isolated from ripening fig fruit. Some of these genes demonstrated positive feedback regulation by ethylene (so-called system 2 is responsible for autocatalytic ethylene production in typical climacteric fruit during ripening), while other(s) were negatively regulated as expected for system 1 acting in vegetative tissues and nonclimacteric fruit. The latter system 1 enzyme had high activity and contributed to the sharp increase of ethylene production in 1-MCP-treated fruit. Moreover, it was suggested that ethylene production in ripening fig fruit is primarily promoted by this highly active system. Expression of an additional ACC-synthase gene was induced by auxin and modulated by both auxin and ethylene.

It has been proposed to classify fig as a representative of a specific nonautocatalytic type of climacteric fruit (Kubo et al. 2003). However, it should be borne in mind that the autocatalytic pattern exists at certain stages of fig development on the tree (Maxie and Crane 1968; Marei and Crane 1971). This is illustrated in Fig. 2.3 and apparently also accepted by Owino et al. (2006). Data presented in Fig. 2.3 show that the climacteric respiration of fig reaches its peak and declines at Stage III. Therefore, the fruit at this stage may be considered postclimacteric, even though ethylene emission at this period continues to increase. In agreement with the opinion of Colelli (1995) and Sozzi et al. (2005), it is conceivable that the specific behavior of harvested fig should be attributed to its postclimacteric character, distinguished by a cessation of autocatalytic ethylene production and further decline in ethylene responsiveness. Indeed, the 'Brown Turkey' figs harvested at relatively advanced ripening stage showed almost no response to 1-MCP, neither by stimulation nor by inhibition of ethylene synthesis (Sozzi et al. 2005).

Biochemical changes of the fig fruit during its maturation and ripening on the tree have been described in detail in the previous section. In general, this process is characterized by continuous fruit enlargement, accumulation of sugar and color changes and, in parallel, by softening and decline of storage potential. After harvest, figs may continue softening and changing color, but their sugar level does not increase

(Aksoy 1997a; Rodov et al. 2002). As a result, the fruit picked at underripe stage never reaches optimal flavor. The consequences of this dilemma between eating quality and fruit storage potential are discussed in next sections

2. Quality Parameters. Quality descriptors of fresh figs comprise fruit size, firmness, skin color, flesh color, flavor, sugar content, and acidity. Other quality indices include defects (such as bird-peck, sunburn, scabs, cracks, and shriveling), insect infestation, and decay (Crisosto and Kader 2004). Fruit-keeping quality is characterized by the rate of changes of quality parameters during storage, for example, softening, color advancement, decay development, and skin cracking.

The postharvest behavior of fruit is greatly affected by cultivar peculiarities. One of the best fig cultivars for fresh consumption is 'Bursa Siyahi' ('Black Bursa') of Turkish origin, characterized by large dark-colored firm fruit, high sugar content, and long postharvest life. At optimal conditions (harvest maturity and storage temperature) the fruit of this cultivar may maintain high quality for up to 6 weeks (Turk 1989). In contrast to many fig cultivars (e.g., 'Goklop', 'Sarilop'), 'Black Bursa' is not prone to cracking (Aksoy and Anac 1994). 'Black Bursa' belongs to the Smyrna type and therefore requires *Blastophaga* pollination for fruit development.

Aksoy (1981) studied cultivar effects on fresh fig storage, in particular on weight loss rate. Not surprisingly, the fastest desiccation was observed in 'Sarilop' 'Calimyrna' fig, a cultivar primarily selected for drying, while the cultivar 'Akca' used for fresh consumption demonstrated 2.5 times slower weight loss. Comparing fig cultivars by their response to vibrational stress revealed 'Masui Dauphine' as a sensitive cultivar while 'Celeste' and 'Brunswick' were relatively tolerant to vibration (Mao et al. 1995). In a similar study carried out on 'Sarilop', 'Black Bursa', and 'Yediveren' figs, the latter cultivar was found the most resistant to transportation mechanical stresses whereas 'Sarilop' was the most susceptible (Aksoy et al. 2003).

In cultivars that produce both nonpollinated (persistent) and pollinated fruit, the quality and storage capacity of these fruit types may be very different. Condit (1920, cited by Baskaya and Crane 1950) studied the effect of caprification on fruit quality of the common type 'Kadota'. The caprified 'Kadota' had ribbed fruit with darker skin and pulp color, and sweeter and richer flavor as compared to the typically smooth nonpollinated fig. Similarly, in 'Brown Turkey' grown in Israel, the pollinated fruits were distinguished by superior quality (higher soluble solid contents, firmness and more intense external and internal color)

and better storage potential than nonpollinated ones (Table 2.4). Pollination of 'Kadota' figs was associated with increased tendency for splitting (Condit 1920, cited by Baskaya and Crane 1950). Cracking and splitting is characteristic of the 'Calimyrna' fig, which requires pollination for commercial cropping. Persistent 'Calimyrna' figs, obtained artificially using growth regulators with auxin effect (e.g., γ-indole-3-*n*-butyric acid or *p*-chlorophenoxyacetic acid) did not split (Crane and Blondeau 1949).

Horticultural practices have a significant effect on the quality and storage potential of fresh figs (Aksoy and Anac 1994a). For example, figs from trees planted at high density were reported to have poor keeping quality as compared with fruit from less dense orchards (Amen 1987). Spraying with 1% calcium chloride solution largely prevented cracking of 'Goklop' figs and significantly reduced this disorder in 'Sarilop' (Aksoy and Anac 1994b). Calcium sprays were also reported to improve firmness in 'Lampa Preta' figs (Antunes et al. 2005b). In the same publication, the authors reported that growing under reduced irrigation regime enhanced postharvest water loss from 'Bebera Branca' figs but not from fruits of 'Lampa Preta' cultivar. Orchard sprays with gibberellic acid significantly reduced fruit weight loss and decay during subsequent storage, whereas chlormequat treatment had the opposite effect (Amen 1987).

Table 2.4. Quality parameters of pollinated and nonpollinated figs (cv. 'Brown Turkey') immediately after harvest and after the indicated periods of storage and shelf life.

Pollination	Storage at 2°C (Days)	Purple Color, (% Surface)[z]	Firmness (Durometer Units)	Internal Ripening Index[z,y]	SSC (%)	Decay[x]
Non-pollinated	0	53.8±5.1	52.1±3.4	1.2±0.1	11.8±0.7	0
Pollinated		73.3±7.6	71.9±3.8	1.6±0.1	13.7±0.6	0
Nonpollinated	12	74.3±4.7	48.9±5.4	1.4±0.1	12.2±0.6	0
Pollinated		85.5±4.7	63.6±9.3	1.8±0.2	13.5±0.7	0
Nonpollinated	12+2[w]	77.8±4.1	21.4±4.3	2.1±0.3	12.7±0.5	13.3
Pollinated		85.3±3.0	31.9±4.8	2.7±0.1	13.6±0.4	0

[z]Mean value ± confidence interval ($p = 0.05$) of 3 replications. Each replication represents the weighted average of visual evaluations of 20 individual fruits.
[y]Evaluation scale: 1 = pink, dry (underripe); 2 = 50% jellylike; 3 = red, jellylike (optimal ripening); 4 = brownish, leaky (overripe).
[x]Percentage of rotten fruit out of a total sample of 60 figs.
[w]Two additional days of shelf life at 20°C.

3. Harvesting. As mentioned, the figs picked at an underripe stage do not reach a desirable flavor even if they are stored for long periods (Aksoy 1997a; Rodov et al. 2002). However, fruit harvested too late is prone to fast deterioration and has a short market life. Due to these reciprocal relations between fig quality and longevity, determining a proper harvest maturity stage is critical for successful marketing of fresh figs. The choice depends on many factors, including consumer quality expectations, life span required for marketing, storage conditions and technologies available, and cultivar storage potential. That is why literature recommendations for optimal harvest maturity may be quite variable, for example, from "fully ripe stage" (Aksoy 1997a) through "almost fully ripe" (Crisosto and Kader 2004) or from "slightly unripe" (Morton 1987) to "beginning of softening" (Tous and Ferguson 1996). Moreover, some authors (Lima et al. 2005) described harvesting and storage of truly unripe fresh 'Roxo de Valinhos' figs having soluble solids content (SSC) below 6%, at least 2.5 to 3 times lower than potential SSC level for the same cultivar. The utilization of these unripe fruit was not clarified; possibly, they could be intended for industrial use (canning), as briefly mentioned by Pasqual et al. (2003).

Fruit firmness and color are the most useful criteria for selecting fruit suitable for picking. 'Mission' figs should be light to dark purple rather than black and yield to slight pressure; 'Calimyrna' figs should be yellowish white to light yellow and firm (Crisosto and Kader 2004). Optimal picking criteria for successful airfreight shipment of summer-crop 'Brown Turkey' figs from Israel to Europe were: firmness, (resilient to soft) and color (70 to 90% purple with background color light green to yellowish). Harvest indices were different for the same cultivar picked in autumn (Rodov et al. 2002). Harvesting 'Black Bursa' figs before full ripeness (firmness of 3.7 N/cm^2 vs 1.5 N/cm^2 in a ripe fruit) extended their storage potential from 4 to 6 weeks, but did not allow the fruit to achieve maximal quality (Turk 1989; Celikel and Karacal 1998). Still, it seems that the quality attained in that case was higher than that of many cultivars present in the market.

Since fresh figs ripen sequentially along the shoot, picking should be done repeatedly during the harvest period. The selective harvesting of suitable fruit demands experienced and trained pickers. A simple portable firmness tester (Shore durometer) may be adjusted in order to train harvest teams and to "calibrate" their picking criteria (Rodov et al. 2002). It is recommended for pickers to wear gloves and long-sleeve clothes to prevent skin irritations caused by the fig latex, although gloves would markedly reduce finger sensitivity so important for fruit firmness perception.

4. Spoilage Factors. Fig fruit are attacked by a range of pathogens. Various fungal species, such as *Botrytis cinerea*, *Rhizopus nigricans* (=*R. stolonifer*), *Alternaria alternata*, *Aspergillus* spp., *Penicillium* spp. and *Cladosporium herbarum*, were registered as causal agents of postharvest fig rots (Ricci 1972; Piga et al. 1995; Nascimento et al. 1999; Montealegre et al. 2000). Even if the inoculation occurs in the orchard in unripe green fig, as in the case of *Fusarium*, *Cladosporium*, *Alternaria* and *Aspergillus* (Michailides 2003), the disease usually is fully manifested with ripening, in particular in harvested fruit. Endosepsis (internal fruit rot), caused by *Fusarium moniliforme*, is one of the major fig fruit diseases. This disease has been described in detail by Michailides et al. (1996) and in other publications of this team. The pollinator fig wasp is the major vector introducing *F. moniliforme* as well as the causal agent of smut disease *Aspergillus niger* into Smyrna-type figs.

Souring is another widespread microbial disorder of ripening figs. It is primarily associated with yeasts causing characteristic fermented odor and exudation from the fruit. *Drosophila* fruit flies were found to transmit microorganisms responsible for souring. Nitta et al. (1997) determined the relationship between fig ripening, the number of *Drosophila* flies attracted to the fruit, and the souring incidence. Sanitation measures in the orchard (e.g., removal of diseased dropped fruit) markedly reduced souring. *Rhizopus* infection was associated with warm and humid environment in the orchard, prevailing particularly during rainy summer season and/or in trees grown under plastic cover (Nitta 1997).

Fungicide treatments can control many postharvest fig pathogens (Bewaji and English 1976; Michailides et al. 1996; Nitta 1997) however, applying fungicides on edible figs is often prohibited (Alfieri and El-Gholl 1993). An alternative strategy in the case of Smyrna-type cultivars is fungicide treatment of inedible caprifigs—a major source of infection transmitted by fig wasps to the edible fruit (Michailides et al. 1996, 2005). Caprifigs should be thoroughly sorted before use in pollination and decayed fruit discarded (Michailides et al. 1996). Bordeaux mix is a wide-spectrum copper-based fungicide and pesticide applied in orchards for more than a century. Although copper spray residue on edible fig fruit was considered undesirable, since the 1970s (Wani and Thirumalachar 1973), the treatment has been extensively used on figs in Brazil (Raga et al. 2003); fruit from that region usually can be recognized by greenish sediment on the skin surface.

Even when not displaying visible fungal decay, overripe figs in storage undergo rapid degradation, expressed as excessive softening, tissue maceration, and exudation of syrupy liquid from the ostiole, which eventually may stimulate the growth of epiphytic microorganisms.

As a result, termination of storage life of fig fruit is typically a result of combined effect of physiological (overripening) and pathological (decay) factors. It may take from 1 to 2 days to 4 to 6 weeks to reach this degradation stage, depending on environmental conditions (primarily temperature), initial fruit ripening stage, and cultivar peculiarities. With fruit harvested at an underripe stage, weight loss and shriveling are often major factors in fruit deterioration (Lima et al. 2005).

5. Preservation of Fresh Figs. *Cold Storage* Low temperature is the major factor controlling spoilage of fresh figs. The fruits are not sensitive to chilling injury, and therefore the recommended conditions for their storage are $-1°$ to 0°C and 90% to 95% relative humidity (RH) (Crisosto and Kader 2004). In practice, temperatures between $-1°$ to 2°C are normally used. Forced-air cooling should be applied in order to reduce the temperature of harvested fruit as soon as possible (Turk 1989). Cooling delay of 4 or 8 hours enhanced softening of 'San Pietro' figs as compared to fruit cooled 1 hour after harvest; however, no such difference was observed in 'Melanzano' cultivar (Eccher Zerbini et al. 1986). Fast precooling extended the life of 'Bursa Siyahi' ('Black Bursa') fig stored at 0°C from 2 to 4 weeks compared to fruit kept at the same temperature without precooling (Celikel and Karacal 1998). These authors showed that without forced cooling, it took 48 hours until the fruit reached a desirable temperature. Vacuum precooling of figs rapidly reduced the fruit temperature but was not recommended due to the negative effect on fruit appearance and quality maintenance (Ito et al. 1987). Figs harvested at optimal maturity stage and properly cooled within 6 hours after harvest could be kept for 20 days at 1°C, for 7 days at 10°C, but only for 2 to 3 days at 20°C (Ito et al. 1987). A similar trend was reported by other authors (Morton 1987; Park et al. 1998). There are only a few reports that do not completely conform to this scheme. Baccaunaud et al. (1995) claimed that storage of 'Sultane' figs at 6 to 8°C was preferable to 2°C as the 2°C–stored fruit underwent faster degradation after transfer to ambient temperature. However, other results presented, even in the same paper, did not support this view.

Atmosphere Composition Little research has been done so far on the effect of reduced oxygen level on keeping quality of fresh stored figs. Tsantili et al. (2003) reported that storage of 'Mavra Makropoulou' figs (a Smyrna type harvested close to full ripening in this study) in an atmosphere of 2% oxygen reduced their respiratory activity and ethylene production and inhibited softening as compared to air storage. The best results were obtained by combining low-oxygen conditions with

storage at −1°C, which allowed maintenance of acceptable fruit quality for one month, as compared to 15 days at 4°C. The influence of carbon dioxide (CO_2) in that study was neutralized by using lime for CO_2 absorption.

The effects of elevated CO_2 level on fresh figs storage have been studied much more extensively. Claypool and Ozbek (1952) reported that storage at 20°C in atmospheres containing up to 60% CO_2 was of little help for extending storage life of 'Mission' figs. However, Colelli et al. (1991) subsequently demonstrated good quality preservation of the same cultivar kept at 0, 2, or 5°C in atmospheres enriched with 15 or 20% CO_2. The advantages of high-CO_2 storage included decay reduction, preservation of firmness, and good fruit appearance, as well as inhibition of ethylene production. Relatively high ethanol level was recorded following high-CO_2 storage in all samples (even at 0°C), and the risk of off-flavor was mentioned. Basically, similar results were reported by other authors (Mathooko et al. 1993; Park et al. 1998; Park and Jun 2000). A desirable CO_2 level of 15% to 20% is mentioned in most recommendations for fresh fig storage (see Kader 2003; Crisosto and Kader 2004). At the same time, Turk et al. (1994), after testing a range of oxygen and carbon dioxide combinations, recommended formulations with lower CO_2 concentrations (3% or 5% combined with the same level of oxygen) for controlled atmosphere (CA) storage of 'Bursa Siyahi' figs. Carbon dioxide inhibited softening of breba 'Nazareth' figs in active modified atmosphere packages only when these conditions were combined: Fruit was harvested at firm and not at resilient stage, the CO_2 concentration was 4 to 6% but not 10% to 12%, and ethylene was removed from the atmosphere by potassium permanganate-containing ethylene absorber (Rodov et al. 1998). Relatively high CO_2 concentrations (10% and above) caused damage to 'Nazareth' figs, manifested as excessive softening, abnormal ripening, and off-flavor. Therefore, optimal atmosphere composition for fresh fig preservation should be determined, especially after taking into account cultivar peculiarities, ripening stage, and other factors (e.g., ethylene presence).

Transportation in elevated CO_2 atmosphere was proposed by Colelli (1995) for fig distribution, similar to the practice widely used with strawberries. However, the commercial use of controlled atmosphere technology with figs is still limited (Kader 2003).

Plastic Packaging Packaging in plastic film may be a practical way to realize the potential of modified atmosphere (MA) composition for improving fruit keeping quality. The MA generation inside the packages was either due to fruit respiration alone (Neves et al. 2002; Hernandez-

Mendez et al. 2003), or aided by package flushing with carbon dioxide, Nitrogen or gas mixtures (Mathooko et al. 1993; d'Aquino et al. 1998; Park and Jung 2000), or further modulated by adding a CO_2-releasing agent such as dry ice (Rodov et al.1998). Absorbers of CO_2, ethylene, or moisture were also used in fig packages (Rodov et al. 1998; Matteo et al. 1999). In addition to modification of oxygen and CO_2 concentrations, high air humidity inside plastic packages reduced weight loss of the fruit (Eccher Zerbini et al. 1986; Piga et al. 1995; Hernandez-Mendez et al. 2003; Lima et al. 2005).

However, plastic packaging does not automatically guarantee the improvement of fig quality. For example, the MA advantages for 'Tiberio' breba storage were achieved by packaging in bi-oriented polypropylene but not in other film types (Hernandez-Mendez et al. 2003). Low-density polyethylene (LDPE) of 22 μm thickness was the best packaging material for preservation of 'Roxo de Valinhos' figs in a trial that included four LDPE samples from 6 to 22 μm thick (Neves et al. 2002). The 'Niedda Longa' figs wrapped in heat-shrinkable polyolefin or in polyvinylchloride (PVC) films demonstrated slight off-flavor and high decay incidence (Piga et al. 1995). Enhanced fruit softening was observed in MA packages during marine transportation of 'Brown Turkey' figs, as compared with regular cartons (Rodov et al. 2003).

The success of plastic packaging may depend on performance of other postharvest operations, in particular fast cooling. Eccher Zerbini et al. (1986) reported that polyethylene (PE) wrapping allowed best quality preservation of 'San Pietro' figs, but only if the fruit were cooled within 1 hour after picking. If PE wrapping was done after 4- or 8-hour cooling delay, the fruit demonstrated poor quality (appearance, aroma, liquid leakage) in subsequent storage. Cooling delay had less detrimental effect on fruit packaged in open or vented containers (Eccher Zerbini et al. 1986). It should be kept in mind that cooling of produce should be performed before plastic packaging, otherwise the film barrier would hinder heat exchange.

6. Pre-Storage Treatments. Various treatments were applied to harvested figs in order to improve their keeping quality. In particular, short (1–2 days) exposure of fresh figs to low-oxygen or high-CO_2 atmosphere was found to reduce their decay susceptibility and/or inhibit ripening, extending the fruit storage life. The 36-hour anaerobic pretreatment in 100% CO_2 at 5 or 10°C was used by Claypool and Ozbek (1952), while Piga et al. (1998) applied a hypoxic mixture of 99% N_2 and 1% O_2. Mathooko et al. (1993) reported a reduction of fig spoilage by 2-day incubation in CO_2-enriched atmosphere containing 60% to 80% carbon dioxide. The

effect of these kinds of treatments is apparently related to generation of volatile metabolites, primarily acetaldehyde and ethanol (Pesis 2005). However, the hypoxic treatment had no negative effect on fruit taste (Piga et al. 1998).

Additional gaseous treatments reported to extend the life of fresh figs included keeping the fruit in atmospheres containing nitrous oxide (N_2O) or sulfur dioxide (SO_2) (Baccaunaud et al. 1995). Storage in an atmosphere of 80% N_2O and 20% air was described as a promising treatment reducing decay, inhibiting fruit softening and color advancement at 8°C and allowing optimal fruit ripening after transfer to ambient conditions. However, it was not clear from the data presented if the observed effects were indeed caused by N_2O or were merely related to the reduced oxygen level to ca. 4%. Sulfur dioxide–releasing sachets were reported to control fruit decay. However, the risk of skin discoloration is possible with SO_2 overdose (Baccaunaud et al. 1995). Control of *Botrytis* decay and extension of fresh fig storage life by SO_2 (0.5 to 8 parts per million [ppm] in air) was described also by de la Plaza (2003).

Several attempts were made to apply ethylene action inhibitor 1-MCP in order to delay ripening of fresh figs. The treatment had only a minor effect (slight weight loss enhancement) in trials with 'Bianca' cultivar (d'Aquino et al. 2003), but it slowed fruit softening in cultivars 'Bardakci' (Gozlekci et al. 2005) and 'Brown Turkey' (Sozzi et al. 2005). In the last case, the retardation of softening was observed only with fruit harvested relatively early (firm fruit) but not with figs harvested at more advanced stages of ripening. In any case, 1-MCP was found to provide only limited benefits in delaying fig ripening in comparison with its effect on other climacteric species, such as apple, pear, kiwifruit, and avocado, as well as in comparison with cooling effect on fig storage (Sozzi et al. 2005). This might be not so surprising if one assumes that in most cases the treatment was applied to postclimacteric fruit. Rather limited and ambiguous information is available regarding the effect of ethylene-absorbing sachets on postharvest behavior of figs (Alique and De La Plaza 1990; Rodov et al. 1998).

Another approach tested was applying surface coatings in order to reduce fruit weight loss and shriveling. Coating figs with the sucrose-ester formulation 'Semperfresh' had little effect on their quality changes but, unexpectedly, reduced the decay of spring-season fruit (Baccaunaud et al. 1995). However, commercial implementation of the technique may be difficult, as mentioned by the authors. Celikel et al. (1998) studied the effect of postharvest coating with antitranspirant pinolene (Vapor Gard) on keeping quality of 'Bursa Siyahi' figs. At 2% concen-

tration, the coating was efficient in controlling weight loss, while the fruit decay was enhanced by the 5% formulation. A number of chemicals possessing antimicrobial properties were tested as postharvest treatments of fresh figs in order to control their decay. Positive results were reported on unripe figs with 40 ppm sodium hypochlorite, especially in combination with subsequent plastic packaging (Lima et al. 2005). The improvement in keeping quality was reached also by dipping the 'Lampa Preta' figs in 1% sodium bicarbonate, while acetic acid dips were less efficient (Antunes et al. 2005a). Treatments of 'Bianca' figs with cinnamic acid and/or ethanol reduced the decay incidence but caused unacceptable peel blemishes and off-flavor (d'Aquino et al. 2003). Certain improvement in fruit taste and color was observed in 'Lampa Preta' figs following 1% calcium chloride dips (Antunes et al. 2003a).

Attempts at using heat for controlling spoilage of fresh figs have been reported. No positive effects of 2-minute dipping in water or in 1% $CaCl_2$ solution at 45°C were observed by Antunes et al. (2003a). Ozer and Sen (2003) tried 4-second steam applications to 'Yediveren' brebas. Although not clearly stated in their publication, the presented results (significant enhancement of weight loss during cold storage and of decay incidence during shelf life) indicate possible heat damage of the fruit. S. Ben-Yehoshua (unpubl. results) observed noticeable control of fungal development on stem-ends of 'Nazareth' breba figs by hot water drenching (ca. 20 seconds at 55 to 60°C).

In conclusion, it seems that preservation of fig fruit for fresh market still has to be based primarily on traditional approaches: selection of suitable cultivars, use of appropriate horticultural practices, harvesting at optimal maturity stages, and strict maintenance of cool chain. Methods of controlled and/or modified atmosphere during storage may be helpful for preservation of fresh figs. However, the practical implementation of these practices cannot be based only on general recommendations and needs fine-tuning for each specific case (cultivar, maturity stage, presence/absence of pollination, storage conditions, etc.). The efficacy of anti-ethylene treatments, for example, 1-MCP, for extending postharvest life of fresh figs has been limited so far, possibly because the harvested fruit may be at postclimacteric stage. Many other postharvest treatments reported were tested in sporadic experiments and are still far from commercial implementation. The improvement in fruit storage potential should not be accompanied by flavor deterioration, which may happen either due to harvesting unripe fruit or applying techniques causing off-flavors. The aspects of food safety, such as toxic residues on the fruit, should not be ignored, as many people consume fresh figs together with the skin.

B. Processed Fruit

Fig fruit attains the best edible quality approximately at the same time as its storage potential tends to zero. One of the approaches to solve this dilemma is processing the fully ripe fruit into a more durable product that whould retain as much as possible the nutritional and hedonic value of the freshly harvested ripe fruit.

Drying is by far the most popular and effective way of processing/preservation of figs known from prehistoric times (Kislev et al. 2006). Important advantages of this method are its low cost and the fact that the obtained product does not depend on refrigeration (Seylam and Olmez 1999). Bolin and King (1980) estimated that dried figs comprise about 90% of the world production. However, Tous and Ferguson (1996) estimated that only approximately 40% of the whole fig crop is sold as dried fruit, produced mainly in Turkey. Regarding the figs grown in California, these authors presented this distribution: 85% of the whole yield marketed as dried fruit, 12% as canned fruit and fig juice, and only 3% as fresh. Dried figs are distinguished by high nutritional value and possess functional food properties (Vinson 1999).

1. Harvesting and Preparation for Drying. Fruit intended for drying are left on the tree until they attain full ripeness, partially desiccate, and eventually fall on the ground. The moisture content in the semidried figs at this stage is 30 to 50% (Aksoy 1997b) or, according to a different source, 55 to 60% (Ural 1997). The ground surface below the tree should be appropriately prepared by weeding, cultivation, and smoothing (Aksoy 1997b); sometimes it may be covered with cloth (Ural 1997). At the end of the harvesting season, an external force has to be applied to initiate falling of fruit to the ground since the abscission layer does not develop properly (Aksoy 1997b). Wind machines, helicopter overflights, or, more commonly, long poles may be used for hastening the fruit drop, although the latter practice is labor-consuming and may damage the trees. The dropped fruit are collected from the ground normally once a day, either manually or (in the United States) using mechanical sweepers (Morton 1987; Aksoy 1997b).

Predrying treatments may include blanching in boiling water (normally for 1 minute) and/or sulfuring or sulfitation (i.e., treatment with sulfur dioxide or sulfite/hyposulfite salts). These methods, however, are not easily compatible with the traditional technique of sun-drying, but they are often practiced before solar or mechanical dehydration (see the next section, "Drying Methods"). The treatments accelerate dehydration, control browning of the drying fruit, and may improve its texture

and reduce infestation (Raghupathy et al. 1998; El-Razik et al. 1999; Gawade and Waskar 2003, 2004, 2005; Piga et al. 2004).

2. Drying Methods. *Traditional Sun Drying* The procedures of sun drying of fig fruit have been described by Ural (1997) and Aksoy (1997). The semidry figs collected from the ground are placed in one layer on wooden drying trays. These trays are positioned in a special part of the orchard, the drying yard, usually located in a sun-exposed open area away from dust and potential sources of infection (e.g., toilets), but not far from a shelter (warehouse) used for storing the dried fruit in piles or sacks before selling it to a procurement agent. During sun drying, the fruits are kept on the trays, and each fig is periodically turned from one side to the other until water content of 18% to 22% is reached. Usually it takes 3 to 5 days, depending on the weather. The effects of ambient temperature and solar radiation on the efficacy of fruit sun drying were investigated by Torgul and Pehlivan (2004) using mathematical modeling.

The main problem of the sun-drying method is the high risk of fruit infestation with pests and pathogens due to its contact with soil and prolonged exposure to open environment. The major concern is colonization of the sun-dried figs with toxinogenic molds, such as *Aspergillus flavus* and *A. parasiticus,* resulting in the presence of poisonous and carcinogenic mycotoxins (e.g., aflatoxin) in the fruit (see Section V.B.4).

Solar Drying Introduction of more sophisticated drying methods is intended to accelerate dehydration and to limit the fruit contact with the environment, thus reducing the risk of contamination. Solar dryers use the same energy source as the traditional sun drying, but the process is more energy-efficient and conducted within plastic- or glass-covered space. The performance of two types of solar installations for drying 'Kadota' figs was examined by El-Razik et al. (1997) under various operation regimes in comparison with sun drying. The solar drying was 2.5 to 3 times faster than the traditional method; however, the sun-dried fruit received better scores in the organoleptic test. Both sun-dried and solar-dried samples were found positive to aflatoxin type B1, although the concentrations were below the Food and Drug Administration (FDA) limit. However, Ozay et al. (1995) reported the reduction of aflatoxin contamination level by using solar drying. A simple and inexpensive solar drier designed in India was reported not only to expedite drying but to improve quality of cultivar 'Bellary' figs (Raghupathy et al. 1997, 1998). Solar tunnel driers developed at Hohenheim University (Germany) and comprising light-powered fans were applied

in Turkey on commercial scale (Green and Schwarz 2001) and were reported to improve microbiological quality of dried figs (Ural 1997). Chimi et al. (2005) have recently reported good performance of a newly developed solar technique for industrial fig drying in Morocco. In spite of these encouraging results, the available information shows that the scope of commercial application of solar technologies in fig drying is still very limited (Green and Schwarz 2001).

Mechanical Dehydration The use of industrial equipment (e.g., dehydrator airflow tunnels) is another alternative to the conventional sun drying. Its advantages include better sanitation conditions, controllable and uniform technological parameters, fast process, and lower labor demand (Piga et al. 2004). Optimization of dehydration parameters, such as airflow and temperature, for mechanical fig dehydration was carried out by Ertekin et al. (2003). Dehydration of figs of nonspecified local Sardinian cultivar in tangential airflow cabinet allowed complete control of process parameters in sanitary conditions and gave a product with high organoleptic quality. However, the process was associated with significant loss of fruit's endogenous ascorbic acid (Piga et al. 2004). Drying figs of cultivar 'Niedda Longa' in industrial 2-stage dehydration system was studied by Papoff et al. (1998) in comparison with simulated sun drying. The study showed that a 7-hour industrial dehydration gave a ready-to-market product provided a preservative potassium sorbate was applied to ensure microbiological stability. Similar quality was attained after simulated sun drying for as long as 120 hours. Extension of industrial dehydration above 11 hours gave a product not requiring chemical additives for its preservation. However, rehydration was needed to ensure appropriate fruit palatability.

Osmotic Dehydration An attempt to use osmotic dehydration of figs was reported by Piga et al. (2005). The authors concluded that whole fig fruit is poorly suitable for this technology, probably due to its morphological and/or anatomical peculiarities. However, G. Goldman (pers. commun. 2006) reported the basic feasibility of this method when applied to figs and obtained some first encouraging results.

3. Quality Parameters. According to the US Standard (2001) and other sources, major quality parameters of dried figs are fruit size, color, firmness (texture), moisture content, maturity, flavor and odor, and defects. The latter category includes in particular sunburn, splitting, physical damage, disease, and insect attack (Aksoy 1986). The possibility

of sorting dried figs for defects with the help of near-infrared equipment has been discussed in the literature (Burks et al. 2000).

Cultivar is probably the major factor determining such quality parameters as fruit size and color. The most popular fig cultivar used for drying is a cultivar known in Turkey as 'Sarilop' and in the United States as 'Calimyrna', characterized by a large fruit and light color. Work is being conducted to further improve its quality by reducing defects and sensitivity to climatic factors (Kutlu and Aksoy 1998). In Italy, the 'Dottato' ('Kadota') cultivar is considered ideal for processing due to its shape, size, porous skin, high sugar content, and organoleptic quality (Genna et al. 2005). The comparative study conducted in India by Gawade and Waskar (2002, 2005) selected the 'Deanne' fig, a local cultivar, as best suited for drying, giving the highest yield of the product with superior organoleptic quality and long storage life.

Fruit-growing conditions are important for the quality of the dried product. In particular, Aksoy and Anac (1994a) reviewed the effects of climate, tree shape, irrigation, and fertilization on the quality of dried 'Sarilop' ('Calimyrna') figs. Similarly, the survey conducted by Bulbul et al. (1998) in the major area of dried figs production in Turkey revealed cultural practices as an important factor affecting the product quality. Extension programs and advisors' activities were presented as a way to improve the dried figs' quality.

Edible quality and storage potential of dried figs are affected by moisture/dry matter content of the product, which in turn obviously depends on the processing method. The US Standard (2001) determines maximal moisture content as 24% for dried figs kept in nonhermetic packages (e.g., cartons or wooden crates) and 30% for those stored in sealed packages (plastic bags, etc.). However, the allowable moisture content in the former package type may be increased to 30% by using an appropriate mold inhibitor. Basically similar ranges are given by the UN Economic Commision for Europe (UN/ECE) standard as referred by Meyvaci et al. (2003b). Very dry samples have good keeping quality but are difficult to eat, and vice versa. Papoff et al. (1998) showed that industrially dried figs of 23 to 25% moisture (77% to 75% dry matter) required adding potassium sorbate for their preservation, while the product with ca. 12% moisture (the level normally unachievable by sun drying) could be stored without additives. However, these overly dried figs were not edible and needed rehydration in order to restore palatability.

Rehydration of dried figs before marketing to at least 30% moisture has gained commercial importance to obtain a ready-to-eat added-value product with optimal edible quality (Meyvaci et al. 2003b). Aksoy et al.

(2005) recommend these optimized conditions for rehydration of dried 'Sarilop' figs: 2 minutes of vapor treatment followed by a 10-minute dip in hot water of 85°C. Adding hydrogen peroxide to the hot rehydration solution was reported to improve the product quality (Demirbuker et al. 2004, 2005).

4. Mycotoxins. As mentioned, food safety problem associated with product contamination with poisonous and/or carcinogenic mycotoxins is one of the most serious challenges to the contemporary fig-drying industry. The latest update on food mycotoxins has been recently published by Murphy et al. (2006). The contaminants most relevant to dried figs, aflatoxins and ochratoxins, are produced by fungal species of *Aspergillus* genus. Aflatoxins are characteristic to fungi of the Section *Flavi*, such as *A. flavus* and *A. parasiticus*, while ochratoxins are produced by species of Section *Circumdati*, for example, *A. ochraceus* (Doster et al. 1996).

Contamination Incidence A survey conducted in California detected spores of toxinogenic *Aspergillus* species in all soil samples from commercial fig orchards. Although the incidence of fruit contamination with these species was low (0.01% to 0.04%), 32% to 83% of infected figs contained high levels of mycotoxins. The study brought Doster et al. (1996) to conclude that figs in commercial orchards are a favorable substrate for infection by and growth of *Aspergillus* spp.

Dried figs or fig pastes imported from Turkey to the United Kingdom in 1988–89 contained 9% to 24% aflatoxin-contaminated samples (Sharman et al. 1991). The survey conducted at the same period in Turkey brought similar results (Ozay and Alperden 1991). More recently, the analysis of dried fig samples intended for export from Turkey to the European Union revealed that 19% to 53.7% of samples were contaminated with aflatoxin B1, ochratoxin A, or both (Senyuva et al. 2005), showing that the problem has not alleviated with time. Mycotoxin contamination of dried figs was detected also in other countries, such as in Brazil (Iamanaka et al. 2005), Egypt (Zohri and Abdel-Gawad 1993), Italy (Chessa and Barberis 2003) and Syria (Haydar et al. 1990).

Detection of Mycotoxin-Contaminated Fruit One of the approaches to reducing health risks from potentially contaminated foods may be careful sorting and discarding all suspicious items. An easy way of detecting aflatoxin-contaminated figs by their characteristic bright greenish yellow fluorescence (BGYF) was proposed by Steiner et al. (1988). Removal of all BGY-fluorescent fruit from a 56-kg dried figs sample reduced the

contamination level from 22.6 to 0.3 ppb of aflatoxin B1. However, a more detailed study showed that BGYF is just indirect indication of possible aflatoxin presence and therefore is not very reliable. Figs infected with nontoxinogenic *Aspergillus* species still had BGYF; more important, some nonfluorescent figs did contain the toxin (Wenk et al. 1994; Doster and Michailides 1998). Still, it was concluded that BGYF may be of help in reducing aflatoxin risks.

Other analytical approaches for revealing mycotoxin-contaminated figs included thin-layer chromatography (TLC) (Allen 1974), high-performance liquid chromatography (HPLC) (Baumann and Zimmerli 1988; Sharman et al. 1991), enzyme-linked immunosorbent assay (ELISA) (Reichert et al. 1988) and other immunoassays (Bacigalupo et al. 1994), polymerase chain reaction (PCR) (Farber et al. 1997), affinity liquid chromatography (MacDonald et al. 2003) and liquid chromatography–mass spectrometry (LC-MS) (Senyuva et al. 2005). Sampling method for inspecting dried fig batches for aflatoxin contamination was described by Wenk et al. (1994).

Preventing Contamination Understanding the process of fruit infection by toxinogenic *Aspergillus* species is necessary for developing contamination-preventing strategies. The experiments of Buchanan et al. (1975) demonstrated that *A. flavus*-inoculated unripe green figs were resistant to the fungal invasion and contained almost no aflatoxin. Fungus development and toxin accumulation started when the inoculated fruit reached firm-ripe stage and continued throughout ripening, reaching maximal level in traditionally sun-dried fruit. Fungal development was arrested in desiccated fruit; therefore, longer periods between the firm-ripe and the dry-fig stages resulted in higher levels of aflatoxin. The inoculation trials conducted by Boudra et al. (1994) confirmed the critical role of the firm ripe stage for the fruit contamination. Attempts to inoculate figs with *A. flavus* at later stages (shriveled and dried fruit) were unsuccessful. A range of fungicides (e.g., mancozeb, benomyl, captan, prochloraz) were applied in orchard trials to control the colonization of figs by *Aspergillus* to reduce ensuing contamination with mycotoxins. At early stages of production cycle (e.g., budbreak), the fungicides were applied both on the tree and on the soil, while at later stages (fruiting, ripening, and shriveling), they were used only on the soil under the trees in order to eradicate the soilborne fungi. In addition, the storage warehouse was pretreated with fungicides. These antifungal treatments effectively reduced fruit contamination, bringing it below the tolerance limits (Tosun and Delen 1998). Attempts are being made to use atoxigenic *Aspergillus* strains (strains not producing toxins) as

biocontrol agents competing in the environment with regular toxigenic strains and thus reducing the aflatoxin contamination in figs (Doster et al. 2005).

Detoxification Additional research is directed at finding treatments to enhance aflatoxin degradation in contaminated figs. Encouraging results were achieved with treating aflatoxin-tainted figs with sodium bisulphate or sulfur dioxide in combination with heat, ultraviolet illumination, hydrogen peroxide, or potassium sorbate (Altug et al. 1990; Icibal and Altug 1992; Elmaci and Altug 1994). The most efficient combinations resulted in reduction in total aflatoxin up to 94%. Further reduction of aflatoxin level was achieved by processing of contaminated dried figs into molasses (Bahar and Altug 1998).

5. Pests. Contact of sun-drying figs with soil and their prolonged exposure to orchard environment favor not only *Aspergillus* infection but also fruit infestation with insect pests. One of the major pests of the drying figs, the dried-fruit beetle *Carpophilus hemipterus*, readily penetrates fallen overripe fruit, but is not attracted to undamaged healthy figs or to fruit that is very dry or far advanced in decay. However, larvae that begin growth in overripe figs may continue their development after the fruit is fairly dry (Simmons and Nelson 1975). Erakay and Ozar (1979) observed rather high *Carpophilus* infestation of attached ripe figs before the abscission. Other important insect pests of dried figs are the moths *Plodia interpunctella* and *Cadra cautella* and the mite *Carpoglyphus lactis* (Erakay and Ozar 1979). In addition to the direct damage, insect pests may reduce the nutritional value of figs (Saleh et al. 1987) and aid in the distribution of *Aspergillus* spores, although they are not necessary for the fungus penetration into the fruit (Buchanan et al. 1975).

For decades, methyl bromide (MBr) fumigation has been the main instrument to control pest development in dried figs (Erakay and Ozar 1979; Ural 1997). However, this application is going to be phased out soon in accordance with the Montreal Protocol (UNEP 2006), due to its ozone-depleting effect. A range of treatments are being investigated as possible substitutes of MBr for pest control in the dried fig industry. In particular, these alternative fumigants have been tested: phosphine (PH_3) released by the hydrolysis of magnesium phosphide (Meyvaci et al. 2003a; Aksoy et al. 2005); propylene oxide in combination with carbon dioxide (Zettler et al. 2003); carbon dioxide (Ferizli and Emekci 2000; Emekci et al. 2003; Meyvaci et al. 2003a), controlled atmospheres comprising 1% or less O_2; and 10% to 15% or 60% to 80% CO_2 (Damarli et al. 1998; Navarro et al. 1998).

Another approach to pest control in dry figs includes physical treatments, such as freezing or heating (Ondogan and Ural 1994; Rahemi and Zare 2002). The high-temperature applications may include, among other methods, solar heating (Shorey et al. 1989) or microwave treatment (Baysal et al. 1998). Biological control approaches—that is, using natural enemies of pest species—are also investigated in controlling pest populations on dried figs (Johnson et al. 2000; Eliopoulos et al. 2003).

6. Packaging and Storage. Dried figs are fairly durable (especially as compared to fresh fruit) and may be stored under nonrefrigerated conditions. Still, reduced temperature and intermediate humidity (4°C and RH 55% to 65%) were preferred as the ideal environment for storing dried figs (Ural 1997). Cold storage allowed product preservation for 6 to 7.5 months (Meyvaci et al. 2003b; Gawade and Waskar 2004) while under nonrefrigerated conditions quality decline started after 2.5 months. Other authors described successful retention of product quality at 20°C for 6 months (Papoff et al. 1998; Piga et al. 2003).

Packaging in plastic films is a common practice with dried figs. The effect of sophisticated packaging methods on keeping quality of dried figs was studied by Meyvaci et al. (2003b). Vacuum packaging had a negative effect on the product quality due to enhanced exudation and fig darkening. Storage in modified atmosphere (20% CO_2 + 80% N_2) slowed the darkening of dried figs at ambient temperature as compared to air or nitrogen atmospheres. However, none of the atmosphere modification methods was as efficient as low temperature in product preservation.

Keeping quality of high-moisture rehydrated figs varied in different years and could be maintained for the periods of 1 to 3 months. The positive effect of CO_2-containing modified atmosphere on the storage of rehydrated figs was also inconsistent (Meyvaci et al. 2003b).

7. Additional Fig Products. Besides drying, fig fruits may be processed by a range of other techniques, such as freezing, canning, and candying (Morton 1987; Waskar et al. 2003). Additional products manufactured from figs include pastes (Sharman et al. 1991), jams (Wang et al. 2003), molasses (Hassan and El-Feitoh 2003), and wine (Moller and Nilsson 1991). Some of these products (e.g., molasses, pastes, wine) are derived from dried figs and may have the same mycotoxin problems as those discussed earlier (see Moller and Nilsson 1991; Sharman et al. 1991).

VI. GENETICS AND BREEDING

Thousands of cultivars, mostly unnamed, have been developed or have come into existence as human migration brought the fig to many places outside its natural range. Almost all fig cultivars grown worldwide are the result of centuries-long selections done among wild seedlings and open-pollinated seedlings of cultivated trees by unknown people. The classical breeding approaches in fig were described by many and summarized by Condit (1947), Storey (1975, 1976, 1977), Obenauf et al. (1978), Ferguson et al. (1990), and Mars (2003). Here we review classical and molecular fig-breeding approaches with emphasis on recent developments.

A. Classical Breeding

Plant breeding is a dynamic area of applied horticultural science. It relies on genetic variation and uses selection to improve plants for traits and characteristics that are of interest for growers and consumers. The genus *Ficus* exhibits two breeding systems, either monoecy (ca. 400 species) or gynodioecy (ca. 350 species, including *Ficus carica*) (Berg 1989). Gynodioecious species are functionally dioecious because hermaphrodites function as males (Janzen 1979; Anstett et al. 1997). Functional dioecy is restricted to the subgenus *Ficus*. The *Ficus* breeding system is particularly interesting because of the tight pollination mutualism with Agaonidae wasps. Coevolution in *F. carica* (Moraceae) and the fig wasp (*Blastophaga psenes*) has resulted in a complex breeding system involving two tree morphs (Caprifig and Edible fig), three floral forms (long-styled female, short-styled female, and male flowers), and the insect pollinator (Beck and Lord 1988). The two female floral forms have been reported to differ only in style length and stigma shape. Breeding studies in the cultivated fig *F. carica* led Storey (1955, 1975) to hypothesize that sex in *Ficus* is genetically determined by a supergene consisting of two very tightly linked genes. The first gene controls the style length of pistillate flowers (the *G*-allele for short styles is dominant over the *g*-allele for long styles) and the second controls the formation of staminate flowers (the *A*-allele for male flowers is dominant over the *a*-allele for absence of staminate flowers). Storey's experiments indicated that males are the heterogametic (*GA/ga*) and females are the homogametic sex (*ga/ga*) (Storey 1955). Males of dioecious *Ficus* retain female flowers, and in *F. carica* there is some ability to produce seeds in the male syconium (Storey 1975; Ne'eman and Galil 1978; Valdeyron and Lloyd 1979). This cross will produce fully fertile homo-

gametic males (GA/GA). Further, there is no evidence for morphologically distinct sex chromosomes in this genus, and 2n=26 is the common somatic chromosome number in *Ficus* (Condit 1964).

The studies on fig floral biology and the understanding of the coevolution with the fig wasp helped to establish the fig breeding techniques (Weiblen 2002; Storey 1975). Traditional breeding techniques are well described in detail by Storey (1975). The juvenile period can be shortened by grafting buds from seedlings onto adult trees (Storey 1975) or by suckering and staking seedlings in a vertical position during early development (Ferguson 1997), followed by intensive growing of upraised seedlings (Flaishman et al. 2007a). Using the last method under the warm climate conditions of Israel, Flaishman and coworkers (2005a) were able to obtain reproductive development and perform first fruit evaluation one year after seed extraction.

The fig industry is not large, and the budget for fig breeding programs is limited. In the United States, two breeding programs were conducted in the beginning of the 20th century, the biggest one at the University of California, led by I. J. Condit and N. B. Storey (begun by R. E. Smith in 1922), and another one at Louisiana State University, led by E. N. O'Rourke Jr in the second half of the 20th century. At the same time, Slykov in the Soviet Union led another breeding program (Storey 1975). Doyle and Ferguson continued the fig breeding program in California (Doyle and Ferguson 1998). In addition, fig crosses and heritage of different fig characters has been described in Japan (Awamura et al. 1996, 1997). Recently, a new fig breeding program has been initiated in Israel. Hybridization began in 2003, and by the end of 2006, about 4,000 hybrid fig seedlings were planted at the Volcani Center, Bet-Dagan, Israel (M. Flaishman, unpubl.). Today, many countries have local fig collections (Table 2.3) that are used for selection of superior clones (Mars et al. 1998; Özeker and Isfendiyaroglu 1998; Mars 2003). The main fig breeding objectives are: (1) maximum productivity; (2) resistance to pests and diseases; (3) high fruit eating quality with improved storage ability; (4) elimination of caprification; and (5) persistence of syconia to ripeness (Storey 1975; IBPGR 1986; Jona and Gribaudo 1991; Mars 2003). Some breeding programs have more specific objects. Thus, Doyle and Ferguson (1998) were looking to develop persistent 'Calimyrna,' and Ferguson (1997) was looking for the development of caprifigs with pollen-producing mammes.

The U.S. breeding program in Davis, California, led by Condit and Storey produced 300 hybrid progenies totaling more than 30,000 seedlings (Storey 1975). The most significant achievement of the California fig breeding program has been five hybrid cultivars: 'Conadria',

'DiRedo', 'Flanders', 'Tena', and 'Excel', Of these cultivars, 'Conadria' was the best-recieved by the fig industry. The cultivar 'Tena' was selected and released in the mid-1970s (Ferguson 1997). More recently, Doyle and Ferguson (2005) released the cultivar 'Sierra', a common fig type with green fig color and late summer maturity that is planted in California. In addition, persistent 'Calimyrna'-like cultivars are in grower trials (Doyle et al. 2003).

B. Marker-Assisted Selection

In figs, like in other plants, quantitative inheritance is a feature of many important traits, such as yield, quality, and disease resistance. Means of analyzing quantitative variation and especially of uncovering its potential genetic basis are therefore of major importance for breeding purposes. Such quantitative variation results from the combined action of multiple segregating genes and environmental factors. The joint analysis of genotype marker segregation and phenotypic values of individuals or lines enables the detection and location of loci affecting quantitative trait loci (QTL). The availability of DNA markers and powerful biometric methods has led to considerable progress in QTL mapping in plants. In a fig breeding program, QTL can be used through the application of molecular markers, providing basis for so-called marker-assisted selection (MAS). It can be employed to enhance fig breeding efforts and to speed up the creation of cultivars.

Molecular identification of fig cultivars has been carried out using isozyme markers (Cabrita et al. 2001), random amplified polymorphic DNA (RAPD) (Cabrita et al. 2001; Khadari et al. 1995; Galderisi et al. 1999; Papadopoulou et al. 2002), Mitochondrial DNA (mtDNA) Restricted Fragment Length Polymorphism (RFLP) (Khadari et al. 2005) or amplified fragment length polymorphism (AFLP) (Cabrita et al. 2001). Currently, microsatellites or simple sequence repeats (SSRs) have become the markers of choice for fingerprinting purposes in most plant species (Gupta and Varshney 2000) due to their high polymorphism, codominance, and reproducibility. Khadari et al. (2001) identified 8 microsatellites in fig (Khadari et al. 2001). More recently, Giraldo et al. (2005) reported on 26 additional microsatellites that were tested in a group of 15 known fig cultivars. Microsatellite polymorphism was evaluated in a sample of 15 fig cultivars representative of different geographical areas. A total of 79 fragments were amplified, with an average of 3 fragments per SSR. With the availability of those microsatellites and the isolation additional new microsatellites, these tools can be very useful in future evaluation of fig progenies in fig breeding programs.

Knowledge of the genetic control of sex determination in *Ficus* is important for the understanding the evolution of functional dioecy in the genus and for the enhancement of breeding programs. Markers for early sexing in *F. carica* are economically important (Storey 1975), but chromosome morphology and flow cytometry cannot be used for this purpose. So far, all knowledge of the genetic control of sex determination in *Ficus* is based on breeding studies in *F. carica*. If sex determination is controlled by a single gene or a group of tightly linked genes, it should be possible to identify sex-specific DNA markers. So far, sex-related markers have been identified in a considerable number of dioecious plant species (e.g., Pistacia vera, Hormaza et al. 1994; Zang et al. 1998; *Cannabis sativa*, Mandolino et al. 1999; *Carica papaya*, Deputy et al. 2002). Recently, Parrish et al. (2004) reported of a male-specific AFLP marker identified in the functionally dioecious fig species *Ficus fulva*. The study of Parrish et al. (2004) suggests that sex-specific AFLP markers are likely also be found in *F. carica*.

C. Mutational Breeding

Research on mutation induction for plant breeding reached its peak a few decades ago and then slowed down (Donini and Sonnino 1998; Van Harten 1998). In fruit crops, mutagenesis has already been used to introduce many useful traits affecting plant size, blooming time and fruit ripening, fruit color, self-compatibility, self-thinning, and resistance to pathogens (Visser et al. 1971; Janick and Moore 1975; Spiegel-Roy.1990; Janick and Moore 1996; Van Harten 1998; Sanada and Amano 1998). Most of these traits continue to be worthy of introduction into many fruit species. The number of cultivars derived from mutation induction increases steadily; by the end of 1999, their number had increased to nearly 2,000, including about 50 cultivars of fruits belonging to more than 20 different species (Predieri 2001).

Mutational variation can be induced either by specific treatments with physical and chemical mutagens or by tissue culture. In figs, studies have reported on the effect of gamma radiation on cuttings, seeds, and pollen. The most frequent findings were dwarfness and acceleration of fruiting (Mars 2003). Some mutants were used in breeding programs and permitted the selection of new types such as the cultivar 'Bol' obtained by seed irradiation (Akhud-Zade 1981). In addition, spontaneous mutants can occur in commercial orchards. Such a mutation has been recently isolated from 'Kadota' commercial orchard in Israel. The new mutant is similar to the known 'Kadota' cultivar, but

has red skin that develops during fruit maturation; therefore, it was named and registered as 'Red Kadota' (Flaishman et al. 2007b).

In vitro tissue culture methods were developed in fig (Muriithi et al. 1982; Pontikis and Melas 1986; Hepaksoy and Aksoy 2006). Those methods may be very useful in selecting new cultivars from somaclonal variation, but none have been released yet from tissue culture mutagenesis (Mars 2003).

D. Molecular Breeding

Over the last few years transgenic crops have moved from being a laboratory curiosity to providing new cultivars grown on large areas worldwide. Dramatic progress has been made over the past two decades in manipulating genes from diverse and exotic sources and inserting them into microorganisms and crop plants to confer: resistance to insect pests and diseases; tolerance to herbicides, drought, soil salinity, and aluminum toxicity; improved postharvest quality; enhanced nutrient uptake and nutritional quality; increased photosynthetic rate, sugar, and starch production; increased effectiveness of biocontrol agents; improved understanding of gene action and metabolic pathways; and production of drugs and vaccines (Sharma et al. 2002). Despite opposition to this technology in some countries, the economic benefits to the farming community has ensured a rapid acceptance in North and South America. Today, developing highly populated countries are already benefiting significantly from advances in plant biotechnology (Dunwell 2000; Toenniessen et al. 2003). Transgenic crops deal with an issue much wider than strict scientific and technical choice (Grumet and Gifford 1998; Robinson 1999). The evolution of consumer opinion concerning food derived from genetic manipulation organism (GMO) is an important consideration that must also be taken into account.

The application of genetic engineering techniques to stably incorporate homologous and/or heterologous genetic material into woody species, including fruit trees, offers the potential of obtaining improved planting stocks for agricultural use in a short period of time compared to traditional breeding techniques. In addition, efficient transformation methods can be used for the production of heterologous polypeptides having nutritional and/or pharmaceutical value. The overall efficiency of techniques for genetically modifying plants depends on the efficiency of the transformation technique(s) used to stably incorporate the desired genetic material into plant cells or tissues and the regeneration technique(s) used to produce viable whole plants from transformed cells.

Successful transformation systems rely on effective systems of regeneration. Within *F. carica*, adventitious shoot regeneration in tissue culture has been reported by Yakushiji et al. (2003). They also reported a method for the induction of organogenesis from leaf explants of *F. carica* using phloroglucinol (PG). However, by this method the frequency of adventitious bud differentiation from leaf fragments was relatively low, and no adventitious buds were observed without PG. An efficient and reproducible system for regeneration of the common fig cultivars 'Brown Turkey' and 'Smyrna' were reported by Yancheva et al. (2005). Regeneration was highly dependent on the dorsoventral orientation of the explants: When explants were cultured with the adaxial surface up, 100% regeneration was achieved with more than 5 shoots per regenerating explant in both studied cultivars. In addition, Yansheva et al. (2005) reported an efficient and reproducible transformation system for both cultivars. Similar to regeneration, the orientation of the leaf surface during organogenesis was a key factor for successful transformation. Leaf explants of in vitro propagated plants were cocultivated with the disarmed *Agrobacterium* strain EHA105 harboring the plasmid pME504 that carried the *uidA*-intron, *bar* and *npt*II genes. Transformants were obtained by selection on the antibiotic Kanamycin. Transformation efficiencies were at a range of 1.7% to 10.0% for 'Brown Turkey', 2.8% to 7.8% for 'Smyrna' (Yancheva et al. 2005), and 2.5% to 6.0% for 'Kadota' (M. Flaishman et al. unpubl). The transgenic nature of the regenerated plants was confirmed by PCR and Southern blot and gave typical staining for the reporting gene GUS. Transgenic plants were propagated in the greenhouse, and transgenic fruits were obtained one year after propagation. Histochemical localization of β-glucuronidase (GUS) activity confirmed that the cauliflower mosaic virus (CaMv) promoter functions in cells of the fig syconium (M. Flaishman et al. unpubl) (Plate 2.2).

VII. HUMAN NUTRITION AND HEALTH

As early as 2900 BCE, in Sumeria, the medical usage of fig fruits, leaves, and the milky latex was reported. Figs and fig latex were the earliest known ancient drugs for cutaneous anthrax (Ben-Noun 2003). The latex released upon picking the fruit is being used by different cultures to treat skin tumors and warts (Ghazanfar 1994). The leaf decoction is taken as a remedy for diabetes and calcifications in the kidneys and liver. Fresh and dried figs have long been appreciated for their laxative action. Several phytochemical investigations of *F. carica* leaves have been published, but with no biological data. Athnasios et al. (1962)

have isolated psoralen, â-sitosterol, bergapten, and taraxasterol from the petroleum ether extract of leaves. Others have isolated triterpenoids (Wasim et al. 1988). Latex from *Ficus* species contains enzymes that help to protect plants from parasites (Smith et al. 1955). Ficin, which is a mixture of proteases found in fig shoots, in some latex, and in immature fruits, is used by the milk and meat industries (Cormier et al. 1989). Some natives of tropical and subtropical regions apply the milky sap (latex) from several *Ficus* species to wounds to promote healing (Bolay 1979). Recently, Richter et al. (2002) investigated the effect of ficin on human blood coagulation and showed that ficin is an activator of Factor X (Factor X is a vitamin K–dependent plasma glycoprotein with a pivotal role in hemostasis), which could explain the use of latex as a local hemostatic agent in natural medicine.

The Wildlife Conservation Society of New York has recently determined that the high calcium content of wild fig fruits makes them a "keystone" fruit, critical to the survival of other plants and animals (O'Brien et al. 1998). The nutritional traits of fig fruits and functional food compounds have been identified by many and summarized by Bolin and King (1980), Vinson (1999) and Slavin (2006).

A. Nutritional Traits of Fig

Based on the Dietary Reference Intakes (DRI) data, published by the Food and Nutrition Board of the Institute of Medicine in the United States, and on the nutrient composition of dried figs (Miura et al. 1998), it is clear that figs can be viewed as a superior source of minerals and vitamins. Figs are fat free, sodium free, and, like other plant foods, cholesterol free (Miura et al. 1998; Goor 1965). A comparison of the nutrient content of figs is given in Table 2.5. One serving of dried figs is 100 g, about ¼ cup, or about three 'Calimyrna' or four to five 'Mission' figs. The main minerals and vitamins provided per 100 g fig serving are: iron 6%, calcium 6%, potassium 7%, thiamin (B1) 7.1%, and riboflavin (B2) 6.2% of daily recommended consumption. Fig fruits contain at least 17 types of amino acids, with aspartic acid and glutamine present in the highest amounts (Goor 1965). A comparison of the nutrient content of figs with that of other common fruits is given in Table 2.6. Of the common fruits, figs have the highest overall content of minerals, and their calcium content per serving is second to oranges. On a weight basis, figs contain more calcium than any of the fruits listed in Table 2.5. Dried figs also contain relatively high amounts of crude fibers (5.8%, w/w), higher than all other common fruits (Miura et al. 1998). More than 28% of the fiber is of the soluble type, which has been shown to aid in

Table 2.5. Nutrient content of figs.

Dietary Component	Amount per 100 g Serving	Daily Value
Total calories	283	–
Calories from fat	4.7	–
Total fat	0.52 g	0%
Saturated fat	0.0 g	0%
Cholesterol	0.0 mg	0%
Sodium	12.26 mg	0%
Potassium	609 mg	7%
Total carbohydrate	66.16 g	9%
Total dietary fiber	12.21 g	
Insoluble	8.74 g	20%
Soluble	3.47 g	
Sugars	49.0 g	–
Protein	3.14 g	–
Vitamin A	9.76 IU	<2%
Vitamin C	0.68 mg	<2%
Calcium	133.0 mg	6%
Iron	3.07 mg	6%

Source: California Fig Advisory Board Report 1998.

the control of blood sugar, blood cholesterol, and contribute to weight loss (Vinson 1999). Pasman et al. (1977) studied obese women and found that average energy intake decreased significantly after fiber supplementation while hunger and satiety scores did not change. In a second study of subjects with low-energy intakes, hunger scores were significantly decreased after fiber supplementation. The authors concluded that, by facilitating compliance to a low-energy intake, fiber may be useful in the treatment of obesity (Pasman et al. 1997). Thus, figs are

Table 2.6. Nutrient content of common fruits, in comparison with dried fig.

Fruit (g)	Calories	Dietary Fiber (g)	Potassium (g)	Calcium (mg)	Iron (mg)
Dried figs (40 g 1/4 cup)	113	4.9	244	53.0	1.2
Apples (154 g 1 medium)	91	3.0	177	11.0	0.3
Bananas (126 g 1 medium)	75	1.7	324	4.9	0.3
Dates (40 g 1/4 cup)	113	3.8	240	10.0	0.2
Grapes (138 g 1/2 cups)	98	0.8	255	15.0	0.4
Oranges (154 g 1 medium)	72	2.9	279	62.0	0.2
Prunes (40 g 1/4 cup)	109	2.4	290	7.2	0.6
Raisins (40 g 1/4 cup)	126	2.3	306	16.0	1.2
Strawberries (147 g 8 medium)	147	2.2	244	20.6	0.6

Source: California Fig Advisory Board Report 1998.

an ideal addition to adults' and children's diet because they represent an excellent source of naturally sweet and fiber-rich food that may help with weight reduction (Bolin and King 1980; Vinson 1999).

Dried figs also contain one of the highest concentrations of polyphenols among the commonly consumed fruits and beverages (Miura et al. 1998). Vinson et al. (2005) determined the amount and quality of polyphenol antioxidants in dried fruits and compared them with the corresponding fresh fruits. They found that processing to produce the dried fruit significantly decreases the polyphenols in the fruits on a dry-weight basis. Compared with vitamins C and E, dried fruits have superior quality antioxidants, with figs and dried plums being the best. Fig antioxidants can enrich lipoproteins in plasma and protect them from subsequent oxidation. Figs produced a significant increase in plasma antioxidant capacity for 4 hours after consumption and overcame the oxidative stress of consuming high-fructose corn syrup in carbonated soft drink (Vinson et al. 2005).

Recently, Solomon et al. (2006) studied the potential health promoting constituents of six commercial fig cultivars differing in color (black, red, yellow, and green) for their total polyphenols, total flavonoids, antioxidant capacity, and amount and profile of anthocyanins. Analysis with reversed-phase liquid chromatograph (RP-LC) revealed varying concentrations of anthocyanins but similar profiles in all cultivars studied. Hydrolysis revealed cyanidin as the major aglycon. Proton and carbon nuclear magnetic resonance (NMR) confirmed cyanidin-3-O-rhamnoglucoside as the main anthocyanin in all fruits. Color appearance of fig extract correlated well with total polyphenols, flavonoids, anthocyanins and antioxidant capacity. Extracts of darker cultivars showed higher contents of phytochemicals, as compared to lighter-colored cultivars. Antioxidant capacity correlated well with the amounts of polyphenols and anthocyanins. Fruit skins contributed most of the phytochemicals and antioxidant activity just mentioned compared to the fruit pulp. In the dark-colored 'Mission' and the red-colored 'Brown Turkey' cultivars, the anthocyanin fraction contributed 36% and 28% of the total antioxidant capacity, respectively. Cyanidin-3-O-rhamnoglucoside contributed 92% of the total antioxidant capacity of the anthocyanin fraction. The average daily intake of anthocyanins per person has been estimated to be up to 200 mg. 'Mission' is the richest fig cultivar in anthocyanins of the six cultivars examined, containing 11.0 $\pm$ 1.0 mg/100 g of fresh weight. Since skins were shown here to be the major source of anthocyanins and polyphenols, the consumption of whole ripe fruits was recommended. Piga et al. (2007) detected phenolic compounds in peel and pulp of figs and found that the black fig cultivar had

the highest content, and most of the polyphenols are concentrated in the peel.

B. Fig as Functional Food

The term *functional food* refers to foods or ingredients of foods providing an additional physiological benefit beyond their basic nutritional value. Health benefits are best obtained through a varied diet containing fruits, vegetables, grains, legumes, and seeds. However, fortified foods and dietary supplements have been marketed and food industries have made functional food one of their current leading trends. Recently, the number of functional foods that have potential health benefits has grown tremendously, and scientific evidence supports the role of functional foods in prevention and treatment of several diseases. Cancer, diabetes, heart disease, and hypertension are the most important diseases that can be treated or prevented by functional foods; other diseases are osteoporosis, abnormal bowel motility, and arthritis. It has been estimated that 80% of cancer in the United States hase a nutrition/diet component, suggesting a potentially great impact of functional foods and food components on incidence and treatment of cancer. Numerous factors complicate the evaluation of scientific evidence, such as the complexity of food substance, effect on food, metabolic changes associated with dietary changes, and the lack of biological markers of disease development.

1. Nonnutrient Compounds and Cancer Risk Reduction. The first scientific investigation of the activity of fig latex was done by Ullman et al. in the 1940s (Ullman et al. 1952). High doses of fig latex injected into rats were found to be lethal. Smaller doses injected into mice bearing a benzpyrene-induced sarcoma caused inhibition of the tumor growth and even the disappearance of small tumors (Ullman at al. 1952). Although isolation of the active components was not pursued, some pharmacological work was reported by the same group. Recently, Rubnov et al. (2001) described the isolation and identification of a potent cytotoxic agent (6-*O*-acyl-*â*-D-glucosyl-*â*-sitosterols) from fig latex, which is also present in soy products that showed in vitro inhibitory effects on proliferation of various cancer cell lines. More recently, Wang et al. (2003) described inhibition of cancer cell line by compounds isolated from figs.

Polyphenols in fruits and vegetables are widely hypothesized to be responsible for ameliorating effects on cancer. Polyphenols can act by several mechanisms to prevent cancer, such as carcinogen-blocking activities, antioxidant activity/ free-radical scavenging, and antiprolif-

eration/antiprogression actions (Kellogg et al. 1994). As described, Solomon et al. (2006) recently isolated and identified cyanidin-3-O-rhamnoglucoside as the main anthocyanin in all fig cultivars examined. Cyanidin-3-O-rhamnoglucoside showed in vitro inhibitory effects on proliferation of skin cancer cell lines (A. Solomon et al. unpubl.). Another group of fig compounds, psoralens, are currently being investigated for the treatment of skin cancer and have been recommended for clinical trials because of their low skin phototoxicity (Bordin et al. 1991). Figs contain other compounds with anticancer activity, specifically benzaldehyde and coumarins. Benzaldehyde has been used successfully to treat terminal human carcinomas. Following benzaldehyde treatment of 57 patients, 19 displayed complete remission and 10 responded with a greater than 50% regression in their tumors (Kochi et al. 1980). Coumarins are the major compounds isolated from the volatile extract of figs (Gibernau et al. 1997). In fact, the total dry-weight coumarinic content of figs is 0.5% (Innocenti et al. 1982). The furanocomarins identified in figs include angelicin, marmesin, psoralen, umbelliferone, and bergapten (Innocenti et al. 1982). Coumarins have also been used for the treatment of prostate cancer (Maucher et al. 1993; Berkarda 1993).

2. Nonnutrients Compounds and Diabetes Risk Reduction. Fig leaf preparations (such as teas) are popularly used for patients with diabetes in Spain and other areas in southwestern Europe (Yeh et al. 2003), though its active component is unknown. Several studies in animal models with diabetes have shown both short- and long-term hypoglycemic effects, although human trials are lacking. Potential hypolipdemic effects in diabetic rats have also been shown (Perez et al. 2003). The mechanism for glucose-lowering effect is unknown; however, some studies suggest facilitation of glucose uptake peripherally. The only available clinical trial is a small crossover study of fig leaf tea for 4 weeks in patients with type-1 diabetes. In this study investigators showed a decrease in postprandial glucose and insulin requirements, but no change in fasting glucose when compared with the control commercial tea (Serraclara et al. 1998). No effect was seen in C-peptide levels, thereby supporting a non–insulin-mediated effect. No adverse effects were reported. Yeh et al. (2003) concluded that more information is needed before the efficacy of *F. carica* can be properly assessed.

3. Nonnutrients Compounds and Heart Disease Risk Reduction. Elevated levels of cholesterol and triglycerides are risk factors for developing heart disease. Figs have been found to contain cholesterol-lowering phytosterols. Jeong and Lachance (2001) studied the phytosterol composition in unsaponifiables of fig variety 'Mission' fruits as

well as fatty acid composition, using gas chromatography and gas chromatography/mass spectrometry. Fourteen compounds were separated in fig fruit. Sitosterol was the predominant sterol in all parts. Also detected were campesterol, stigmasterol, and fucosterol. Fatty acids in fig fruit, determined as their methyl esters, were myristic (14:0), palmitic (16:0), stearic (18:0), oleic (18:1), linoleic (18:2), and linolenic (18:3) acids. The results indicate that fig might serve as a good source of phytosterols.

Flavonoids in figs and other foods may provide additional protection against heart disease. The first indication that flavonoids could protect against heart disease came in a study using data from 17 countries, showing an inverse relationship between coronary artery disease mortality and wine drinking (St Léger et al. 1979). Further suggestion came from an epidemiological report indicating that the intake of antioxidant flavonols reduced the rate of coronary heart disease mortality (Hertog et al. 1993).

Vinson et al. (1998) measured the quantity of total polyphenols in dried figs after an acid hydrolysis. Table 2.6 compares total polyphenols content in other foods and beverages in vegetable and in fig fruits (Kühnau 1976; Shahidi and Naczk 1995; Vinson 1999). Evidently, on a weight basis, figs contain one of the highest concentrations of polyphenols among the commonly consumed foods and beverages. Only barley, some sorghums, and some beans have similarly high levels of polyphenols. Compared with figs, red wine and tea, two well-known and well-publicized sources of polyphenols, are relatively low in phenols. Putting it in perspective, 40 g of figs, the suggested serving size, provide an average of 444 mg of phenols, which is more than the daily per capita consumption of polyphenols from vegetables, estimated 218 mg/day (Vinson et al. 1998).

Resveratrol and its glycoside are considered to have beneficial effects on human health because of their anti-inflammatory, antiplatelet, and anticarcinogenic activities (Manna et al. 2000). The production of resveratrol is regulated by the key enzyme stilbene synthase, which converts one molecule of *p*-coumaroyl-CoA and three molecules of malonyl-CoA into 3,4,5-trihydroxystilbene, commonly known as resveratrol. These precursor molecules are present throughout the plant kingdom as substrates for chalcone synthase, the key enzyme in the flavonoid pathway. Therefore, the introduction of a single stilbene syntase gene is sufficient to synthesize resveratrol in heterologous plant species. Recently, transgenic figs carrying the stilbene synthase gene were obtained. The transgenic plants accumulated a compound not present in the nontransformed fig that was identified as trans-stilbene

by HPLC. Stilbene levels varied among transgenic lines and fruits (Flaishman et al. 2007a).

There is considerable interest in developing food products from plants rich in protective vitamins or other compounds with potential health benefits. Genetic engineering, recently developed in figs (Yancheva et al. 2005), allows the development of fig cultivars that are highly elevated in a specific compound.

VIII. CONCLUSION

Kislev et al. (2006) have recently proposed based on the use of parthenocarpic figs 12000 years ago that fig trees were the first domesticated crop. This hypothesis is not poven by the finds that fig types that produce pharthenocarpic fruit also carry seeded ones (Lev-Yadun et al. 2006). In any case, the early domestication of the fig was due to the simplicity of fig tree propagation, achieved by merely cutting and planting branches (Zohary and Hopf 2000). In horticulture, fig preceded other fruit trees, such as grape, olive, and date, by almost five millennia (Stager 1985).

There is increasing interest in marketing of fresh figs as a complement to the rich pleasures of dried figs and their products. While markets for fresh figs are growing, more extensive developments are required, such as significant postharvest technology development and selection or even development of appropriate cultivars. Based on consumer response to premium fresh figs, the potential for fresh figs is very large. Delivery of such a richness and food functionality of fig to the consumers around the world would be certain to result in a more significant role for fresh figs in the marketplace.

Today, in many countries figs are grown in the traditional way. However, because of losses in transport and short shelf life, fresh figs are becoming a high-value fruits of limited demand. The best outlet is direct sale at roadside stands or farmers' markets. Figs for shipping are collected daily just before they reach the fully ripe stage, but yield to a soft pressure, usually indicated by small cracks in the skin. They need immediate refrigeration. Improvements in the fig industry may lead to five major changes in the fresh fig market:

1. A number of cultivars suitable for fresh consumption with advanced storage ability have been recently identified in fig fruit collections. In addition, the worldwide trade of fresh figs became

possible mainly due to the accumulation of knowledge and technological developments in the area of postharvest fruit preservation.

2. There is growing interest in breba and late-summer fig cultivars. These figs appear early and late in the season and produce fruits not attacked by fruit fly because the harvest is before or after the fruit fly appearance. Recently, selections in fig collections and breeding programs produced breba and late-season new cultivars, such as 'Sierra', for fresh consumption.
3. Traditional fig orchards with large trees and broad spacing without irrigation are replaced by modern, compact irrigated orchards. Figs produced under innovative technology are expected to have high yield, and the returns allow farmers to adopt postharvest technology, such as refrigeration equipment in order to increase the amounts of marketable fruits. In addition, the development of the organic growth system can be also used to get high-value exportable product.
4. Sophisticated and expensive growing systems such as hydroponics and greenhouses allow continous growth of high-yielding figs and year-round production. Combining this information with the high commercial value of fresh figs in the market, we expect fig production to be an attrctive activity with a rising future that can attract many farmers to supply figs year-round in higher volume and better fruit quality.
5. Improving storability of high-quality fresh figs is probably the key factor that would determine chances to extend their consumption. Reaching this aim is complicated by biological peculiarities of the fig fruit, in particular by the fact that they are typically harvested at postclimacteric stage. Therefore, novel methods such as 1-MCP application, which have already revolutionized the postharvest handling of many other fruits, have brought so far only a limited success with figs. However, considerable progress has been made in the last years in understanding the molecular mechanisms underlying maturation and ripening of fig fruit (Owino et al. 2004; Owino et al. 2006). One can expect that this understanding will eventually result in better control of postharvest fruit preservation, using molecular technologies, marker-guided breeding, and/or new physiological approaches.

Currently, tissue culture in fig is being used mainly for propagation, genetic transformation, and mutational breeding. With the development of this system it could be further used for three things:

1. Elimination of fig mosaic disease, which is one of the most common diseases of figs worldwide. Fig mosaic disease may become more of an agricultural problem with the introduction of intensive cultivation. The effect of fig mosaic is significant in reducing fruit size and yield with a delayed ripening. Several recent studies (Gella and Errea 1998; Leonhardt et al. 1998) demonstrated the use of tissue culture as a means for the elimination of viruses from trees' genetic stock known carry infected viruses. Recently, Lopez Corrales et al. (1998) showed that growing fig in tissue culture with alternating, high-temperature regime resulted in fig plants with no external symptoms of fig mosaic disease.
2. The intensive conservation efforts in fig cultivars (Mars 2003) around the world may benefit from the development of cryopreservation for in vitro fig cultures.
3. In vitro screening systems offer a promising approach for identification and isolation of disease-tolerant individuals, following the exposure of pro-embryogenic masses to filtrates of different pathogenic fungi and bacteria. Recently, a disease-tolerant mutant was isolated in plants by using in vitro screening systems (Jayasankar and Gray 2000; Jayasankar et al. 2003). The use of this system in fig may promote the isolation of disease-tolerant individuals and add breeding systems in figs. The use of breeding and genetics to boost crop productivity and quality and the use of agricultural chemicals to protect crops and enhance plant growth were the two prominent features of agriculture in the 20th century (Dandekar and Gutterson 2000). In the 21st century, in addition to providing necessary nutrients, crops are also expected to improve consumers' health. Figs are an excellent source of fiber, minerals, and polyphenols. They are low in sodium and have no fat or cholesterol. It remains to be shown in future studies whether the human consumption of figs can lead to the lowering of risk factors for cancer, heart disease, and diabetes.

Successful transformation of commercial fig cultivars provides a new promising tool for the introduction of desirable genes into transgenic fig cultivars, if public resistance to "genetic engineering" proves short-lived. The regeneration and transformation methodologies may pave the way for transgenic cultivars with improved agronomic characteristics, such as disease resistance, fruit storability, and enhance fruit quality and flavor. In addition, transformation in figs will provide the means for the production of desired proteins in the edible parts of fig, leading to improved nutritional and/or pharmaceutical composition. Different studies can focus on optimizing the gene expression in

transgenic figs by screening various constitutive and tissue-specific promoters, or selectable markers. An efficient transformation system could be used to induce mutagenesis by transposable elements. Transposable elements, following McClintock's seminal work (McClintock 1944; Fedoroff 1984), possess the potential of becoming a powerful tool for inducing mutations by the use of insertional mutagenesis. Recently, insertional mutagenesis was reported in *Citrus* (Trainin et al. 2004). In can be further used in figs and advance the knowledge and use of classic mutagenesis.

Integrating conventional technologies with those based on molecular biology and genetic engineering could enhance desirable characteristics of agricultural crops while reducing the expression of undesirable ones. Using improved conventional breeding in fig, by molecular markers or by the newly introduced genetic engineering technology, could enhance new properties, such as health-promoting compounds. The given phenotype of a fig cultivar (quality, yield, vigor, and more) is a result of complex interactions among the environment, the management regime, and the genotype of the cultivar. Integration of the scientific approaches described in this review may contribute to the successful incorporation of new and interesting fig cultivars and horticultural practices and may pave the way for improving new cultivar performance and further distribution of fig orchards around the world.

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X. LITERATURE CITED

Akhud-Zade, I.M. 1981. Radiation mutagenesis in subtropical crops. (in Russian, English abstract). L-ya Vses Konf. po Prikl. Radiobiol. 1981:50–51.

Aksoy, U. 1981. Studies on fruit development, maturation and cold storage of the fig (*Ficus carica* L.) fruit cvs. Akca, Goklop and Sarilop. (in Turkish). PhD thesis. Ege Univ., Izmir, Turkey.

Aksoy, U. 1986. An evaluation of the dried fig crop with respect to the standard quality requirements (in Turkish). Ege Universitesi Ziraat Fakultesi Dergisi. 23:23–30.

Aksoy, U. 1995. Present status and future prospects of underutilized fruit production in Turkey, pp. 97–107. In G. Llácer, U. Aksoy, and M. Mars (eds.), Underutilized fruit crops in the mediterranean region. Ciheam-iamz, Zaragoza.

Aksoy, U. 1997a. Fruit formation and development. Advanced Course on Fig Production, pp. 13–18. 16–28 June, Ege University, Izmir, Turkey.

Aksoy, U. 1997b. Harvest and drying of figs. Advanced Course on Fig Production. 16–28 June, Ege University, Izmir, Turkey.

Aksoy, U. 1998. Why figs? An old taste and a new perspective. Acta Hort. 480:25–27.

Aksoy, U. 2005. Advances in fresh and dried fig sector for higher quality and safety. In Third Int. Symp. on Fig. 16–20 May. Vilamoura, Portugal.

Aksoy, U., and D. Akyüz. 1993. Changes in K, Ca and Mg contents in different parts of the fig fruit during development, pp. 305–309. In Optimization of plant nutrition. Kluwer Academic Dordrecht, The Netherlands.

Aksoy, U., and D. Anaç. 1993. Determination of optimum soil and plant nutrients for higher yield and quality in fig production, pp. 309–313. In Optimization of plant nutrition. Kluwer Academic Dordrecht, The Netherlands.

Aksoy, U., and D. Anac. 1994a. Factors affecting quality of fresh and dried fig fruits. Acta Hort. 368:763–766.

Aksoy, U., and D. Anaç. 1994b. The effect of calcium chloride application on fruit quality and mineral content of fig. Acta Hort. 368:754–762.

Aksoy, U., A. Altindisili, and S. Bulbul. 1994. Postharvest problems in the organic production of dry and dried fruits. Proc. Agribiomediterraneo (Marseilles, France) 94:41–43.

Aksoy, U., B. Balci, H.Z. Can, and B. Hepaksoy. 2003. Some significant results of the research-work in turkey on fig. Acta Hort. 605:173–180.

Aksoy, U., K.B. Meyvaci, F. Sen, and M. Cakir. 2005. Studies to optimize pre-treatments for high moisture dried figs, p. 39. In Third Int. Symp. on Fig. 16–20 May, Vilamoura, Portugal.

Aksoy, U., F. Sen, and K.B. Meyvaci. 2005. Phosphine fumigation to control pests as an alternative to methylbromide and its effect on dried fig quality, p. 48. In Third Int. Symp. on Fig. 16–20 May, Vilamoura, Portugal.

Alfieri, S.A. Jr., and N.E. El-Gholl. 1993. *Phytophthora* fruit rot of fig, *Ficus carica* L. Plant Pathol. Circ. 362, Fla. Dept. Agr. Consumer Serv., 3.

Alique, R., and J.L. De La Plaza.1990. Effects of high CO2 pretreatments and ethylene removal on the ripening of refrigerated figs. In Abstracts of Contributed Papers, Int. Hort. Congr., Firenze, Italy, Abstr. 3322.

Allen, L. 1974. Two-dimensional thin layer chromatography of aflatoxins in figs. J. Assoc. Anal. Chem. 57:1398–1401.

Altindisili, A., and A. Ertem. 1998. Organic fig production in Turkey. Acta Hort. 480:227–232.

Altug, T., A.E. Yousef, and E.H. Marth. 1990. Degradation of aflatoxin B_1 in dried figs by sodium bisulphate with or without heat, ultraviolet energy or hydrogen peroxide. J. Food Protect. 53:581–583.

Amen, K.I.A. 1987. Effect of planting density and applications of certain growth regulators on fruit quality and storage ability of Sultani fig cultivar. II. Storage ability. Assiut J. Agro. Sci. 18:139–152.

Anstett, M.C., M. Hossaert-McKey, and F. Kjellberg. 1997. Figs and fig pollinators: Evolutionary conflicts in a coevolved mutualism. Trends Ecol. Evol. 12:94–99.

Antunes, M.D.C., H.M. Vollebregt, M.G. Miguel, M.A. Martins, C. Pica, and M.A. Neves. 2003a. The effect of calcium chloride and thermal postharvest treatments on storage ability and quality of fig fruit. Acta Hort. 604:715–719.

Antunes, M.D.C., N.N.J. Chalfun, M. Pasqual, L.F. Dutra, and J.M. Cavalcante-Alves. 2003b. Factors affecting rooting of figs (*Ficus carica* L.) cuttings. Acta Hort. 605:141–146.

Antunes M.D.C, P. Costa, M.G. Miguel, M.A. Martins, C. Gomes, and M.A. Neves. 2005a. The effect of postharvest treatments with sodium bicarbonate or acetic acid on storage ability and quality of fig fruit, p. 47. In Third Int. Symp. on Fig. 16–20 May, Vilamoura, Portugal.

Antunes M.D.C., V. Mendonça, M.G. Miguel, M.A. Martins, D. Martins, C. Gomes, C. Pica, and M.A. Neves. 2005b. The effect of irrigation level and pre-harvest treatments with calcium oxide on storage ability of fig fruits (*Ficus carica* L. cvs. 'Lampa Preta' and 'Bêbera Branca'), p. 75. In Third Int. Symp. on Fig, 16–20 May, Vilamoura, Portugal.

Athnasios, A.K., I.E. El Kholy, G. Soliman, and M.A.M. Shaban. 1962. Constituents of the leaves of *Ficus carica* L. part I. Isolation of psoralen, Bergapten,ψ-taraxasterol, and β-sitosterol. Int. J. Chem. Soc. 62:4253–4254.

Atzmon, N., and Z. Henkin. 1998. Establishing forest tree species on peatland in a reflooded area of the Huleh Valley, Israel. Forestry 71:141–146.

Awamura, M., K. Shoda, and D. Yahata. 1996. Effect of various seed parents on frequency distribution of parthenocarpy among seedling progenies of fig (*Ficus carica* L.). J. Japan. Soc. Hort. Sci. 65:21–26.

Awamura, M., D. Yahata, and K. Shoda. 1997. Differences in fruit weight and soluble solids content in the juice from caprifig and fig types, and first or second crops among fig (*Ficus carica* L.) hybrid seedlings. J. Japan. Soc. Hort. Sci. 66:77–84.

Baccaunaud, M., J. Raynal, and F. Baboulene. 1995. Figs: maintaining quality after harvest. (in French). Arboriculture-Fruitiere. 489:37–42.

Bacigalupo M.A., A. Ius, G. Meroni, M. Dovis, and E. Petruzzelli. 1994. Determination of aflatoxin B1 in agricultural commodities by time-resolved fluoroimmunoassay and immunoenzymometric assay. Analyst 119:2813–2815.

Bahar, B., and T. Altug. 1998. Investigation of aflatoxin passing through molasses produced from contaminated dried figs. Rev. Med. Vet. 149:561.

Baskaya, M., and J.C. Crane. 1950. Comparative histology of naturally parthenocarpic, hormone-induced parthenocarpic and caprified fig syconia. Bot. Gaz. 111:395–413.

Bataglia, O.C., J.A. Quaggio, O. Brunini, and D.M. Clarelli. 1985. Aadubação nitrogenada e ajustamento osmótico em milho e sorgo. Pesquisa Agropecuária Brasileira, Brasília. 20:659–665.

Baumann, U., and B. Zimmerli. 1988. A simple determination of ochratoxin A in foods. (in German). Mitteilungen-aus-dem-Gebiete-der-Lebensmitteluntersuchung-und-Hygiene. 79:151–158.

Baysal, T., A. Ural, M. Cakr, and C.N. Ozen. 1998. Microwave application for the control of dried fig moth. Acta Hort. 480:215–219.

Beck, N.G., and E.M. Lord. 1988. Breeding system in *Ficus carica*, the common fig. II. Pollination events. Am. J. Bot. 75:1913–1922.

Ben-Noun, L.L. 2003. Figs – the earliest known ancient drugs for cutaneous antrax. Ann. Pharmacother. 37:297–300.

Ben-Yehoshua, S., S. Iwahori, and J.M. Lyons. 1970. Role of ethylene and ethrel in the development of fig fruit. Israel J. Agri. Res. 20:173–177.

Berg, C.C. 1989. Classification and distribution of *Ficus*. Experientia 45:605–611.

Berg, C.C. 2003. *Flora malesiana* precursor for the treatment of Moraceae 1: The main subdivision of *Ficus*: The subgenera. Blumea 48:167–78.

Berkarda, B. 1993. Coumarin derivatives and cancer: a review of my work in this field. J. Irish. Coll. Phys. Surg. 22:69.

Bewaji, O., and H. English. 1976. Control of Alternaria surface rot of Kadota figs. Proc. Am. Phytopath. Soc. 3:278.

Biale, J.B. 1960. Respiration of fruit. Handbuch der Pflanzenphysiologie, Vol. 12, part II, pp. 536–592. Springer Verlag, Heidelberg.

Bolay, E. 1979. Feigen und Würgefeigen. Pharmazie in Unserer Zeit 4:97–112.

Bolin, H.R., and A.D. King Jr. 1980. Figs, pp. 492–505. In S. Nagy and P.E. Shaw (eds.), Tropical and subtropical fruits: Composition, properties and uses. AVI Publ., Westport, CT.

Bordin, F., G. Call'Acqua, and A. Guiotto. 1991. Angelicins, angular analogs of psoralens: Chemistry, photochemical, photobiological and phototherapeutic properties. Phamacol. Ther. 52:331.

Botti, C., N. Franck, L. Prat, D. Ioannidis, and B. Morales. 2003. The effect of climatic conditions on fresh fig fruit yield, quality and type of crop. Acta Hort. 605:37–44.

Boudra, H., J. Le Bars, P. Le Bars, and J. Dupuy. 1994. Time of *Aspergillus flavus* infection and aflatoxin formation in ripening of figs. Mycopathologia 127:29–33.

Buchanan, J.R., N.F. Sommer, and R.J. Fortlage. 1975. *Aspergillus flavus* infection and aflatoxin production in fig fruits. Appl. Microbiol. 30:238–241.

Bulbul, S., H. Atl, and S. Hepaksoy. 1998. A general study of commercial dried fig production in the Big Meander Valley of Turkey. Acta Hort. 480:317–320.

Burks, C.S., F.E. Dowell, and F. Xie. 2000. Measuring fig quality using near-infrared spectroscopy. J. Stored Prod. Res. 36:289–296.

Cabrita L.F., U. Aksoy, S. Hepaksoy, and J.M. Leitão. 2001. Suitability of isozyme, RAPD and AFLP markers to assess genetic differences and relatedness among fid (*Ficus carica* L.) clones. Scientia Hort. 87:261–273.

Caetano, L.C.S., A.J. Cordeiro de Carvalho, E. Campostrine, E. Fernandes de Sousa, K.R.N. Murakami, and B.S. Cereja. 2005. Effect of the number of productive branches on the leaf area development and fig tree yield. Rev. Bras. Frutic. 27:426–429.

California Fig Advisory Board Rep. 1998.

California Fresh Fig Growers Association. 2006. Seasons and varieties. March 2006. www.calfreshfigs.com/seasons.html.

Celikel, F.G., and I. Karacal. 1998. Effects of harvest maturity and precooling on fruit quality and longevity of "Bursa Siyah" figs (*Ficus carica* L.). Acta Hort. 480:283–288.

Celikel, F.G., K. Kaynas, S. Ozelkok, U. Ertan, A.B. Kuden, and F.G. Dennis Jr. 1997. Effects of ethephon in fruit development and ripening of the fig (*Ficus carica* L.) variety 'Bursa Siyahi'. Acta Hort. 441:145–151.

Celikel, F.G., K. Kaynas, S. Ozelkok, and U. Ertan. 1998. Effect of antitranspirant treatment on water loss and keeping quality of the fig cultivar Bursa Siya. (in Turkish). Bahce 25:21–28.

Chessa, I. 1997. Fig, pp. 245–268. In S. Mitra (ed.), Postharvest physiology and storage of tropical and subtropical fruits. CAB Int. Wallingford, Oxon, UK.

Chessa, I., and A. Barberis. 2003. Technological innovations to improve and enhance the Italian dry fig. A coordinated research program. Acta Hort. 605:277–282.

Chessa, I., and G. Nieddu. 2005. Analysis of diversity in the fruit tree genetic resources from a Mediterranean island. Gene. Res. Crop Evol. 52:267–276.

Chimi, H., A. Ouaouich, M. Semmar, and S. Tayebi. 2005. Industrial processing figs by solar drying in Morocco, p. 74. In Third Int. Symp. on Fig. 16–20 May, Vilamoura, Portugal.

Claypool, L.L., and S. Ozbek. 1952. Some influences of temperature and carbon dioxide on the respiration and storage life of the Mission fig. Proc. Am. Soc. Hort. Sci. 60:226–230.
Colelli, G. 1995. Physiological aspects of ripening and postharvest technology of fig (*Ficus carica* L.) fruits. (in Italian). Riv. Frutticoltura Ortofloricoltura 57:71–77.
Colelli, G., F.G. Mitchell, and A.A. Kader. 1991. Extension of postharvest life of 'Mission' figs by CO_2-enriched atmospheres. HortSci. 26:1193–1195.
Condit, I.J. 1920. Caprifigs and caprification. Calif. Agr. Expt. Sta. Bull. 319:341–375.
Condit, I.J. 1928. Cytological and morphological studies in the genus Ficus. I. Chromosome number and morphology in seven species. Univ. Calif. Publ. Bot. 11:233–244.
Condit, I.J. 1932. The structure and development of flowers in *Ficus carica* L. Hilgardia 6:443–481.
Condit, I.J. 1934. Cytological and morphological studies in the genus Ficus. II. Chromosome number and morphology in thirty-one species. Univ. Calif. Publ. Bot. 17:61–74.
Condit, I.J. 1947. The fig. Massachusetts: Chronica Botanica Waltham, MA.
Condit, I.J. 1955. Fig varieties: A monograph. Hilgardia 23:323–538.
Condit, I. J. 1964. Cytological studies in the genus Ficus III. Chromosome numbers in sixty-two species. Madrono 17:153–154.
Condit, I.J. 1969. *Ficus*: The exotic species. Univ. California, Div. Agr. Sci.. Berkeley
Cormier, F., C. Charest, and D. Dufresne. 1989. Partial purification and properties of proteases from fig (*Ficus carica*) callus cultures. Biotechnol. Lett. 11:797–802.
Crane, J.C., 1986. Fig. In S. P. Monselise (ed.), Handbook of fruit set and development. CRC Press, Boca Raton, FL.
Crane, J.C., and R. Blondeau. 1949. The use of growth-regulating chemicals to induce parthenocarpic fruit in the Calimyrna fig. Plant Physiol. 24:44–54.
Crane, J.C., and R.E. Baker. 1953. Growth comparisons of the fruits and fruitlets of figs and strawberries. Proc. Am. Soc. Hort. Sci. 62:142–153.
Crane, J.C., and J.B. Brown. 1950. Growth of the fig fruit, *Ficus carica* var. Mission. Proc. Am. Soc. Hort. Sci. 56:93–97.
Crane, J.C., and J. van Overbeek. 1965. Kinin-Induced Parthenocarpy in the Fig, *Ficus carica* L. Science 147:1468–1469.
Crisosto, C.H., and A.A. Kader. 2004. Fig. In K. Gross (ed.), The commercial storage of fruits, vegetables, florist, and nursery stocks. ARS-USDA Handb. 66, www.ba.ars.usda.gov/hb66.
Damarli, E., H. Gun, G. Ozay, S. Bulbul, and P. Oechsle. 1998. An alternative method instead of methyl bromide for insect disinfestation of dried figs: controlled atmosphere. Acta Hort. 480:209–214.
Dandekar, A.M., and N. Gutterson. 2000. Genetic engineering to improve quality, productivity and value of crops. Calif. Agr. 54(4):49–56.
d'Andria, R., D. Calandrelli, G. Grassi, F. Limongelli, and A. Maggio. 1992. Effetti deli'irrigazione sull'accrescimento del fico nel Cilento. Riv. Frutticoltura 11:75–81.
d'Aquino, S., A. Palma, A. Dore, and M. Agabbio. 2003. Non-conventional treatments to reduce figs decay. Acta Hort. 604:817–821.
d'Aquino, S., A. Piga, M.G. Molinu, M. Agabbio, and C.M. Papoff. 1998. Maintaining quality attributes of "Craxiou de porcu" fresh fig fruit in simulated marketing conditions by modified atmosphere. Acta Hort. 480:289–294.
Datwyler, S.L., and G.D. Weiblen. 2004. On the origin of the fig: phylogenetic relationships of Moraceae from *ndh*F sequences. Am. J. Bot. 91:767–777.
De Candolle, A. 1886. Origin of cultivated plants. 2nd ed. Hafner, New York.
Demirbuker, D., I. Arcan, F. Tokatli, and A. Yemenicioglu. 2005. Effects of hot rehydration in the presence of hydrogen peroxide on microbial quality, texture, color, and antiox-

idant activity of cold-stored intermediate-moisture sun-dried figs. J. Food Sci. 70:M153-M159.

Demirbuker, D., S. Simsek, and A. Yemenicioglu. 2004. Potential application of hot rehydration alone or in combination with hydrogen peroxide to control pectin methylesterase activity and microbial load in cold-stored intermediate-moisture sun-dried figs. J. Food Sci. 69:170–178.

Deputy, J.C., R. Ming, H. Ma, Z. Liu, M.M.M. Fitch, M. Wang, R. Manshardt, and J.I. Stiles. 2002. Molecular markers for sex determination in papaya (*Carica papaya* L.). Theor. Appl. Genet. 106:107–111.

Donini, P., and A. Sonnino. 1998. Induced mutation in plant breeding: current status and future outlook, pp. 255–291. In S.M. Jain, D.S. Brar, and B.S. Ahloowalia (eds.), Somaclonal variation and induced mutations in crop improvement. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Doster, M.A., T.J. Michailides, and D.P. Morgan. 1996. Aspergillus species and mycotoxins in figs from California orchards. Plant Dis. 80:484–489.

Doster, M.A., and T.J. Michailides. 1998. Production of bright greenish yellow fluorescence in figs infected by Aspergillus species in California orchards. Plant Dis. 82:669–673.

Doster M.A., T.J. Michailides, P.J. Cotty and L. Doster. 2005. Biocontrol of aflatoxins in figs, p. 40. In Third Int. Symp. Fig. 16–20 May, Vilamoura, Portugal.

Doyle, J.F., and L. Ferguson. 1998. Breeding persistent figs with calimyrna quality. Acta Hort. 480:259–264.

Doyle J.F., L. Ferguson, and K. Herman. 2003. Fig cultivar development and evaluation. Acta Hort. 605:29–32.

Doyle, J.F., and L. Ferguson 2005. Sierra: A new non-caprifying calimyrna, p. 60. In Third Int. Symp. Fig. 16–20 May, Vilamoura, Portugal.

Dunwell, J.M. 2000. Transgenic approaches to crop improvement. J. Exp. Bot. 51:487–496.

Eccher Zerbini, P., M. Grassi, and S. Vaccari. 1986. The influence of packaging and of delayed cooling on the quality of fresh figs after refrigerated transport. Annali IVTPA 17:95–99.

Eliopoulos, P.A., C.G. Athanassiou, N.E. Palyvos, G.J. Stathas, and C.T. Buchelos. 2003. Dominance and frequency of predatory mites in stored products in Greece. Advances in stored product protection, pp. 258–262. Proc. 8th Int. Working Conference on Stored Product Protection. 22–26 July 2002, York, UK.

Elmaci, Y., and T. Altug. 2004. Aflatoxin degradation in dried figs on industrial scale by using sulphur dioxide alone and together with heat, hydrogen peroxide or washing treatments, pp. 290–296. In H. Kozlowska, J. Fornal, and Z. Zdunczyk (eds.), Bioactive substances in food of plant origin, Vol. 2, Olsztyn, Polish Acad. Sci.

El-Razik, F.A.A.A., S.A. Farghal, and S.M. El-Kayati. 1999. Utilization of solar energy in drying Kadota fig fruit. Desert Inst. Bul. Egypt. 47:323–344.

Emekci, M., A.G. Ferizli, S. Tütüncü, and S. Navarro. 2003. Modified atmosphere as an alternative to MBr in the dried fig sector in Turkey. In Annual Int. Res. Conf. on Methyl Bromide Alternatives and Emissions Reductions, 3–6 Nov. 2003, San Diego, CA.

Erakay, S., and A.H. Ozar. 1979. Preliminary investigations on infestation rates and control measures concerning insects injurious to dried figs in the Aegean region. (in Turkish). Bitki-Koruma Bulteni. 19:159–173.

Erez, A., M.A. Flaishman, and Z. Yablowitz. 2003. Breba production under net; effect of training system. Acta Hort. 605:119–123.

Erez, A., and Y. Shulman. 1982. Growing breba figs in a meadow orchard: A possibility for commercial fig growing. (in Hebrew). Hassadeh 63:969–971.

Erez, A., and Y. Yablowitz. 2000. Técnicas de producción de brevas en Israel, pp. 1–13. In C. Botti (ed.), Cultivos frutales para zonas aridas. Escuela de Agronomía, Facultad de Ciencias Agronómicas, Univ. Chile.

Ertekin, C., O. Yaldiz, and W. Muhlbauer. 2003. Thin layer drying of fig as affected by different drying conditions. Acta Hort. 605:283–291.

FAO. 2005. Agricultural data. FAOSTAT faostat.fao.org/faostat/collections?subset=agriculture, Aug. 2006.

Farber, P., R. Geisen, and W.H. Holzapfel. 1997. Detection of aflatoxinogenic fungi in figs by a PCR reaction. Int. J. Food Microbiol. 36:215–220.

Fedoroff, N.V. 1984. Transposable genetic elements in maize. Sci. Am. 250:65–74.

Ferguson, L. 1977. Fig breeding. Advanced course on fig production. EUFA, Turkey.

Ferguson, L., T.J. Michailides, and H. Shorey. 1990. The California fig industry. Hort. Rev. 12:409–490.

Ferguson, L., M. Mariscal, H. Reyes, and P. Metheney. 2003. Using girdling to improve black mission fig size. Acta Hort. 605:167–169.

Ferizli, A.G., and M. Emekci. 2000. Carbon dioxide fumigation as a methyl bromide alternative for the dried fig industry. Ann. Res. Conf. on Methyl Bromide Alternatives and Emissions Reductions, p. 81. 6–9 Nov. 2000, Orlando, FL.

Flaishman, M.A., and F.A. Al Hadi. 2002. Fig growth in Israel. (in Hebrew). Alon Hanotea 56:56–57.

Flaishman, M.A., and H. Oren. 2005. The fig industry in Israel: Present state. (in Hebrew). Alon Hanotea 59:105–107.

Flaishman, M.A., S. Golubowicz, Z. Yablowicz, A. Erez, A. Solomon, Z. Kerem, and G. Rotcheld. 2007b. Red Kadota—new registered fig variety. (in Hebrew). Alon Hanotea 61:684–686.

Flaishman M.A., Z. Yablowich, S. Golobowich, A. Solomon, Y. Cohen, A. Perl, S.D. Yancheva, Z. Kerem, and E. Haklay. 2007a. Molecular breeding in Fig (*Ficus carica* L.) by the use of genetic transformation. Acta Hort. (in press).

Flores, A. 1990. La higuera: Frutal mediterráneo para climas cálidos. Mundi-Prensa, Madrid, España.

Galderisi U., M. Cipollaro, G. Di Bernardo, L. De Masi, G. Galano, and A. Cascino. 1999. Identification of edile fig 'Bianco del Cilento' by random amplified polymorphic DNA analysis. HortSci. 34:1263–1265.

Galil, J., and D. Eisikowitch. 1968. Flowering cycles and fruit types of *Ficus sycomorus* in Israel. New Phytol. 67:745–758.

Galil, J., and G. Neeman. 1977. Pollen transfer and pollination in the common fig (*Ficus carica* L.). New Phytol. 79:163–171.

Gawade, M.H., and D.P. Waskar. 2002. Physico-chemical characteristics of indigenous and exotic varieties of fig grown under arid conditions. South Indian Hort. 50:505–508.

Gawade, M.H., and D.P. Waskar. 2003. Studies on processing and storage of fig fruits. J. Maharashtra Agri. Univ. 28:148–150.

Gawade, M.H., and D.P. Waskar. 2004. Dried fig (*Ficus carica* L.) storage under various environments. J. Food Sci. Technol. Mysore 41:426–429.

Gawade, M.H., and D.F. Waskar. 2005. Effect of different varieties and pretreatments on yield and quality of dried fig fruits. Indian J. Agr. Res. 39:138–141.

Gella, R., and P. Errea. 1998. Application of in vitro therapy for ilarvirus elimination in three Prunus species. J. Phytopath. 146:445–449.

Genna, A., A. Maestrelli, P. De Vecchi, and M. Bruno. 2005. Quality of "Cosenza dried fig". A sensory and physicochemical approach, p. 72. In Third Int. Symp. Fig. 16–20 May, Vilamoura, Portugal.

Ghazanfar, S.A. 1994. Handbook of Arabian medicinal plants. CRC Press, Boca Raton, FL.
Gibernau, M., H.R. Buser, J.H. Frey, and M. Hossaert-McKey. 1977. Volatile compounds from extracts of figs of *Ficus carica*. Phytochem. 46:241.
Giraldo, E., M.A. Viruel, M. López-Corrales, and J.I. Hormaza. 2005. Characterization and cross-species transferability of microsatellites in the common fig (*Ficus carica* L.). J. Hort. Sci. Biotech. 80:217–224.
Giraldo E., M. López-Corrales, and J.I. Hormaza. 2007. The use of ssr markers to screen new accessions before their incorporation into fig germplasm collections. Acta Hort. (in press).
Golombek S.D., and P. Lüdders. 1990. Effects of short-term salinity on leaf gas exchange of the fig (*Ficus carica* L.). Plant & Soil 148:21–27.
Goor, A. 1965. The history of the fig in the Holy Land from ancient times to the present day. Econ. Bot. 19:124–129.
Gozlekci, S., M. Erkan, I. Karasahin, and G. Sahin. 2005. Effect of 1-methylcyclopropene (1-MCP) on fig (*Ficus carica* L. cv. Bardakci) storage. p. 73. In: Third Int. Symp. Fig. Vilamoura, Portugal, 16–20 May.
Green, M.G., and D. Schwarz. 2001. Solar drying technology for food preservation. GATE Tech. Inform. E14e. GTZ-GATE. www.gtz.de/gate.
Grumet, R., and F. Gifford. 1998. Plant biotechnology in the United States: Issues and challenges en route to commercial production. HortSci. 33:187–192.
Gupta, P.K., and R.K. Varshney. 2000. The development and use of microsatellite markers for genetic analysis and plant breeding with emphasis in bread wheat. Euphytica 113:163–85.
Hakerlerler, H., S. Aydin, M.E. Irget, U. Aksoy, and M. Tutam. 1999. The effect of soil and foliage applied zinc on yield and quality of fig (*Ficus carica* cv. Sarilop) for drying. 6th Int. Meeting on Soils with Mediterranean Type of Climate, 4–9 July, Barcelona, Spain.
Hakerlerler, H., N. Saatci, S. Hepaksoy, and U. Ahsoy. 1998. Fruit and leaf nutritional status of some fig clones and cultivars and relationships with some sugar fractions. Acta Hort. 480:247–252.
Hassan, A.A., and S.M.A. El-Feitoh. 2003. Production and utilization of fig molasses as sugar substitute in some food products. Arab Univ. J. Agr. Sci. 11:637–655.
Haydar, M., L. Benelli, and C. Brera. 1990. Occurrence of aflatoxins in Syrian foods and foodstuffs: A preliminary study. Food Chem. (Lattakia) 37:261–268.
Hepaksoy, S., and U. Aksoy. 2006. Propagation of *Ficus carica* L. clones by *in vitro* culture. Biologia Plant. 50:433–436.
Hernandez-Mendez, M.T., C. Gervasini-Rodriguez, and M.J. Bernalte-Garcia. 2003. Sensory quality of cv. Tiberio breba. Acta Hort. 605:233–235.
Hertog, M.G.L., E.J.M. Feskens, P.C.H. Hollman, M.B. Katan, and D. Kromhout. 1993. Dietary antioxidant flavonoids and risk of coronary heart disease; the Zuphen elderly study. Lancet 342:1007.
Hormaza, J.I., L. Dollo, and V.S. Polito. 1994. Identification of a RAPD marker linked to sex determination in *Pistacia vera* using bulked segregant analysis. Theor. Appl. Genet. 89:9–13.
Hosomi, A., M. Dan, and A. Kato. 2002. Screening of fig varieties for rootstocks resistant to soil sickness. J. Japan. Soci. Hort. Sci. 71:171–176.
Iamanaka, B.T., M.H. Taniwaki, H.C. Menezes, E. Vicente, and M.H. Fungaro. 2005. Incidence of toxigenic fungi and ochratoxin A in dried fruits sold in Brazil. Food Addit. Contam. 22:1258–1263.
IBPGR. 1986. Genetic resources of tropical and sub-tropical fruits and nuts. Int. Board Plant Gen. Res., Rome.

Icibal, N., and Altug, T. 1992. Degradation of aflatoxin B_1 in dried figs by sulphur dioxide alone and in combination with heat, ultraviolet energy and hydrogen peroxide. Lebensm. Wiss. Technol. 25:294–296.

Innocenti, G., A. Bettero, and G. Sulla Caporale. 1982. Determinazione dei costituenti cumarinici delle foglie di *ficus carica* mediante HPLC. Il Farmaco Ed. Sc. 37:475.

Irget, M.E., Ş,. Aydin, M. Oktay, M. Tutam, U. Aksoy, and M. Nalbant. 1998. Effects of foliar potassium nitrate and calcium nitrate application on nutrient content and fruit, pp. 121–126. In Quality of fig. Kluwer Academic Publ. Dordrecht, The Netherlands.

Ito, H., and E. Sato. 1987. Studies on the transport of figs. 5. The quality of the fruit after vacuum precooling. (in Japanese). Res. Bull. Aichi ken Agri. Res. Center (Japan) 19:296–302.

Ito, H., S. Iwamoto, and E. Sato. 1987. Studies on the transport of figs. 4. The effect of low temperature on quality maintenance in fig fruits. (in Japanese). Res. Bull. Aichi ken Agri. Res. Center (Japan) 19:286–295.

Janick, J., and J.N. Moore. 1975. Advances in fruit breeding. Purdue Univ. Press, West Lafayette, IN.

Janick, J., and J.N. Moore. 1996. Fruit breeding, Vol. I, Tree and tropical fruits. Wiley, New York.

Janzen, D.H. 1979. How to be a fig. Annu. Rev. Ecol. Syst. 10:13–51.

Jayasankar, S., and D.J. Gray. 2003. *In vitro* selection for disease resistance in plants—an alternative to genetic engineering. AgBiotechNet 5, ABN 111.

Jayasankar, S., Z. Li, and D.J. Gray. 2000. *In vitro* selection of *Vitis vinifera* 'Chardonnay' with *Elsinoe ampelina* culture filtrate is accompanied by fungal resistance and enhanced secretion of chitinase. Planta 211:200–208.

Jeong, W.S., and P.A. Lachance. 2001. Phytosterols and fatty acids in fig (*Ficus carica*, var. Mission) fruit and tree components. J. Food Sci. 66:278–281.

John, P. 1993. In Biosynthesis of the major crop products, p. 114–126. Wiley, New York.

Johnson, J.A., K.A. Valero, M.M. Hannel, and R.F. Gill. 2000. Seasonal occurrence of postharvest dried fruit insects and their parasitoids in a culled fig warehouse. J. Econ. Entomol. 93:1380–1390.

Jona, B., and I. Gribaudo. 1991. *Ficus* spp., pp. 76–93. In: Y.P.S. Bajaj (ed.), Biotechnology in agriculture and forestry. Vol. 16, Trees III. Springer-Verlag, Berlin.

Kader, A.A. 2003. A summary of CA requirements and recommendations for fruits other than apples and pears. Acta Hort. 600:737–740.

Kang, H., M.Y. Kang, and K.H. Han. 2000. Identification of natural rubber and characterization of rubber biosynthetic activity in fig tree. Plant Physiol. 123:1133–1142.

Kawamata, M., E. Nishida, H. Ohara, K. Ohkawa, and H. Matsui. 2002a. Changes in the intensity of bud dormancy and internal compositions of current shoot in fig. J. Japan. Soc. Hort. Sci. 71:177–182.

Kawamata, M., H. Ohara, K. Ohkawa, Y. Murata, E. Takahashi, and H. Matsui. 2002b. Double cropping of fig under hydroponic culture. J. Japan. Soc. Hort. Sci. 71:68–73.

Kawase, K. 1990. Properties and utilization of rootstocks for fruit crops Crops, pp. 469–475. Nobunyo, Tokyo.

Kellogg, G.J., C.W. Boone, V.E. Steele, J.R. Fay, R.A. Lubet, J.A. Crowell, and C.C. Sigman. 1994. Mechanistic considerations in chemopreventive drug development. J. Cell. Biochem. Suppl. 20:1.

Khadari, B., C. Grout, S. Santoni, and F. Kjellberg. 2005. Contrasted genetic diversity and differentiation among Mediterranean populations of *Ficus carica* L.: A study using mtDNA RFLP. Genet. Res. Crop Evol. 52:97–109.

Khadari, B., I. Hochu, S. Santoni, and F. Kjellberg. 2001. Identification and characterization of microsatellite loci in the common fig (*Ficus carica* L.) and representative species of the genus *Ficus*. Mol. Ecol. Notes 1:191–193.

Khadari, B., I. Hochu, S. Santoni, A. Oukabli, M. Ater, J.P. Roger, and F. Kjellberg. 2003. Which molecular markers are best suited to identify fig cultivars: A comparison of RAPD, ISSR and microsatellite markers. Acta Hort. 605:69–75.

Khadari, B., P. Lashermes, and F. Kjellberg. 1995. RAPD fingerprints for the identification and genetic characterization of fig (*Ficus carica* L.) genotypes. J. Gen. Breed. 49:77–86.

Khadari, B., A. Oukabli, M. Ater, A. Mamouni, J.P. Roger, and F. Kjellberg. 2004. Molecular characterization of Moroccan fig germplasm using Intersimple Sequence Repeat and Simple Sequence Repeat markers to establish a reference collection. HortSci. 40:29–32.

Kim, J.S., Y.O. Kim, H.J. Ryu, Y.S. Kwak, J.Y. Lee, and H. Kang. 2003. Isolation of stress-related genes of rubber particles and latex in fig tree (*Ficus carica*) and their expressions by abiotic stress or plant hormone treatments. Plant Cell Physiol. 44:412–414.

Kislev, M.E., A. Hartmann, and O. Bar-Yosef. 2006. Early domesticated fig in the Jordan Valley. Science 312:1372–1374.

Kjellberg F., P.H. Gouyon, M. Ibrahim, M. Raymond, and G. Valdeyron. 1987. The stability of the symbiosis between dioecious figs and their pollinators: A study of *Ficus carica* L. and *Blastophaga psenes* L. Evolution 41:693–704.

Kochi, M., S. Takeuchi, T. Mizutani, K. Mochizutki, Y. Matsumoto, and Y. Saito. 1980. Antitumor activity of benzaldehyde. Cancer Treat. Rep. 64:21.

Krezdon, A.H., and S.K. Glasgow. 1970. Propagation of *Ficus carica* on tropical species of Ficus. Proc. Tropical Region Am. Sci. Hort. Sci. 14:156–164.

Kubo, Y., W.O. Owino, X. Liu, K. Hiwasa, R. Nakano, and A. Inaba. 2003. Differential regulation of ripening ethylene biosynthesis in several climacteric fruits, pp. 239–240. In M. Vendrell, H. Klee, J.C. Pech, and F. Romojaro (eds.), Biology and biotechnology of the plant hormone ethylene III. IOS Press, Amsterdam.

Küden, A.B., and E. Tanriver. 1998. Plant genetic resources and selection studies on figs in the east Mediterranean and south east Anatolia regions. Acta Hort. 480:49–54.

Kühnau, J. 1976. The flavonoids. A class of semi-essential food components: their role in human nutrition. World Rev. Nutr. Diet. 24:117–191.

Kutlu, E., and U. Aksoy. 1998. Further evaluation of selected Sarilop (Calimyrna) clones. Acta Hort. 480:265–269.

Lamb, C., and R.A. Dixon. 1997. The oxidative burst in plant disease resistance. Annu. Rev. Plant Physiol. Plant Mol. Biol. 48:251–275.

Leonhardt, W., C. Wawrosch, A. Auer, and B. Kopp. 1998. Monitoring of virus diseases in Austrian grapevine varieties and virus elimination using in vitro thermotherapy. Plant Cell Tissue Organ Cult. 52:71–74.

Lev-Yadun, S., G., Ne'eman., S., Abbo and M.A. Flaishman 2006. Comment on "Early Domesticated Fig in the Jordan Valley". Science 314, 1683; www.sciencemag.org/cgi/content/full/314/5806/1683a.

Lima, L.C., M.S.C. Dias, M.V.de. Castro, R.N. Martins, P.M. Ribeiro-Junior, and E. de B. Silva. 2005. Post-harvest conservation of unripe figs (*Ficus carica* L.) cv. "Roxo de Valinhos" treated with sodium hypochlorite and stored under refrigeration in passive modified atmosphere. (in Portuguese). Ciencia-e-Agrotecnologia 29:810–816.

Lopez Corrales, M., R. Gella, J.A. Marin, and F. Toribio. 1998. Elimination of fig mosaic from fig shoot-tip cultures by thermotherapy. Acta Hort. 480:173–178.

Maas, E.V. 1993. Testing crops for salinity tolerance, pp. 234–236. Proc. Workshop on Adaptation of Plants to Soil Stress, p. 234–247. In: J.W. Maranville, B.V. Baligar, R.R.

Duncan, J.M. Yohe. (eds.) INTSORMIL. Pub. No. 94–2, Univ of Ne, Lincoln, NE, Univ. Nebraska. Intersomil Publ.

MacDonald, S.J., S. Anderson, P. Brereton, and R. Wood. 2003. Determination of ochratoxin A in currants, raisins, sultanas, mixed dried fruit, and dried figs by immunoaffinity column cleanup with liquid chromatography: interlaboratory study. J. AOAC Int. 86:1164–1171.

Mandolino, G., A. Carboni, S. Forapani, V. Faeti, and P. Ranalli. 1999. Identification of markers linked to the male sex in dioecious hemp (*Cannabis sativa* L.). Theor. Appl. Genet. 98:86–92.

Manna, S.K., A. Mukhopadhyay, and B.B. Aggarwa. 2000. Resveratrol suppresses TNF-induced activation of nuclear transcription factors NF-K B, Activator Protein-1, and apoptosis: Potential role of reactive oxygen intermediates and lipid peroxidation. J. Immunol. 164:6509–6519.

Mao, L.C., T.J. Ying, Y.F. Xi, and Y.H. Zhen. 1995. Respiration rate, ethylene production, and cellular leakage of fig fruit following vibrational stress. HortSci. 30:145.

Marei, N., and J.C. Crane. 1971. Growth and respiratory response of fig (*Ficus carica* L. cv. Mission) fruits to ethylene. Plant Physiol. 48:249–254.

Mars, M. 2003. Fig (*Ficus carica* L.) genetic resources and breeding. Acta Hort. 605:19–27.

Mars, M., T. Chebli, and M. Marrakchi. 1998. Multivariate analysis of fig (*Ficus carica* L.) germplasm in southern Tunisia. Acta Hort. 480:75–81.

Matteo, M.di., M. Rapacciuolo, and L. Cinquanta. 1999. Cold storage of figs using semi-permeable plastic film. (in Italian). Informatore-Agrario. 55:35–36.

Mathooko, F.M., T. Sotokawa, Y. Kubo, A. Inaba, and R. Nakamura. 1993. Retention of freshness in fig fruit by CO_2-enriched atmosphere treatment or modified atmosphere packaging under ambient temperature. J. Japan. Soc. Hort. Sci. 62:661–667.

Matsuura, K., K. Tanabe, F. Tamura, and A. Itai. 2001. Distribution of 13C administered to a leaf of a bearing shoot of fig trees during the fruit enlargement and maturation stages at the lower nodes. J. Japan. Soc. Hort. Sci. 70:466–472.

Maucher, A., M. Karger, and E.T. von Angerer. 1993. Evaluation of the antitumour activity of coumarin in prostate cancer models. Cancer Res. Clin. Oncol. 119:150.

Maxie, E.C., and J.C. Crane. 1968. Effect of ethylene on growth and maturation of fig (*Ficus carica* L.) fruit. Proc. Am. Soc. Hort. Sci. 92:255–267.

McClintock, B. 1944. The significance of responses of genome to change. Science 226:792–801.

Melgarejo, P. 1996. La higuera (*Ficus carica* L.). Universidad Politécnica de Valencia. Orihuela, España.

Meyvaci, K.B., F. Sen, U. Aksoy, A. Altindisli, F. Turanli, M. Emekci, and A.G. Ferizli. 2003a. Project to phase out methyl bromide in the dried fig sector in Turkey. Acta Hort. 628:73–81.

Meyvaci, K.B., F. Sen, U. Aksoy, F. Ozdamar, and M. Fakir. 2003b. Research on prolonging the marketing period of dried and ready-to-eat type figs (*Ficus carica*). Acta Hort. 628:439–445.

Michailides, T.J. 2003. Diseases of fig, pp. 253–273. In: R.C. Ploetz (ed.), Diseases of tropical fruit crops. CAB Int. Wallingford, UK.

Michailides, T.J., D.P. Morgan, D. Felts, and M.A. Doster. 2005. Control of decay in caprifigs with fungicides; p. 67. In Third Int. Sym. Fig. 16–20 May, Vilamoura, Portugal.

Michailides, T.J., D.P. Morgan, and K.V. Subbarao. 1996. Fig endosepsis: An old disease still a dilemma for California growers. Plant Dis. 80:828–841.

Miura, Y., K. Kondo, T. Saito, H. Shimada, P.D. Fraser, and N. Misawa. 1998. Production of carotenoids lycopene, β-carotene and astaxanthin in the food yeast *Candida utilis*. Appl. Environ. Microbiol. 64:1226.

Moller, T., and K. Nilsson. 1991. Aflatoxins in fig wine. (in Swedish). Var-Foda. 43:111–113.

Montealegre, J., J. Oyarzun, R. Herrera, H. Berger, and L. Galletti. 2000. Fungi producing postharvest decay on brevas and fig fruits. (in Spanish). Boletin Sanidad Vegetal Plagas 26:439–443.

Morton, J.F. 1987. Fig, pp. 47–50. In Fruits of warm climates. Publ. Creative Resource Systems, Winterville, NC.

Murphy, P.A., S. Hendrich, C. Landgren, and C.M. Bryant. 2006. Food mycotoxins: An update. J. Food Sci. 71:R51–R65.

Muriithi, L.M., T.S. Rangan, and B.H. Waite. 1982. In vitro propagation of fig through shoot tip culture. HortSci. 17:86–87.

Nascimento, L.M., E.M.deC. Nogueira, T. Namekata, and E.M.F. Martins. 1999. Evaluation of ripening and fungal diseases in stored fig fruit under different conditions. (in Portuguese). Arquitos do Inst. Biologico, Sao Paulo. 66:47–51.

Navarro, S., E. Donahaye, M. Rindner, and A. Azrieli. 1998. Storage of dried fruits under controlled atmospheres for quality preservation and control of nitidulid beetles. Acta Hort. 480:221–226.

Neeman, G., and J. Galil. 1978. Seed set in the 'male syconia' of the common fig *Ficus carica* L. (Caprificus). New Phytol. 81:375–380.

Neves, L.C., A.C. Rodrigues, and R.L. Vieites. 2002. Low density polyethylene (LDPE) in postharvest preservation of Roxo de Valinhos figs. (in Portuguese). Rev. Brasileira Fruticultura. 24:57–62.

Nitta, H. 1997. The control of fruit rots in figs. 1. The control of Rhizopus rot and souring improved growing conditions (temperature and humidity), fungicides, and by covering fruit with waxed-paper bags (in Japanese). Bull. Hiroshima Prefectural Agri. Res. Center 65:17–26.

Nitta, H., S. Furui, and J. Ito. 1997. The control of fruit rots in figs. 2. The current situation regarding souring and Rhizopus rot and the cultural control of these diseases (in Japanese). Bull. Hiroshima Prefectural Agri. Res. Center 65:27–34.

Obenauf, G., M. Gerdts, G. Leavitt, and J. Crane. 1978. Commercial dried fig production in California. Univ. Calif. Agr. Ext. Leafl. 21051:30.

O'Brien, T.G., M.F. Kinnaird, E.S. Dierenfeld, N.L. Conklin-Brittain, S.C. Silver, and R.W. Wrangham. 1998. What's so special about figs. Nature 392:668.

Ohri, D., and T.N. Khoshoo. 1987. Nuclear DNA contents in the genus *Ficus* (Moraceae). Plant Syst. Evol. 156:1–4.

Ondogan, E.N., and A. Ural. 1994. Thermophysical properties of the dried figs for freezing, pp. 105–112. In New applications of refrigeration on fruit and vegetable processing. Refrigeration Sci. Technol. Proc. IIF, Istanbul.

Owino, W.O., Y. Manabe, F.M. Mathooko, Y. Kubo, and A. Inaba. 2006. Regulatory mechanisms of ethylene biosynthesis in response to various stimuli during maturation and ripening in fig fruit (*Ficus carica* L.). Plant Physiol. Biochem. 44:335–342.

Owino, W.O., R. Nakano, Y. Kubo, and A. Inaba. 2004. Coordinated expression patterns of genes encoding cell wall modifying enzymes during ripening in distinct anatomical regions of the fig (*Ficus carica* L.) fruit tissue. Postharvest Biol. Tech. 32:253–261.

Ozay, G., and I. Alperden. 1991. Aflatoxin and ochratoxin—a contamination of dried figs (*Ficus carina* L.) from the 1988 crop. Mycotoxin Res. 7:85–91.

Ozay, G., N. Aran, and M. Pala. 1995. Influence of harvesting and drying techniques on microflora and mycotoxin contamination of figs. Nahrung 39:156–165.

Özeker, E., and M. Isfendiyaroglu. 1998. Evaluation of table fig cultivars in Çesme Peninsula. Acta Hort. 480:55–60.

Ozer, K.B., and F. Sen. 2003. Effects of some postharvest treatments on preserving quality of Yediveren fig fruits. Acta Hort. 605:211–218.

Papadopoulou, K., C. Ehaliotis, M. Tourna, P. Kastanis, I. Karydis, and G. Zervakis. 2002. Genetic relatedness among dioecious *Ficus carica* L. cultivars by random amplified polymorphic DNA analysis, and evaluation of agronomic and morphological characters. Genetica 114:183–192.

Papoff, C.M., G. Battacone, M. Agabbio, G.A. Farris, A. Vodret, G. Milella, C. Sotgiu, and F.E. Sanna, A. Piga and S. d'-Aquino. 1998. The influence of industrial dehydration on quality of fig fruits. Acta Hort. 480:233–237.

Park, Y.S., and S.T. Jung. 2000. Effects of CO_2 treatments within polyethylene film bags on fruit quality of fig fruits during storage. J. Korean Soc. Hort. Sci. 41:618–622.

Park, Y.S., B.W. Kim, and S.T. Jung. 1998. Effects of storage temperature and CO_2-enriched atmospheres on the shelf life of fig fruits during storage. J. Korean Soc. Hort. Sci. 39:184–188.

Parrish, R.L., H.P. Koelewijn, and P.J. van Dijk. 2004. Identification of a male-specific AFLP marker in a functionally dioecious fig, *Ficus fulva* Reinw. ex Bl. (Moraceae). Sex Plant Reprod. 17:17–22.

Pasman, W.J., W.H. Saris, and M.A. Wauters. 1977. Effect of one week fibre supplementation and satiety ratings and energy intake. Appetite 29:77.

Pasqual, M., N.M.J. Chalfun, P.M. Norberto, L.F. Dutra, and J.M. Cavalcante-Alves. 2003. Early yielding of unripe figs cv. Roxo de Valinhos. Acta Hort. 605:125–130.

Perez, C., J.R. Canal, J.E. Campillo, A. Romero, and M.D. Torres. 2003. Experimental diabetes treated with *Ficus carica* extract: effect on oxidative stress parameters. Acta. Diabetol. 40:3–8.

Pesis, E. 2005. The role of the anaerobic metabolites, acetaldehyde and ethanol, in fruit ripening, enhancement of fruit quality and fruit deterioration. Postharvest Biol. Tech. 37:1–19.

Piga, A., M. Agabbio, and G.A. Farris. 2003. Dehydration performance of local fig cultivars. Acta Hort. 605:241–245.

Piga, A., S. d'-Aquino, M. Agabbio, and C. Papoff. 1995. Keeping quality of fresh figs by postharvest film wrapping. Italus Hortus 2:3–7.

Piga, A., S. d'-Aquino, M. Agabbio, and C.M. Papoff. 1998. Short-term nitrogen atmosphere exposure extends shelf-life of fresh 'Niedda longa' fig fruits. Acta Hort. 480:295–299.

Piga, A., A. Del Caro, G. Milella, I. Pinna, V. Vacca, and S. Schirru. 2007. HPLC analysis of polyphenols in peel and pulp of fresh figs. Acta Hort. (in press).

Piga, A., A. Del Caro, and I. Pinna. 2005. Osmo-dehydration of fig fruits with five sugars, p. 70. In Third Int. Symp. on Fig. 16–20 May, Vilamoura, Portugal.

Piga, A., I. Pinna, K.B. Ozer, M. Agabbio, and U. Aksoy. 2004. Hot air dehydration of figs (*Ficus carica* L.): Srying kinetics and quality loss. Int. J. Food Sci. Technol. 39:793–799.

Plaza, J.L.de la. 2003. Sulfur dioxide for the long-term storage of fresh figs. Acta Hort. 605:225–228.

Pontikis, C.A., and P. Melas. 1986. Micropropagation of *Ficus carica* L. HortSci. 21:153.

Predieri, S. 2001. Mutation induction and tissue culture in improving fruits. Plant Cell, Tissue Organ Cult. 64:185–210.

Proebsting, E.L., and R. Tate. 1952. Seasonal changes in nitrate content of fig leaves. Proc. Am. Soc. Hort. Sci. 60:7–10.

Proebsting, E.L., and R.M. Warner. 1954. The effect of fertizers on yield, quality and leaf composition of figs. Proc. Am. Soc. Hort. Sci. 63:8–10.

Puebla, M., F. Toribio, and P. Montes. 2003. Determination of fruit bearing pruning date and cutting intensity in "San Pedro" (*Ficus carica* L.) type fig cultivars. Acta Hort. 605:147–157.

Raga, A., M.F. Souza Filho, and M.E. Sato. 2003. Effectiveness of protectants of fig ostiole against the fly *Zaprionus indianus* (Gupta) (Diptera: Drosophilidae) in the field. Arq. Inst. Biol., São Paulo 70:287–289.

Raghupathy, P.R., A.A. Hussain, P.N. Reddy, V.K. Megheri, A. Krishnanand-Gavali, and N.B. Naravani. 1997. Evaluation of tray type bamboo basket solar driers for figs. Karnataka J. Agr. Sci. 10: 420–423.

Raghupathy, P.R., A.A. Hussain, P.N. Reddy, V.K. Megeri, and N.B. Krishnanand-Gavali Narvani. 1998. Evaluation of tray type bamboo basket solar driers for figs. Karnataka J. Agr. Sci. 11:268–269.

Rahemi, M., and H. Zare. 2002. The effects of temperature treatments on the disinfestation and storage of dry figs of Estahban. J. Sci. Technol. Agr. Natural Res. 6:29–41.

Ramirez, W.B. 1974. Coevolution of *Ficus* and Agaonidae. Ann. Missouri Bot. Gard. 61:770–780.

Reichert, N., S. Steinmeyer, and R. Weber. 1988. Determination of aflatoxin B1 in dried figs by visual screeing, thin-layer chromatography and ELISA. (in German). Z. Lebensmittel Untersuchung Forschung. 186:505–508.

Ricci, P. 1972. Studies on the rotting of fresh figs after harvest. (in French). Anna. Phytopath. 4:109–117.

Richter, G., H.P. Schwarz, F. Dorner, and P.L. Turecek. 2002. Activation and inactivation of human factor X by proteases derived from *Ficus carica*. British J. Haematology 119:1042–1051.

Robinson, J. 1999. Ethics and transgenic crops: A review. Elect. J. Biotech. http://ejb.ucv.cl/content/vol2/issue2/full/3.

Rodov, V., B. Horev, G. Goldman, Y. Vinokur, and M.A. Flaishman. 2003. Developing dark figs for export: Trial shipment of figs of 'Brazilian' variety to Europe by sea. (in Hebrew). Alon Hanotea 57:118–122.

Rodov, V., B. Horev, G. Goldman, Y. Vinokur, Z. Yablowich, S. Golubowich, S., and M.A. Flaishman. 2005. Purple fig: Pollination effects on fruit quality and storage potential. (in Hebrew). Alon Hanotea 60:110–112.

Rodov, V., J. Percelan, B. Horev, Y. Vinokur, S. Ben-Yehoshua, Z. Yablowich, and M.A. Flaishman. 2002. Development of dark figs for export: I. Optimal picking criteria for the 'Brazilian' variety. (in Hebrew). Alon-Hanotea 56:372–376.

Rodov, V., E. Pesis, R. Marinianski, J. Peretz, J., and S. Ben-yehoshua. 1998. Effect of modified-atmosphere packaging on the quality of breba figs harvested at two different firmness levels. (in Hebrew). Alon Hanotea 52:258–262.

Rubnov, S., Y. Kashman, R. Rabinovitch, M. Schlesinger, and R. Mechoulam. 2001. Suppressors of cancer cell proliferation from fig (*Ficus carica*) resin: Isolation and structure elucidation. J. Nat. Prod. 64:993–996.

Ruth, I. 1975. Fruits of angiosperms. Gebruger Borntrarger, Berlin.

Ryall, A.L., and W.T. Pentzer. 1982. Handling, transportation and storage of fruits and vegetables. Vol. 2. Fruits and tree nuts, 2nd ed. AVI, Westport, CT.

Sahin, N. 1998. Fig adaptation studies in Western Turkey. Acta Hort. 480:61–73.

Saleeb, W.F., and W. Storey. 1975. The genetics of persistent vs. caducous synconia in fig. HortSci. 10:328.

Saleh, S.M., G.A. Yacout, and M.M. El-Sadek. 1987. Comparative studies on sound and infested dried fig with *Carpoglyphus lactis* (Linne). Alexandria J. Agri. Res. 32:409–418.

Sanada, T., and E. Amano. 1998. Induced mutation in fruit trees, pp. 401–409. In S.M., Jain, D.S. Brar, and B.S. Ahloowalia (eds.), Somaclonal variation and induced mutations in crop improvement. Kluwer Academic Publ., Dordrecht, the Netherlands.

Senyuva, H.Z., J. Gilbert, S. Ozcan, and U. Ulken. 2005. Survey for co-occurrence of ochratoxin A and aflatoxin B1 in dried figs in Turkey by using a single laboratory-validated alkaline extraction method for ochratoxin A. J. Food Prot. 68:1512–1515.

Serraclara, A., F. Hawkins, C. Perez, E. Dominguez, J.E. Campillo, and M.D. Torres. 1998. Hypoglycemic action of an oral fig-leaf decoction in type-I diabetic patients. Diabetes Res. Clin. Pract 39:19–22.

Seylam, A., and H.K. Olmez. 1999. GAP (Southeast Anatolia Project) and drying with solar energy. (in Turkish). Tarm ve Koyisleri Bakanlg Dergisi. 126:55–57.

Shahidi, F., and M. Naczk. 1995. Food phenolics: Sources, chemistry, effects, applications. Technomic, Lancaster, PA.

Sharma, H.C., J.H. Crouch, K.K. Sharma, N. Seetharama, and C.T. Hash. 2002. Applications of biotechnology for crop improvement: Prospects and constraints. Plant Sci. 163:381–395.

Sharman, M., A.L. Patey, D.A. Bloomfield, and J. Gilbert. 1991. Surveillance and control of aflatoxin contamination of dried figs and fig paste imported into the United Kingdom. Food Addit. Contam. Anal. Surveillance. Eval. Control. 8:299–304.

Shigeoka, S., T. Ishikawa, M. Tamoi, Y. Miyagawa, T. Takeda, Y. Yabuta, and K. Yoshimura. 2002. Regulation and function of ascorbate peroxidase isoenzymes. J. Exp. Bot. 53:1305–1319.

Shorey, H.H., L. Ferguson, and D.L. Wood. 1989. Solar heating reduces insect infestations in ripening and drying figs. HortSci. 24:443–445.

Simmons, P., and H.D. Nelson. 1975. Insects on dried fruits. USDA ARS, Handb. 464.

Slavin, J.L. 2006. Figs: Past, present, and future. Nutrition Today 41:180–184.

Smith, E.L., J.R. Kimmel, D.M. Brown, and E.O.P. Thompson. 1955. Isolation and properties of a crystalline mercury derivative of a lysozyme from papaya latex. J. Biol. Chem. 215:67–89.

Solomon, A., S. Golubowicz, Z. Yablowicz, Z. Kerem, and M.A. Flaishman. 2006. Antioxidant activities and anthocyanin content of fresh common fig (*Ficus carica* L.) fruits. J. Agr. Food Chem. 54:7717–7723.

Sozzi, G.O., M.A. Abrajan-Villasenor, G.D. Trinchero, and A.A. Fraschina. 2005. Postharvest response of 'Brown Turkey' figs (*Ficus carica* L.) to the inhibition of ethylene perception. J. Sci. Food Agri. 85:2503–2508.

Spiegel-Roy, P. 1990. Economic and agricultural impact of mutation breeding in fruit trees. Mutation Breed. Rev. 5:1–26.

Stager, L. 1985. The First Fruits of Civilization. pp. 172–188. In J. N. Tubb, (ed.), Palestine in the Bronze and Iron Age: Papers in honour of Olga Tufnell, Inst. Archaeology, London.

Steiner, W.E., R.H. Rieker, and R. Battaglia. 1988. Aflatoxin contamination in dried figs: Distribution and association with fluorescence. J. Agri. Food Chem. 36:88–91.

St Leger, A.S., A.L. Cochrane, and F. Moore. 1979. Factors associated with cardiac mortality in developed countries with particular reference to the consumption of wine. Lancet 12:1017–1020.

Storey, W.B. 1955. Sex inheritance in figs. California Fig Institute. Proc. Annu. Res. Conf. 9:15–17.

Storey, W.B. 1975. Figs, pp. 568–589. In: J. Janick and J. N. Moore (eds.), Advances in fruit breeding. Purdue Univ. Press, West Lafayette, IN.

Storey, W.B. 1976. Fig *Ficus carica* (Moraceae), pp. 205–208. In N. W. Simmonds, (ed.), Evolution of crop plants. Longman, London.

Storey, W.B. 1977. The fig (*Ficus carica* Linnaeus): Its biology, history, culture, and utilization. Riverside, Jurupa Mountains Cultural Center, CA.

Stover, E., and M. Aradhya. 2007. Fig genetic resources and research at the U.S. National Clonal Germplasm Repository in Davis, California. Acta Hort. (in press).

Tapia, R., C. Botti, O. Carrasco, L. Prat, and N. Franck. 2003. The effect of four irrigation rates on growth of six fig cultivars. Acta Hort. 605:113–118.

Toenniessen, G.H., J.C. O'Toole, and J. DeVries. 2003. Advances in plant biotechnology and its adoption in developing countries. Curr. Opin. Plant Biol. 6:191–198.

Togrul, I.T., and D. Pehlivan. 2004. Modelling of thin layer drying kinetics of some fruits under open-air sun drying process. J. Food Eng. 65:413–442.

Tosun, N., and N. Delen. 1998. Minimising of contamination of aflatoxigenic fungi and subsequent aflatoxin development in fig orchards by fungicides. Acta Hort. 480:193–197.

Tous, J., and L. Ferguson. 1996. Mediterranean fruits, pp. 416–430. In J. Janick (ed.), Progress in new crops. ASHS Press, Arlington, VA.

Trainin, T., A. Lipsky, A.A. Levy, and D. Holland. 2004. Prolonged somatic transposition in Citrus: The autonomous Ac transposable element remains active in the Citrus genome for several years. J. Am. Soc. Hort. Sci. 129:95–101.

Tsantili, E., G. Karaiskos, and C. Pontikis. 2003. Storage of fresh figs in low oxygen atmosphere. J. Hort. Sci. Biotech. 78:56–60.

Turk, R. 1989. Effects of harvest time and precooling on fruit quality and cold storage of figs (*F. carica* L. cv. "Bursa Siyahi"). Acta Hort. 258:279–285.

Turk, R, A. Eris, M.H. Ozer, and E. Tuncelli. 1994. Research on the CA storage of fig cv. Bursa Siyahi. Acta Hort. 368:830–839.

Ullman, S.B., G.M. Clark, and K.M. Roan. 1952. The effects of the fraction R-3 of the latex of *Ficus carica* on the tissues of mice bearing spontaneous mammary tumors. Exp. Med. Surg. 10:287–305.

UNEP. 2006. Handbook for the Montreal Protocol on substances that deplete the ozone layer, 7th ed. Ozone Secretariat, UN Environment Programme, Nairobi.

Ural, A. 1997. Processing of dried figs. In Advanced course on fig production, 16–28 June 1997, Ege Univ. Izmir, Turkey.

Valdeyron, G., and D.G. Lloyd. 1979. Sex differences and flowering phenology in the common fig, *Ficus carica* L. Evolution 33:673–685.

Van Harten, A.M. 1998. Mutation breeding: Theory and practical applications. Cambridge Univ. Press, Cambridge.

Van Noort, S. 2004. How fig trees are pollinated—the ultimate challenge. Veld & Flora, March: 13–15.

Vinson, J.A. 1999. The functional food properties of fig. Cereal Foods World 44:82–87.

Vinson, J.A., Y. Hao, and L. Zubik. 1998. Phenol antioxidant quantity and quality in foods: vegetables. J. Agr. Food Chem. 46:3630.

Vinson, J.A., L. Zubik, P. Bose, N. Samman, and J. Proch. 2005. Dried Fruits: Excellent in vitro and in vivo antioxidants. J. Am. College Nutr. 24:44–50.

Visser, T., J.J. Verhaegh, and D. De Vries. 1971. Pre-selection of compact mutants induced by X-ray treatment in apple and pear. Euphytica 20:195–207.

Wang, L., W. Jiang, K. Ma, Z. Ling, and Y. Wang. 2003. The production and research of fig (*Ficus carica* L.) in China. Acta Hort. 605:191–196.

Wani, D.D., and M.H. Thirumalachar. 1973. Control of anthracnose disease of figs by fungicides and antifungal antibiotic aureofungin. Hindustan Antibiotics Bul. 15:79–80.

Waskar, D.P., M.H. Gawade, and S.D. Masalkar. 2003. Processing and storage of fig fruit—a review. J. Maharashtra Agri. Univ. 28:137–141.

Wasim, A., K. Abdul-Qasim, and M. Abdul. 1988. Two triterpenoids from the leaves of *Ficus carica*. Planta Med. 54:481.

Watkins, C.B., and W.B. Miller. 2004. A summary of physiological processes or disorders in fruits, vegetables and ornamental products that are delayed or decreased, increased, or unaffected by application of 1-methylcyclopropene (1-MCP). www.hort.cornell.edu/mcp.

Watson, L., and M.J. Dallwitz. 2004. The families of flowering plants: Descriptions, illustrations, identification, and information retrieval. http://biodiversity.uno.edu/delta (accessed June 2004).

Weiblen, G.D. 2000. Phylogenetic relationships of functionallydiocious Ficus (Moraceae) based on ribosomal DNA sequences and morphology. Am. J. Bot. 87:1342–1357.

Weiblen, G.D. 2002. How to be a fig wasp. Annu. Rev. Entomol. 47:299–330.

Wenk, P., W. Winiger, K. Zurcher, and W. Stutz. 1994. A new proposal for the control of aflatoxins in dried figs (in German). Mitteilungen Gebiete Lebensmitteluntersuchung Hygiene. 85:737–750.

Yablowicz, Z., S. Golobowich, V. Rodov, and M.A. Flaishman. 2005. 'Stavit Hadvash': A new fig cultivar for export. (in Hebrew). Alon Hanotea 59:113–116.

Yablowitz, Z., G. Nir, and A. Erez. 1998. Breba fig production in Israel: regular and pesticide-free systems. Acta Hort. 480:137–141.

Yakushiji, H., N. Mase, and Y. Sato. 2003. Adventitious bud formation and plantlet regeneration from leaves of fig (*Ficus carica* L.). J. Hort. Sci. Biotech. 78:874–878.

Yancheva, S.D., S. Golubowicz, Z. Yablowicz, A. Perl, and M.A. Flaishman. 2005. Efficient *Agrobacterium*-mediated transformation and recovery of transgenic plants from fig (*Ficus carica* L.). Plant Sci. 168:1433–1441.

Yeh, G.Y., D.M. Eisenberg, T.J. Kaptchuk, and R.S. Phillips. 2003. Systematic review of herbs and dietary supplements for glycemic control in diabetes. Diabetes Care 26:1277–1294.

Zang, Y.H., V.S. Distilio, F. Rehman, A. Avery, D. Mulcahy, and R. Kesseli. 1998. Chromosome specific markers and the evolution of dioecy in the genus Silene. Genome 41:141–147.

Zettler, J.L., P.L. Hartsell, D.B. Allred, J.S. Muhareb, J.M. Hurley, and R.F. Gill. 2003. Sorption and insect toxicity of propylene oxide in dried fruits and nuts, pp. 921–924. In Advances in stored product protection. Proc. 8th Int. Working Conference on Stored Product Protection, 22–26 July 2002, York, UK.

Zohary, D., and M. Hopf. 2000. Domestication of plants in the old world. 3rd ed. Oxford Univ. Press, New York.

Zohri, A.A., and K.M. Abdel-Gawad. 1993. Survey of mycoflora and mycotoxins of some dried fruits in Egypt. J. Basic Microbiol. 33:279–288.

Plate 2.1. Grapevine shape training systems using trellising method, in commercial orchards for fresh fig production in Israel (Photo by Z. Yablowitch, Israel). A. 'Kadota' cultivar at spring. Note the winter pruning and new leaf development. B. 'Brown Turkey' cultivar at late summer. Note the fig trees in trellising method grown inside a nethouse.

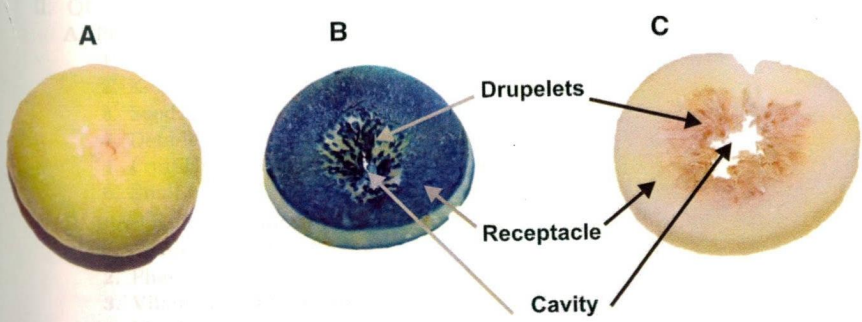

Plate 2.2. Transgenic 'Kadota' fig fruit transformed by the plasmid pME504 that carried the *uid* A-intron, *bar* and *npt* II genes, under the control of constitutive promoters (Photo by S. Golobowitch, Israel). A. Typical transgenic fruit. B. Cross-section of GUS histochemical analysis of 'Kadota' syconium in transgenic fig fruit. C. Cross-section of GUS histochemical analysis of 'Kadota' syconium in non-transgenic fig fruit.