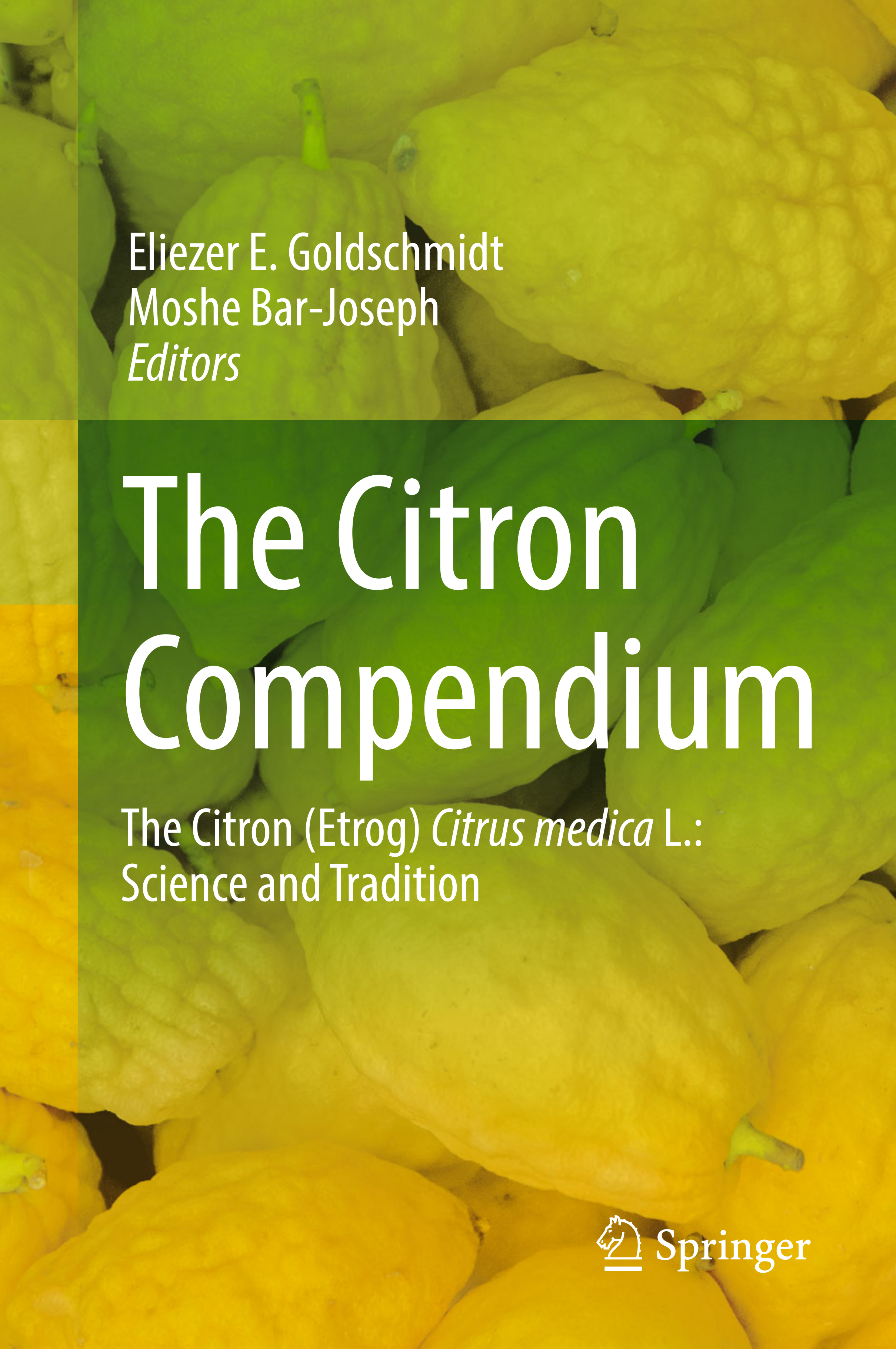

Eliezer E. Goldschmidt
Moshe Bar-Joseph
Editors

The Citron Compendium

The Citron (Etrog) *Citrus medica* L.: Science and Tradition

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Dedicated to
Ian J. Warrington
Emeritus Professor, Massey University,
Palmerston North, New Zealand

With appreciation and gratitude
for his outstanding editorial work
in the preparation of
The Citron Compendium

But the noble-hearted man has noble
purposes, and by these he will be guided
(Jes. 32, 8) BBE

Foreword

The Citron Compendium, co-edited by Eliezer E. Goldschmidt and Moshe Bar-Joseph, is an expanded revision from a Hebrew work published in 2018. It includes twenty-two chapters written by thirty authors covering citron history, cultivation, biology, genetics, diseases, and iconography; it will prove to be a classic compilation of the citron literature. Eliezer E. Goldschmidt is an eminent horticulturist and Hebrew scholar whom I have known for many years. Among his many achievements, he is a world authority on etrog, the Hebrew name for an ancient type of citron. Moshe Bar-Joseph is a world-renowned citrus pathologist specializing in plant virology and experienced in citron propagation for viroid diagnosis.

Citron (*Citrus medica* L.) is a large fragrant fruit with a bumpy rind and thick white albedo that is barely edible, yet it was highly esteemed in antiquity. As the epithet of its scientific name implies, it was deemed to have medical properties and was once considered an antidote for poisons. It was referred to as the Median (Persian) apple by Theophrastus in the fourth century BCE. In Europe, the sugar-infused albedo (candied citron) was a favorite of Christopher Columbus, and the citron was imported to the New World in his second voyage (1493). An unusual form of citron, whose fruit is segmented in fingered sections, and referred to as Buddha's hand, is a popular offering in Buddhist temples.

Citrus is native to Southeast Asia, and there are a number of indigenous species in Australia. *Citrus medica* (citron) along with *C. reticulata* (mandarin) and *C. maxima* (pummelo) are considered foundational species for citrus. The lemon genome derives mostly from citron; rough lemon, a hybrid of citron and mandarin, is a widely used citrus rootstock.

Although etrog is not native to the Middle East, it holds a key position in Jewish history. The citron was introduced to Israel after the return of Judeans from Babylonian captivity (586–516 BCE). The fruit now maintains a featured role in the week-long festival of Sukkot (Tabernacles), celebrated by worship and dining in huts (*sukkot*), commemorating the forty years that the Jewish people spent in the desert on their way to the Promised Land.

Four plants are commanded to be gathered in the celebration. These are defined in Leviticus 23:40 as *Pri etz hadar* (fruit of a goodly tree), *lulav* (palm fronds), *hadas* (myrtle leaves), and *arava* (willow). The fruit of a goodly tree was defined as etrog in the Mishnah, a rabbinical codification of Jewish law written in the third century. It was chosen, perhaps, for its unique appearance and divine fragrance. Etrog is depicted in second-century Bar Kokhba Revolt coins and in the sixth-century Beit Alpha synagogue in Israel.

Later rabbis would insist that the fruits had to be unblemished and borne on a non-grafted tree, undoubtedly derived from the prohibition of mixing species in Jewish law. Furthermore, the presence of a *pitam* (remnants of the stigma and style) was especially esteemed. The difficulties of obtaining these fruits on the appropriate date made the etrog a very expensive fruit in the Diaspora. Thus, the production of these fruits would become a very special horticultural skill for the Jewish market.

The chronicle of the etrog emphasizes the close connection of plants and the human experience. Plants, flowers, and fruits are revered in many cultures and become celebrated in legends, songs, and traditions. Many cultures formed a cultural bond between the plants that sustained them. Olive, wheat, rice, and maize were revered plants incorporated in the symbolism of many religions. Tree worship is ancient, and evergreen trees and wreaths symbolize eternal life in many cultures. Fruits are particularly esteemed. In the United States, the use of a carved pumpkin to make Jack-o'-lanterns in the celebration of Halloween has made pumpkin a symbolic fruit, and millions of homes use them as doorway decorations in the fall.

The unblemished etrog is the symbolic fruit of the Jewish people. *The fruit of the land shall be the pride and honor of the survivors of Israel* (Isa. 4:2).

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Preface

The present volume—*The Citron Compendium*—follows its predecessor, *The Etrog Citron: Tradition and Research*, which appeared in Hebrew.[1] To some extent, it is also a descendant of Tolkowsky's classic, *Hesperides*.[2] However, the present volume is not merely a translation of the Hebrew text; it is in fact an entirely revised and expanded edition. While the Hebrew edition was intended mostly for the traditional Jewish audience, the current volume is internationally and scientifically oriented, having in mind the broader citrus professional community. Led by this vision, we deleted some traditional sections, revised the previous chapters, and added a few new ones in an attempt to provide the most extensive coverage of the citron theme.

The citron (*Citrus medica* L.) is one of the forefathers of the citrus tribe and was probably the first to have reached the Near East and the Mediterranean. The citron fruit received great attention due to its unique appearance, fragrance, presumed medical qualities, and was subject to scientific investigations by classical botanists (Fig. 1).[3]

Over the last millennium, however, as other, juicy citrus varieties became available in Europe, the interest in the citron declined considerably. Thus, although the significance of citron as a citrus forefather was undisputable, attention has shifted mostly towards the etrog citron and its role in the Jewish Tabernacles festival (Sukkot), and its culture which was mainly intended for that religious purpose (with some tangential culinary uses). Presently, very few researchers concern themselves with the citron, with the exception of some viral pathologists, and the broader ramifications of this subject have not been compiled. The present volume is an attempt to fill this void. Bringing a full range of the citron's cultural, scientific, and historic aspects under

[1] Eliezer E. Goldschmidt and Moshe Bar-Joseph, *The Etrog Citron: Tradition and Research—Essays on the Scientific, Halachic and Historical Significance of the Etrog Citron* (Jerusalem: Mossad Harav Kook, 2018).

[2] Samuel Tolkowsky, *Hesperides: A History of the Culture and Use of Citrus Fruits* (London: John Bale, Sons and Curnow).

[3] Giovanni B. Ferrari, *Hesperides, Sive De Malorum Aureorum cultura et usu libri quatuor* (Rome: Hermanni Scheus,1646).

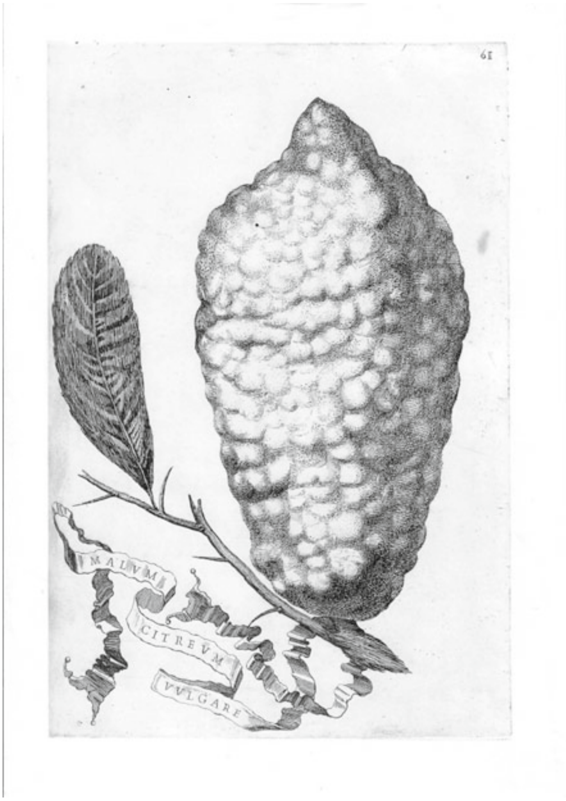

Fig. 1 Picture of citron fruit from the Hesperides of Ferrari (1646). (*Photo* E. E. Goldschmidt)

the same roof has been our dream, and this goal has now been achieved. The best professional experts have joined us for this international operation.

The Etrog Citron: An Appreciation

The etrog citron has become a Jewish symbol as much as the menorah (the seven-branched candelabrum), and has been depicted on coins, mosaics, floor tiles, and wall paintings in ancient synagogues in Israel and the Diaspora (Fig. 2).

Evidence of the great efforts expended by Jews of antiquity in observing the Four Species ritual (Lev. 23:40) is found in the "Four Species Letter" of Bar Kokhba, written on papyrus in 134 CE and discovered by Prof. Yigael Yadin:

To Yehuda bar Menasheh of Kiryat Arbiya (modern-day Arub, south of Jerusalem). I sent you two donkeys so that you can send them with two men to Yonatan bar Baaya and to Masbala, so that they can load palm fronds and etrogs to send to the camp for you. And you should send other people from your camp to bring myrtles and willows,

Fig. 2 Mosaic in the synagogue of Ma'on (Nirim; sixth century), showing two citron fruits on both sides of the sanctuary candelabrum (*Photo* Z. Radovan. The Israel Antiquities Authority)

and arrange them in sets and send them to the camp, because the army is very large. Peace unto you.[4]

Even now, despite the intervening centuries since the suppression of the Bar Kokhba Revolt by the Romans, it is thrillingly clear how much effort the revolt leader and his men expended in order to provide the Four Species and observe the Sukkot holiday, even during the most critical times of the failed revolt.

Jumping from the immemorial past to our time, anyone who wishes to experience the excitement and affection that Jews feel towards the etrog citron should visit one of the Four Species markets that appear prior to Sukkot all over Israel and in centers of Jewish life around the world. There one can see thousands of citron fruits carefully displayed for sale, surrounded by customers from the widest range of socioeconomic and religious backgrounds, all intent on selecting the perfect and most beautiful fruit.

In previous generations, citrons were scarce even in the Land of Israel, and all the more so in the colder countries of the Diaspora. Those fruits that reached the market were so expensive that very few could afford them, and most people could only envy wealthy worshippers with their citrons. In recent years, citrons have again become available throughout Israel and the Diaspora, so that all who wish to purchase a citron can readily do so (Fig. 3).

[4] Yigael Yadin, *Bar Kokhba: The Rediscovery of the Legendary Hero of the Last Jewish Revolt Against Imperial Rome* (Jerusalem: Weidenfeld & Nicolson, 1971).

Fig. 3 Views of the Etrog market toward Sukkot (Collage by Dr. Yoel Fixler)

The Citron Compendium

The present volume with its twenty-two chapters is divided into four sections.

Part I, entitled “Citron Biology,” contains a broad bio-historical and evolutionary analysis of the citron and the citrus tribe, citron phytochemistry, and an up-to-date account of citron genomics.

Part II, entitled “Cultivation and Production,” covers a range of practical aspects of citron culture–horticulture, post-harvest, pests and diseases and, finally, detailed accounts on the history of citron culture in China, Calabria, Corsica, and the United States. A lovely description of the culinary use of citrons in the Mediterranean terminates this section.

Part III, entitled “Tradition,” addresses religious and cultural aspects of the citron–Talmudic and mystic facets, and the significance of the citron in medicine, art, and literature.

Part IV, entitled "History," traces the culture and commerce of citrons from antiquity, through the Middle Ages and up to modern times, paying special attention to the citron grafting controversy.

A pictorial album and a glossary complement this volume. Thus, with help of the Almighty, now we can congratulate the finished.

Finally, on a personal note, this is not our first encounter with the subject. The citron, with all its diverse aspects, has concerned us for many years. We trust that this volume will attract the interest of a wide range of scientists, horticulturists, historians, and intellectuals, and find a place of honor in the libraries of all those interested in the citron and its broader extensions.

Rehovot, Israel — Eliezer E. Goldschmidt
Rishon LeTsiyon, Israel — Moshe Bar-Joseph
May 21, 2023; Sivan 1, 5783

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The production of *The Citron Compendium* would not have been possible without the dedicated help of numerous colleagues and friends, many of whom acted voluntarily. The board of Mossad Harav Kook Publishing House, Jerusalem–R. Yehuda Leib Rafael, R. Natan David Shapira, and R. Yosef Eliyahu Movshovitz–generously permitted the use of chapters from their 2018 Hebrew edition of the book as a basis for the current English edition.

Zuzana Bernhart, our Springer Science Editor, accompanied the development of *The Citrus Compendium* from its earliest beginnings with personal attention and advice. Our senior colleague, Jules Janick, contributed a thoughtful foreword.

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Our colleague and friend, Moshe Huberman, was always there for us with unfailing, fullhearted assistance. Ellen Wachtel assisted in editing parts of the "Diseases" chapter.

R. Yeshaya Kirszenbaum and R. Elimelech Retman generously allowed us to use specimens from their etrog collection for the pictorial album. The photographs were taken by Yoel Fixler, who also designed the Etrog Market collage; Yiphat Kedem arranged the Pictorial Album; and Saar Zini prepared the map of the Mediterranean basin.

Our dedicated authors did not spare any effort in providing an intriguing coverage of their topic. Sadly, our colleague, Haim Aviv, author of Chap. 12, passed away during the preparation of this manuscript. The translators of the Hebrew chapters did their best in clarifying the meaning of the texts.

Shirley Zauer and Ian Warrington, our chapter editors, did a marvelous, endless job in the editing and styling of the entire manuscript.

Thanks are due also to Amudha Vijayarangan, Peggy Papandreou, Ineke Ravesloot and, in particular, Madanagopal Deenadayalan, who bore the major brunt of the publication.

Last but not least, we are ever-grateful to Leah Goldschmidt and Hannah Bar-Joseph, our life partners, who endured with us years of work on this volume and whose unfailing support and advice helped bring us to this point.

Eliezer E. Goldschmidt
Moshe Bar-Joseph

Contents

Part I
Citron Biology

Chapter 1
The Biology of the Citron (*Citrus medica* L., Rutaceae-Aurantioideae-Aurantieae), its Hybrids and their Allies

David J. Mabberley

Abstract The biology of citrus is briefly reviewed, pointing up how surprisingly little is known of pollination and dispersal in wild species. The classification of the citron, *Citrus medica*, in modern science is set out in a historical context: its taxonomic relationships in the light of the evolution of the genus *Citrus* and the citron's role in the origin of major citrus crops as well as the importance of the etrog citron in the traditional Jewish Tabernacles festival are outlined. The global threat to the citron and all other citrus from the bacterial disease, *huanglongbing*, is explained. As an aid to understanding the much-confused citrological literature, the formal taxonomy of the citron is presented in an Appendix, complete with a nomenclatural account of those commercial crops which have citron in their make-up; for example, the Rangpur lime (a rough lemon) is *Citrus* × *otaitensis* (syn. *C.* × *volcameriana, C.* × *jambhiri*).

1.1 Introduction

The etrog is one of the most celebrated examples of the citron (Fig. 1.1), which is a species of *Citrus* (so, for example, one cultivar is written *Citrus medica* L. 'Etrog'; see Appendix)—and citrus-growing is the most important fruit industry of all in warm countries. In 2016, world production of citrus fruit was some 124 million tons, about half of which was oranges (UN Food and Agriculture Organization 2016) well over twice what it had been in the 1980s, though that in Israel had halved over this time and was estimated to be just some 525 thousand tons in 2020. Nonetheless, the Mediterranean region is very close in production to that of each of China and Brazil, the biggest producers—and three times that of USA, where yields have been falling since the 1990s.

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Fig. 1.1 *Citrus medica* (citron). (Reproduced from Henri Louis Duhamel du Monceau, *Traité des arbres et arbustes*, ed. 2, 7: t. 22 (1819))

1.2 The Family Rutaceae

Citrus and its allies form the most "natural" subfamily, subfam. Aurantioideae, of the family Rutaceae, which is found throughout the tropical and other warm parts of the world. The family Rutaceae (Kubitzki 2011; Mabberley 2017; Appelhans et al. 2021) is represented by some 2,000 or so species in about 155 genera especially well represented in the tropics. They are characterised by being aromatic trees and shrubs, rarely herbs. The scents are due to the presence of secretory cavities, which, in the leaves of most species, appear to the naked eye as transparent dots, often a good "field" character for family identification. Their leaves are usually pinnate or trifoliolate, more rarely simple blades, and their fruits are of a wide range of forms from those splitting open to fleshy ones such as berries or drupes.

The aromatic nature of the plants and the fleshy fruits of many are the basis of their interest to humans. Rue (*Ruta graveolens*) is a strongly flavoured herb in the Mediterranean, curry-leaf (*Bergera koenigii*) is an essential in curries in the East, and angostura (*Galipea* spp.) provides the bitters of a pink gin. The essential oils of *Agathosma* spp. from Africa are the source of *buchu* used in medicine and flavouring, while species of *Zanthoxylum* from Asia yield fruits sold as spices, notably *sansho*, one of the few condiments in Japanese cuisine.

Some Rutaceae provide timber such as satinwood (*Chloroxylon swietenia* from southern India and Sri Lanka) and sneezewood (*Ptaeroxylon obliquum* from Africa), but also other commercial timbers from tropical American species of *Amyris*, *Balfourodendron* and *Euxylophora*, besides Australian species of *Bouchardatia*, *Flindersia*, *Geijera* and *Halfordia*. Also from tropical America come the medicinal products known as *jaborandi* (*Pilocarpus* spp.) used in the treatment of glaucoma. Important constituents of commercial scent include extracts from species of *Boronia* (Australia) and, most importantly, *Citrus*.

Many Rutaceae are beautiful ornamentals, notable in northern-hemisphere gardens being the burning bush, *Dictamnus albus,* the Mexican *Choisya* species and hybrids, *Ptelea* spp. from North America, and *Orixa* , *Skimmia* and *Tetradium* spp. from temperate east Asia. Similarly, in the tropics and subtropics widely grown ornamentals include Cape chestnut (*Calodendrum capense*) from Africa, *Correa* spp. from Australia and species of *Atalantia*, *Euodia*, *Melicope*, *Murraya* and *Triphasia* from the Asia–Pacific region.

But, in terms of global commerce, it is the fruits of Rutaceae that are the most significant. Although the *bael* (*Aegle marmelos*), and species of *Clausena* and *Glycosmis* as well as the wood apple (*Limonia acidissima*), all from Asia, and the white sapote (*Casimiroa edulis*) of Mexico, are of local importance, it is only the fruits of *Citrus* that command world attention (Mabberley 2004).

Citrus and its closest allies (Rutaceae–subfam. Aurantioideae–tribe Aurantieae [Citreae]) are characterised by their fruits being berries having pulp derived from multicellular hairs within the ovary, becoming "pulp vesicles" within "segments" of a unique fruit type known as a hesperidium (Fig. 1.2), the rest of the subfamily (tribe Clauseneae) notably *Bergera*, *Clausena* and *Glycosmis* being without such. The name of the tough-coated hesperidium is an allusion to the mythological Golden Apples of the Hesperides (meaning daughters of the evening in Greek), said to lie beyond the Atlas Mountains of North Africa (Hammond and Scullard 1970). The mythological Hesperides sisters (variously three, four or seven), included Aegle and Hesperethusa, commemorated today in rutaceous generic names, the first for the *bael* fruit (*Aegle marmelos*) sacred to Hindus, the second now a synonym of *Naringi* (probably a rendering of the Hindi *nārangī* - see below), both referring to citrus allies. But the original Golden Apples of the Hesperides seem to have been quinces (*Cydonia oblonga*, Rosaceae), though, with the introduction of citrus fruits to the Mediterranean, the name was soon transferred to them.

1.3 The Genus *Citrus*

Citrons, oranges and lemons have been referred to the genus *Citrus* since the time of the eighteenth-century naturalist, Carl Linnaeus, who took up the classical name once used for the sweet-scented timber of *Tetraclinis articulata*, known to the Ancient Greeks as *thyon* and to the Romans as *citrus* (Meiggs 1982; they used *citreum* for what we now call citrus fruits), from the Greek kitros, meaning aromatic. Before Linnaeus's time, the fruits had been known as Aurantia (= gold) in Latin and, possibly then from French "*or*" (gold), comes "*orange*" in Old French, though the Arabic

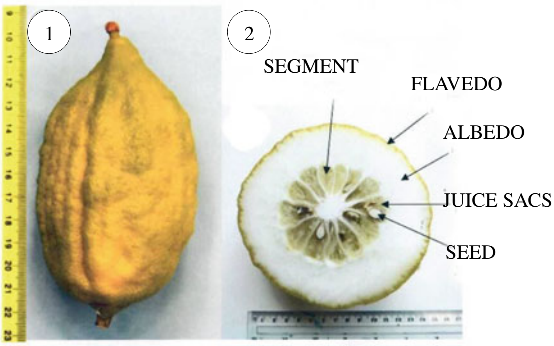

Fig. 1.2 The hesperidium of citron (*Citrus medica* L.)
1. A 'Calabria' etrog citron. Note the persistent style—'pitam', peduncle, bumpy rind, and essential oil glands in pits
2. Cross section of an etrog citron. Note rind components—flavedo and albedo; pulp segments containing juice sacs and seeds

word is *nāranj* from Hindi *nārangī* and Persian *nārang* which seems to be a more plausible origin (Mabberley 2004). Thence has come the name citron (*Citrus medica*), but confusingly the *citron* of France is the lemon (*Citrus* × *limon*), as is the *citroen* of The Netherlands and *Zitrone* of Germany. This is the result of the lemon and citron anciently being considered forms of the same thing and, in early texts, it is often difficult to determine which of the two is meant. It is very interesting to reflect on this, once the origin of the lemons is considered (see below), but Linnaeus in 1753, in face of considerable criticism, made the lemon a variety of the citron in his classification.

The genus *Citrus*, as now understood (Zhang and Mabberley 2008; Kubitzki 2011; Mabberley 2013, 2022; Wearn and Mabberley 2016), comprises as few as 25 tree species growing naturally in the wild from South Australia northwards as far as China and extending east to New Caledonia and west to north-eastern India, but citrus fruits have now been introduced to most of the warm parts of the world, in many of which they have become naturalized so as to appear wild. The genus (Mabberley 1998, 2002, 2017, 2022; Olliltrault et al. 2020; Appelhans et al. 2021) now includes, once more, the formerly segregated genera, *Eremocitrus*, *Fortunella* (kumquats), *Microcitrus* and *Poncirus* (trifoliate orange). Contrary to information presented in books and on the Internet, most of them are not native in China and neighbouring territories, the region with the highest number of indigenous *Citrus* species being Australasa, where some of them are in commerce as "bush-tucker" and are also being hybridized with long established crop cultigens (Mabberley 2013), now apparently a matter of vital importance to the future of the citron (see below).

1.3.1 Morphology, Anatomy and Phytochemistry

Typical of tropical plants, *Citrus* buds are not surrounded with protective scales, but are almost naked (Bartholomew and Reed 1943). The dominance of the apical buds is especially strong in the citron (and the lemon). Lateral buds in the axes of the leaves are usually with the rudiments of a thorn (two in *C. inodora* of tropical Australia), especially in rapidly growing shoots. Because examples are known where in rapidly growing shoots of sweet orange 'Washington Navel' (older name 'Baia') such have borne not only leaves and "secondary" thorns, but also flowers and even fruits, they have been considered homologous with shoots (Shamel and Pomeroy 1918). The thorns are particularly large and tough in juvenile phases, much as in for example *Gleditsia* (Leguminosae; see Janzen and Martin 1982), suggestive of defences against large animals, which in mature trees might also be dispersal agents. The thorns are often a nuisance in orchards, causing injuries to pickers as well as to fruits subsequently infected with disease through punctures.

Bonavia (1888) concluded that the typical citrus leaf is derived from a compound one (Fig. 1.3) and illustrated citrus seedlings showing trifoliolate leaves (1890: t. 246). The apparently simple leaves are therefore unifoliolate, the trifoliolate *C. trifoliata* of China being an intermediate condition to that of the pinnate leaves in many Rutaceae.

With the exception of annually deciduous *Citrus trifoliata* and its hybrids, *Citrus* spp. are evergreen, the leaves persisting for up to two seasons or more (Bartholomew and Reed 1943; Primo-Millo and Agusti 2020). Stomata are produced during the early stages of lamina development and are found only on the abaxial (lower) surface, save a few sometimes on the upper side of the midvein. In lemons they are more numerous than in oranges (Reed 1931) and, in Aurantioideae as a whole, those from more tropical regions have the highest density, up to 500 per square millimetre,

Fig. 1.3 *Citrus* leaves in a reduction series when compared with other Rutaceae; (left to right) *Zanthoxylum simulans*, *Citrus trifoliata, Citrus* × *aurantium* (Sources: *Z. simulans* modified from https://plants.ces.ncsu.edu/plants/zanthoxylum-simulans/, Krzysztof Ziarnek, Kenraiz; *C. trifoliata* modified from https://plants.ces.ncsu.edu/plants/citrus-trifoliata/, Meneeke Bloem; *C.* × *aurantium* Sour Orange Group, Y. Yaniv with permission)

Citrus medica having one of the highest numbers of all, on average 673 per square millimetre (Hirano 1931), while a desert species, *C. glauca* (Australia), has as few as 167, on average.

The fragrance of citron and other citrus leaves and fruits is due to the release of essential oils when the tissues are bruised. The synthesis, secretion and accumulation of these oils are in the oil glands characteristic of the family Rutaceae. In oranges (Thomson et al. 1976), the young glands in leaves comprise a central group of polyhedral cells surrounded by layers of radially flattened ones. The oil chamber forms from the separation of the cell walls of the central ones, which become flattened as it increases in size through the secretion of oil from the central cells. The more-or-less spherical essential oil cavity in citrus fruit peel forms similarly, though formerly believed to be due to the disintegration of cells (Fahn 1974), such lysigenous development releasing the cells' contents into the cavity, but this is now known to be an artefact of specimen preparation techniques, in lemon at least (Turner et al. 1998). The acid oil droplets in juice vesicles of some species of *Citrus* 'subg. *Papeda*' make the fruits inedible to humans.

The biological function of the oil is not fully understood but it is likely to be concerned with deterrence of pests: indeed, the use of citrons and other citrus against the depredations of moths and other insects has long been known and exploited by humans. It is notable that it is only the stamens (Bartholomew and Reed 1943) that are free of the oil glands, such that they are unlikely to deter pollinators, which could damage tissues and release any such oil whilst collecting pollen. Interestingly, the stamens contain high concentrations of caffeine (which has insecticidal qualities), in the anthers and pollen almost as high as in coffee beans (Kretschmar and Baumann 1999). It has been shown that bees rewarded with caffeine are three times as likely to remember a learned floral scent as are those rewarded only with sucrose, so that it has been argued that there is selective advantage for the plant to produce enough caffeine to ensure pollinator fidelity but not enough to be repellent (Wright et al. 2013). Citrus also has the highest nectar concentrations known of the insect neurotransmitters, octopamine and tyramine, which at least in bumblebees interact with caffeine to affect floral preferences and sucrose responsiveness besides long-term memory (Muth et al. 2022). The fact that fruits hang so long on the tree and can be transported over long distances, while remaining "fresh", is testament to the efficacy of the pericarp components in deterring not only insects but also fungi and other pathogens. Insecticidal compounds include naringin used as a bittering agent instead of quinine in tonic water, though only half as bitter (ironically it has been chemically manipulated to a dihydrochalcone 500 times as sweet as sucrose and so related compounds are now being developed as commercial sweeteners in USA (Mabberley 2017).

Citrus oil comprises chiefly hydrocarbons, largely terpenes and sesquiterpenes. The terpene d-limonene makes up the largest proportion of oil in oranges and lemons, but citral is the characteristic one, lemon having many times more than do oranges. The different stereoisomers of limonene are responsible for the different tastes of oranges and lemons, for example. In citron (Bhuiyan et al. 2009) there are 19 components making up 99.9% of the oil in the leaves—eruclamide (28.43%), limonene

(18.36%) and citral (12.95%) being the main ones. The pericarp oil has 43 components making up 99.8%, mainly isolimonene (39.37%), citral (23.12%) and limonene (21.78%). The phytochemistry and pharmacological properties of *Citrus medica* extracts have been reviewed by Panara et al. (2012), who reported that the citron has analgesic, hypoglycaemic, anticholinesterase, anti-cancer, antibiotic, hypocholesterolemic, hypolipidemic, insulin secretagogue, anthelmintic, antimicrobial, anti-ulcer and oestrogenic properties.

1.3.2 Pollination and Dispersal

When mature, a *Citrus* tree can produce more than 200,000 flowers annually—in tropical countries throughout the year, but especially in Spring, as in temperate ones. As few as 0.1%, but usually 1–5%, of the flowers mature as fruits (Agusti and Primo-Millo 2020). Floral initiation in the Mediterranean is promoted by low temperatures and short photoperiod, in the tropics by water stress engendered by seasonal drought (Southwick and Davenport 1986). Indeed, manipulation of water-supply can be used to extend the productive season and therefore commercial viability of lemon plantations (Davis and Albrigo 1994).

The flowers are generally strongly sweet-scented (though apparently scentless in the tropical Australian *C. inodora*), the fragrant oils from those of bitter oranges being the neroli of commerce (petitgrain oil being that extracted from the twigs and leaves). Neroli oil has antibacterial and fungicidal properties (Haj Ammar et al. 2012). The flowers are visited by a wide range of nectar-seeking insects, especially bees, the sought-after nectaries forming a prominent ring around the ovary base (Fahn 1974), though there are few reports of pollination studies in truly wild *Citrus* species. There are stomata with wide apertures on raised portions of the ring; both epidermal and parenchyma cells are capable of nectar secretion, the nectar being secreted into intercellular spaces and exuded by the stomata. Nonetheless, the citron is self-compatible and the flowers are largely cleistogamous, so that modern cultivars have high levels of homozygosity (Wu et al. 2018).

The epidermis of the developing corolla has papillose cells, the papillae being numerous near the apices and margins of the young petals (Ford 1942). The papillae overlap and interlock the petals to form a closed corolla. The opening of the flower is associated with the shrinking and plasmolysis of these papillose cells, while the stigma exudes a viscid secretion from long papillose unicellular epidermal hairs, which traps pollen; the stigma, at least in oranges, is receptive for up to eight days (Bartholomew and Reed 1943). Pollen grains, at least in pomelo, *Citrus maxima* (Banerji 1954), germinate at once and, indeed their viability is short, being reduced to 10% in 24 h and nil in 48 h. Functionally male flowers and those that set no fruit abscise at the base, though often the petals, stamens and pistils sometimes fall before that (Ford 1942). The nectary disc, the calyx and a small part of the flower stalk (pedicel) usually remain on the fruit until it is ripe and together they are known as the "button" of the fruit (Bartholomew and Reed 1943).

In navel oranges, pollination is required before seeds will develop even though those are not the products of cross-fertilization (pseudogamy; see below). The fruit develops from a syncarpous gynoecium with axile placentation (Fahn 1974), the developing fruit differentiating three more-or-less distinct strata of cells. The exocarp (flavedo) comprises small dense collenchyma cells, which contain chromoplasts, with essential oil cavities; the epidermis consists of very small thick-walled cells, on the surface resembling a cobbled effect, these cells containing chromoplasts and oil droplets. The mesocarp (albedo) comprises loosely-connected colourless cells; the endocarp is thin and comprises very elongated, thick-walled cells forming a compact tissue. The stalked spindle-shaped juice vesicles (almost spherical in the Australian *C. australasica* and the Chinese *C. mangshanensis* (Gmitter et al. 2020)), which fill the locules as the fruit ripens, develop from the cells of the inner epidermis and subepidermal layers. Each juice vesicle is covered with a layer of elongated cells, which enclose very large, extremely thin-walled juice-cells.

The vesicles adhere and, with the endocarp, make up a "segment". The epidermis of a vesicle is covered with a thin cuticle, on top of which there are wax secretions which hold the vesicles together in the segment (Fahn et al. 1974). One problem in the canning industry is that this adhesion fails during processing. In *Citrus australasica*, the finger lime of eastern Australia, there appears to be no such adhesion and the individual vesicles burst out of the fruit when it is opened, such that they have been marketed as "citrus caviar" (Hardy et al. 2010).

In many citrus, especially in cultivation, one or more asexually produced embryos, besides sexually generated ones, can develop from the nucellus of the ovule. Being diploid, they are in effect clones of the mother plant. This is usually the cause of polyembryony, where seeds can yield two or more seedlings. At the beginning of the eighteenth century, the Dutch microscopist, Antoni van Leeuwenhoek showed that such citrus seeds often have several embryos, the first time the phenomenon of polyembryony was described (Fig. 1.4). Polyembryony is particularly common in the makrut (the lime-leaves of Thai cooking) or leech lime, *Citrus hystrix,* wild in Malesia but widely cultivated, and the calamondin, *C.* × *microcarpa.* Three to 12 embryos develop from the nucellus alongside the normal one, as was first described by the German cytologist, Edouard Strasburger in 1878 (Maheshawari 1950).

The fruits mature over a long period, those of 'Valencia' oranges (*Citrus* × *aurantium* Sweet Orange Group), for example, taking 12–14 months (Bain 1958) and therefore trees start flowering again before the previous season's fruits are ripe. Bain recognised three phases of fruit development, the first "cell-division" period being of just a few weeks, in which the exocarp develops from the ovary wall, cells differentiate giving the exocarp and mesocarp, while the vesicles are formed in the carpels. The increase in fruit size in this phase is due mainly to the growth of the pericarp. In the second "cell enlargement" phase of around six months the tissues expand due to enlargement of cells, which differentiate, and the exocarp becomes yellow. The increase in fruit size is largely due to the growth of the carpels (segments), which leads to a thinning of the pericarp width. The final "maturation period" phase of over six months has a slowing of growth and anatomical change but the exocarp becomes orange.

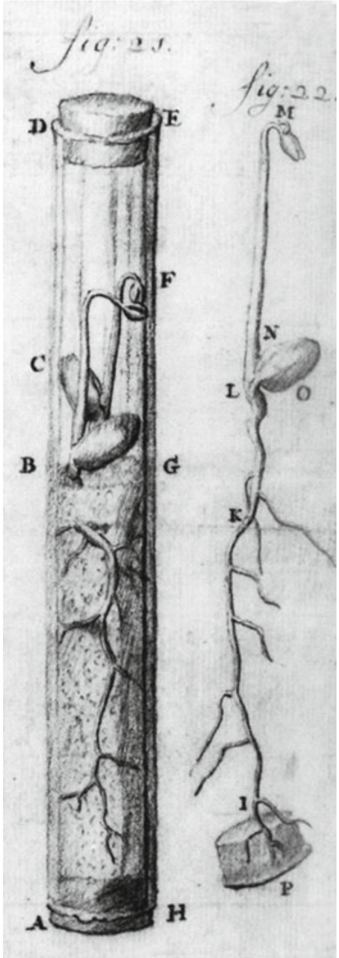

Fig. 1.4 Polyembryonous seed of citrus (left); red chalk drawing sent by Antoni van Leuwenhoek from The Netherlands to the Royal Society of London in [?]1719

The primordia of the all-important juice vesicles, in grapefruit (*Citrus* × *aurantium* Grapefruit Group) at least, are initiated two days before the flowers open, such that the main juice vesicle body is subtended by highly vacuolated stalk-cells attached to the carpel walls (Burns et al. 1992). They begin development immediately after fertilization; the epidermal cells first increase in length and then divide by anticlinal walls, the subepidermal eventually dividing in all planes, resulting in papillate processes extending into the locules (Banerji 1954). Between four and ten weeks after flower-opening, an oil cavity begins to develop and remains in place up to a year in the vesicle's development. These oils give the characteristic tastes to different citrus fruits.

The vesicles in the fruits hold a very large amount of water, up to 92% by weight, and this can be withdrawn to other tissues under stress in dry seasons (Bartholomew and Reed 1943). They also contain vitamins (particularly vitamin C), sugars and acids, principally citric, but also, in at least grapefruit, tartaric, malic and oxalic acids. The large, heavy, watery, long-lived fruits pose questions with regard to their dispersal. The fruits of tachibana in the mandarin complex (*C.* × *tachibana*) are taken by monkeys in Japan (Grimshaw and Bayton 2010) but also float (though killed by seawater) and are possibly spread by river waters as with pomelo (*Citrus maxima*) introduced in Fiji (Ridley 1930), though in Jamaica, citrus are dispersed by birds (Ridley 1930) and, in Madagascar, by lemurs, bush-pigs and humans (Humbert 1950). Indeed, the large, succulent vitamin- and sugar-rich fruits strongly suggest animal dispersal, the smaller species perhaps involving birds, but the very large fruits like the pomelo—and indeed the citron—are, on the whole, enigmatic.

In a similarly large fruit, of a similarly bee-pollinated species, the orchard apple (*Malus domestica*, Rosaceae), the original dispersal agents seem to have been bears, which also feed on the honey made by bees from nectar in the fruit-forests of the Tian Shan in western China (Juniper and Mabberley 2019), where the domestic apple originated. Could it be that bears are also efficacious dispersal agents for the larger-fruited bee-pollinated *Citrus* species? There seems to be little documentation of any such interaction, but a number of videos on the internet show bears very dextrously eating citrus fruits, ripping open the hesperidia with their claws, discarding the bitter pericarp and swallowing the endocarp, complete with the seeds. With different bear species across the range of the genus, perhaps they could be dispersal agents west of Wallace's Line, but what about east of it, for example in New Caledonia where there are no non-flying mammals? But it is also known from such films that elephants too not only relish citrus fruits, but also void apparently viable citrus seeds in their faeces. So, what dispersal syndrome is associated with the thick brightly-coloured pericarp of the citron? And why is that so different from that of its closest ally, *Citrus indica*? What is the ecological significance of the bitterness in citron and pomelo, yet the sweetness of mandarin and kumquat? There is much to be done on the basic natural history of wild citrus, not least citron and its allies.

1.3.3 Phylogeny

Molecular clock studies have led to the conclusion that the minimum age of the family Rutaceae is between late Eocene and late Palaeocene (Pfeil and Crisp 2008) though it could have diverged from other families much earlier (Heads 2012). Pfeil and Crisp give an age of "a maximum of 11.8 Ma" for the genus *Citrus*, when, as Heads argues, this is a minimum on the evidence presented, and their assertion that the progenitors of the eastern species of the genus therefore "must have arrived in New Caledonia by long distance dispersal" is fallacious. Heads uses the geographical breaks in the molecular clades with regional tectonics to argue that the main clades in Rutaceae originated in the Early Cretaceous, with what would be recognised as Rutaceae (but see Mabberley 1984) being even older.

The unravelling of the affinities between *Citrus* and other Aurantioideae genera is well advanced, but there is still resolution needed with respect to the placement of the Asiatic genera *Murraya* and *Merrillia* despite intensive recent DNA work (Bayer et al. 2009; Appelhans et al. 2021). It is remarkable that the largely Asiatic Aurantioideae, with some representatives in mainland Africa, are not native in Madagascar.

1.3.4 Palaeobotany and Archaeological Records

Wood fossils, which were referred to as two species of *Citrusoxylon*, are known from the Eocene of Paris over 41 M years ago (Privé-Gill 1981), while a species of '*Citroxylon*' is from the Miocene (5.3–23 M years ago) of Bavaria. Fossil leaves referred to *Citrus*, though these, like the last, could be referred to a number of allied genera if they were alive today, are known (Fischer and Butzmann 1998) from the Pliocene of Italy (*C. meletensis*), but also allegedly from the Palaeocene/Eocene of Guangdong (China—*C. nigra* ['niger']) and even the Cretaceous (Cenomanian) as well as Eocene of North America and possibly the Oligocene of the Caucasus (*Citrophyllum* spp.). Perhaps the most convincing is the late Miocene leaf fossil *Citrus linczangensis* from Yunnan (Xie et al. 2013). How this overall fossil record relates to the present distribution of modern *Citrus* species is unclear, but it is a common finding that many genera of plants currently restricted to the tropics and the subtropics of south-east Asia are represented by fossils in Europe.

The earliest archaeological evidence of citrus seeds is from the early second millennium BCE of northern India, while citrus wood charcoal of BCE 1400–1300 is claimed for Karnataka in south-west India (Pagnoux et al. 2013). Nothing in the Mediterranean is known before c. BCE 1200 where some mineralized seeds found in Hala Sultan Tekke in Cyprus are claimed to be citrus. More certain is citrus peel as evidenced by polymethoxyflavones (citrus-specific polyphenols) in organic residues in a wine-jug used as an offering for the dead and preserved in a cremation grave of the sixth-century BCE necropolis of Monte Siraï in southern Sardinia. This suggests that Phoenician settlers were responsible for the spread of plants from the eastern to western Mediterranean, as they were in southern Italy in the ninth century BCE, so closely linked with the Cypriot influence with regard to trading iron and associated technology.

Other first-millennium evidence comes from Cuma near Naples, the site of the city of Cumae (Kyme), one of the earliest Greek colonies in Italy. The amount of *Citrus* pollen there is remarkable, bearing in mind that *Citrus* species are insect-pollinated, suggesting that the trees must have been intensively cultivated locally. Pollen is recorded from many other younger sites. By the Roman period there is citrus wood from near Pompeii in which city there are frescoes and mosaics depicting citrus trees (Andrews 1961), even though certainly they were being cultivated by the beginning of the first century CE, and possibly much earlier. However, neither Columella, *De re rustica* (first century CE), nor the earlier Varro in *Res rustica* and Cato in *De agricultura* mention citrus-growing, suggesting it was not widely practised in Italy, though Pliny wrote of the exotic ‘malus Assyria’ and Palladius has ‘citreum’ in his late fourth- or early fifth-century CE *Opus agriculturae* and mentions a ‘citretum’ where the ‘citreum’ were grown under a tegumentum (roof) to protect them from cold. Perhaps this was a proto-orangery.

Moreover, recent investigations (Pagnoux et al. 2013) have revealed mineralised and carbonised citron seeds in the pre-Roman Samnites levels under the Temple of Venus in Pompeii, as well as seeds and peel, perhaps of lemon, in central Rome from c. CE 100. Both finds suggest that citrus fruit was precious and used in sacred ceremonies.

1.4 The Citron, *Citrus medica*

Of the 25 or so wild species of *Citrus* known today (Mabberley 2022), the citron, *Citrus medica,* was the first known to Western science, brought from Asia to the Mediterranean, probably via Persia (Ramón-Laca 2003; Wearn and Mabberley 2016) and is traditionally associated with Alexander the Great’s imperial push into modern-day India.

But in CE 228, at Naukratis (Nikratj, near today’s Kom Gi’eif), a city on the western branch of the Nile, 72 km SE of the later capital of Ptolemaic Egypt, Alexandria, the first and, for much of its early history, the only permanent Greek colony permitted in Egypt, the Greek rhetorician and grammarian (remembered now as the first writer on patents), Athenaeus of Naukratis could write (Needham 1986),

> I am in a position to assure you that Hegesander the Delphian [? post BCE 283-239] nowhere mentions the citron, for I read through the whole of his “memorials” with the express purpose of finding out.

However, Theophrastus (Hort 1916), who effectively wrote up the results of Alexander’s expedition (Stearn 1977), gave a good description about BCE 309.

> And in general the lands of the East and South appear to have peculiar plants, as they have peculiar animals; for instance, Media and Persia have, among many others, that which is called the ‘Median’ or ‘Persian apple’ (citron). This tree has a leaf like and almost identical with that of the andrachne [*Arbutus andrachne*], but it has thorns like those of the pear or white-thorn [*Crataegus* sp.], which however are smooth and very sharp and strong. The ‘apple’ is not eaten, but is very fragrant, as also is the leaf of the tree; and if the ‘apple’ is placed among clothes, it keeps them from being moth-eaten. It is also useful when one has drunk deadly poison; for being given in wine it upsets the stomach and brings up the poison; also for producing sweetness of breath; for, if one boils the inner part of the ‘apple’ in a sauce, or squeezes it into the mouth in some other medium, and then inhales it, it makes the breath sweet.

> The seed is taken from the fruit and sown in spring in carefully tilled beds, and is then watered every fourth or fifth day. And, when it is growing vigorously, it is transplanted, also in spring, to a new soft well-watered place, where the soil is not too fine; for such places it loves. And it bears its ‘apples’ at all seasons; for when it has been gathered, the flower of others is on the tree and it is ripening others…It is also sown, like date-palms, in pots with a hole in them.

Indeed, unlike most citrus grown in the Mediterranean where they flower in spring, the citron is notable for its continuous flowering and fruiting, but also other rain-forest features such as nearly naked buds, making it more susceptible to frost than most citrus (Isaac 1959). By comparison with other *Citrus* species, it is a rather small tree or shrub and has large simple serrate leaves without a winged petiole typical of oranges, with fruits to 30 cm long weighing more than 2 kg. Georg Rumpf in seventeenth-century Ambon, Indonesia (Beekman 2011) described a particularly large-fruited form later to be called *Citrus papaya*, so resembling the large fruits of payaya (*Carica papaya,* Caricaceae), pointing out that.

> its peel is…very good for confections [i.e., "candied peel" as still used today].... One scrapes off the outer greenishness, soaks the rest in water for several days, then it is boiled with sugar….this is mostly done by the Chinese and Europeans.

However, Theophrastus's use of 'melon Persicon' became confused with other things including the peach (Andrews 1961), which confusion survives today in the Latin name for the peach, *Prunus persica*, originally a Chinese plant.

Theophrastus also noted in his *Enquiry into Plants* (Hort 1916),

> And they say that in the citron those flowers which have a kind of distaff [i.e. pistil] growing in the middle are fruitful, but those that have not are sterile

a clear allusion to sex (monoecy) in plants nearly 2000 years before Camerarius (1691) or Bobart, the northern Europeans usually attributed with drawing attention to sex in plants.

Theophrastus called the citron the Apple of the Medes—and Pliny the Elder took this forward in his *Naturalis Historae* (12: 7) of CE 77–79. 'Malus', originally used for the domestic apple, *Malus domestica* (*M. pumila*), was thereby expanded in a kind of carpological classification that now seems faintly absurd (cf. Greene 1983), though perfectly logical then, to take in other fruits as they were introduced from the east, with 'Malus Armenaica' for the apricot (*Prunus armenaica*) and 'M. Persica' for the peach (*P. persica*) for example. 'Malus arantia [sic]' was used for the orange (*Citrus* × *aurantium*), 'M. limonia' for the lemon (*C.* × *limon*) and so, via the great early western botanist, Pietro Andrea Matthioli (his *Commentaries*: 244, 248 (1565)) the Latinized name for the citron, 'Malus medica' came to Gaspard Bauhin (his *Pinax*: 435 (1671)), who was to be quoted by Linnaeus (1753), in whose *Species Plantarum*, the starting-point for today's plant nomenclature—where he coined the binomial *Citrus medica* L., though, bearing in mind its well-known medicinal uses, one cannot rule out some punning wordplay here (Fig. 1.5).

It is likely that citron fruits, brought back from Persia, had been for sale in Greek markets long before Theophrastus's work. The way he wrote suggests that his readers would have been familiar with the fruit, though he seems emphatic that the trees were then only known to him as growing in Persia. Indeed, recent excavations in Israel suggest strongly that the Persians introduced citron to the Holy Land, probably in the fifth century when the Jewish "temple state" was instituted. The Ramat Rahel site (Lipschits et al. 2012) on a hill above modern Jerusalem has revealed a palace from the period of the Persian occupation, complete with an elaborate irrigated garden.

Fig. 1.5 *Citrus medica* ('Malus medica'). (In Mathias de l'Obel, *Plantarum seu Stirpium Icones* 1581)

From the linings of the watercourses, replastered through time so capturing the pollen rain of the period, it has been possible to identify what plants were being cultivated there. Besides figs and grapes and olives, widely grown species also not indigenous to the region, also found in one of the layers, dated to the Persian period (the 400s BCE), were local fruit trees, ornamentals, and imported trees, including other exotic species such as walnuts and citrons. Perhaps these exotics were imported from remote parts of the Persian Empire by the ruling elite to show off their power. Indeed, it seems reasonable to suppose that efforts would have been made to grow the citron, then greatly admired and valued for its fruit as a drug and scent, besides being placed amongst clothes as an effective deterrent to moths and other insects. It would seem likely that the cultural significance of the etrog citron at that time led to its becoming a crucial feature of the Jewish Tabernacles festival, as obtains right up until today.

By the time of Virgil (c. BCE 30) citrons were growing in Italy (Fairclough 1960) "with it the Mede treats his noisome breath, and cures the asthma of the old") and commonplace by the time Pedanius Dioskorides (c. CE 40–90), Greek physician and botanist of Anazarbus (later Caesarea, today's Anavarza in southern Turkey) was writing (CE 15):

> Those which are called Median, Persian, or cedromela and in the Latin citria, are known to all for it is a tree that bears fruit throughout the whole year one under another. The fruit itself is somewhat long, wrinkled, resembling gold in colour, smelling sweet with heaviness, with seed similar to a pear. Taken as a drink in wine it is able to resist poisons and subducere [to draw off] bowels. A decoction or the juice is a mouth rinse for sweet breath. It is especially eaten by women [as a remedy] against their lusting [anaphrodisiac]. The leaves are thought to preserve cloths from being motheaten if they are put into the chests where the cloths are.

Despite all this ancient knowledge, it is still unclear where the citron grows wild, as it has been transported widely—as far south as Indonesia in pre-European times for example. In CE 284 a consignment of citrons from the Roman Empire to China is held to indicate that it was not native in China (Swingle 1943) but material collected in Guangxi had been named *C. kwangsiensis* in 1931 (Zhang and Mabberley 2008). Although Swingle posited that the citron might be native in Arabia, it is most often said to be native in India, but Bonavia (1888) wrote,

> I am still in doubt whether it is indigenous in India. It does not appear to have any ancient Sanskrit name and the number of varieties, if they are variations, on the western sea-coast [of India] is suggestive. It is curious that they should be found in the area which came into most contact with foreigners.

Besides the 'wild type' there are a number of cultivars, some, like 'Etrog', formally named, some resembling a berry affected by bud mites being introduced to China by the eighth century CE (Needham 1986), where they are still used to scent rooms and flavour sweets and tea (Valder 1999). In the West these are sold by florists as Buddha's Hand (see Appendix) (Fig. 1.6).

1.5 *Citrus* Classification

The most comprehensive account of the group (now 80 years old with minor revisions since) is Swingle's account in Webber and Batchelor's *The Citrus Industry* (1943). In it a lot of progress was made in that the hordes of apomictic clonal lines of cultivated plants formally afforded species rank were re-amalgamated in a smaller number of

Fig. 1.6 *Citrus medica* a Fingered Group cultivar (From B. Hoola van Nooten, *Fleurs, Fruits et Feuillages Choisis de la Flore et de la Pomone de L'Île de Java Fleurs, Fruits et Feuillages Choisis de la Flore et de la Pomone de L'Île de Java* (1863))

species. However, the arrangement of them and the lack of understanding that almost all the commercial citrus are of complex hybrid ancestry means that the account is fatally flawed. More than this, several species now known to be true *Citrus* were segregated in separate genera, so that when artificial hybrids were raised between such plants they were given unwieldy hybrid genera names like × *Citrofortunella* and × *Citroncirus*.

Mabberley (1998, 2002) showed, largely from classical morphological studies, that the then recognised genera *Fortunella*, *Eremocitrus*, *Microcitrus* and *Poncirus* belong in *Citrus* itself, as had largely been proposed by Burkill (1930), leading to the demise of the hybrid genera concept. This was supported by the chloroplast DNA work of Bayer et al. (2009), who showed that *Eremocitrus* and *Microcitrus*, from Australia and nearby, with *Clymenia* and *Oxanthera* from Papuasia to New Caledonia, were not only part of *Citrus* but also very closely related to *Citrus medica*. This relationship, despite the geographical incongruity, has been recovered in many analyses published since, most notably Carbonell-Caballero et al. (2015), who reviewed previous molecular phylogenetic work within the genus. As *Citrus medica* is the type species of the genus, this largely "eastern" group makes up subg. (or sect.) *Citrus* (syn. subg. *Microcitrus*), one of the major clades recovered in the genus as now redefined, the other, a "western" one including the rest of commercial citrus including, mandarin, kumquat and their allies (which can be further subdivided into subg. *Papeda* and subg. *Fortunella*, with *C. trifoliata* in the monospecific subg. *Pseudaegle*). As there is such rampant hybridization in this small genus (Mabberley 2021), any infrageneric classification is likely otiose (as well as confusing, bearing in mind the use of such infrageneric names in the past).

Heads (2012) argued that the eastern species of citrus need not necessarily be the result of a long-distance dispersal event from India (with no surviving species between there and New Guinea) but could reflect a sequence of differentiation in an ancestral taxon that was formerly more widespread in the region. The biogeographic breaks in the current distribution coincide with the tectonic boundaries involving the accretion of India in the Eocene, the extrusion of Indochina from Asia and rifting in the western Pacific.

In molecular analyses (Fig. 1.7), *Citrus medica* always comes closest to *C. indica*, an apparently truly wild plant in north-eastern India (Fig. 1.8). First known to the west through the collection made on 15 August 1850 by Joseph Hooker (1817–1911), who was on a major collecting expedition in India for Kew Gardens, and Thomas Thomson (1817–1878), a fellow-student and friend at Glasgow University (Desmond 1999). Thomson had been an assistant surgeon in the East India Company but had been captured in the Afghan War when "taken to Bokhara to be sold into slavery", but survived to return to the army. He took leave to botanise with Hooker, their leaving together from Darjeeling on 1 May 1850, transferring to elephants at the foot of the Khasi Hills, Hooker (1854) writing about their base-camp,

> We returned on the 7th of August to Churra [i.e., Sohra = today's Cherrapunji], where we spent the rest of the month in collecting and studying the plants of the neighbourhood. We hired a large and good bungalow, in which three immense coal fires were kept up for drying plants and papers, and fifteen men were always employed, some in changing, some in collecting, morning to night…. Torrents of rain descended almost daily, twelve inches in as many hours being frequently registered.

Indeed, Cherrapunji is the wettest place on earth in terms of maximum monthly and annual precipitation (26,461 mm in 1860–1, according to *Guinness World Records*).

Citrus indica populations in the Nokrek Biosphere Reserve in the Garo Hills, also in Meghalaya of north-eastern India, have much smaller fruits than, but are similar in many ways to, citrons. Can it be that this wild plant resembles the original citron from which all its modern forms have been derived? Whatever its true origin and distribution, *Citrus medica* is a major contributor to the modern citrus industry in providing the acid component.

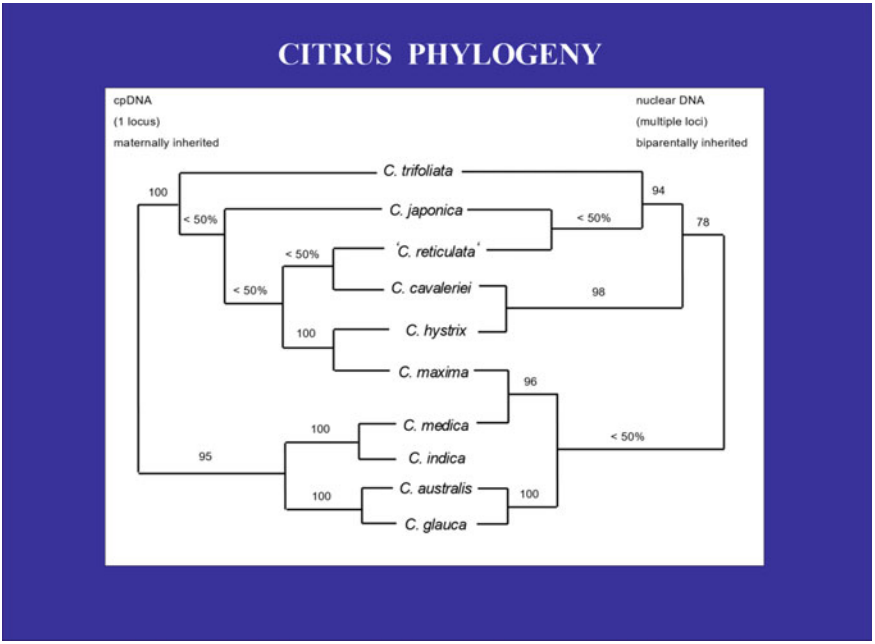

Fig. 1.7 Combined plastid and nuclear gene trees of some *Citrus* species (modified from Bayer et al. (2009) and García-Lor et al. (2013))

1.6 The Role of *Citrus medica* in Other Citrus Crops

Only long after the introduction of the citron did oranges and lemons, limes, mandarins and kumquats, makrut (or leech-) limes and others appear in the Mediterranean from further east in Asia. Lemons, limes, pomelos and sour oranges were introduced by the Muslims via the Iberian Peninsula and Sicily, sweet orange and mandarin only later, between the fifteenth and nineteenth centuries, particularly through trade with Portugal's and Britain's Asian colonies (Ramón-Laca 2003).

But it has become clear that there is no such thing as an orange, lemon or lime species in the wild. So, what are the origins of these cultigens? A ground-breaking paper by Scora (1975) revealed from phytochemical studies that they were very likely hybrids between truly wild species. The fact is that humans have been associated with citrus plants for a very long time and that in bringing wild species and selected forms of them together from outside their natural ranges, hybrids have arisen. All *Citrus* have 2n = 18, though some cultivated forms have 27 and 36: there are no known wild polyploids. But diploid hybrids are readily raised and, because seeds can be set through apomixis, that is without a fertilisation, embryos arising from the diploid nucellar tissue, desirable forms can readily be propagated.

Hybridization and apomixis have led to the taxonomic havoc in the genus, besides given rise to the modern commercial crops of the global citrus industry, notably

Fig. 1.8 *Citrus indica*, Garo Hills, Megahalaya, India. (Photo D.J. Mabberley)

involving the true wild mandarin (‘*C. reticulata’*—see Mabberley and Kodela 2015; Mabberley 2017; Wu et al. 2018; Mabberley and Xu 2022) of ancient China, and the pomelo, which may have been wild in tropical south-east Asia. Until humans started moving these crop-plants around, it would appear that they were largely geographically isolated, though they are largely interfertile.

The effect of bringing them together and the pollinating activities of bees and other insects led to the origin of many interspecific hybrids, the earliest perhaps being mandarin-pomelo crosses which have given rise to the *C.* × *aurantium* complex, comprising all the oranges—both sour and sweet, the grapefruit, tangelos, ortaniques etc. and most of the commercial tangerines and mandarins, which are not the unadulterated wild mandarin of China and Japan (Mabberley 1997, 2017; Mabberley and Kodela 2015; Wu et al. 2018; Mabberley and Xu 2022). Further hybrids include the calamondin or calamansi, *Citrus* × *microcarpa*, which is a cross between the mandarin and the kumquat, *C. japonica*, which, despite its Latin name, is native in China (as are many plants with this epithet as they first came to the notice of Western botanists from examples cultivated in the gardens of Japan).

Almost inevitably the citron became involved in this gigantic and probably completely unintentional hybridization program: it seems always to be the pollen parent. It is now believed that lemons arose as crosses between *C.* × *aurantium* and the citron, such that the lemon has the “blood” of three *Citrus* species. Different crosses and back-crosses in this complex gave the bergamot, sweet lemons and so on. In contrast, the so-called bush lemon (or Rangpur lime), *C.* × *otaitensis* (see Appendix), is apparently a direct cross between the citron and the true mandarin.

The culinary lime, *Citrus* × *aurantiifolia*, would appear to be a cross between the lemon and *C. hystrix* of the Malay Archipelago, though the seedless Tahitian lime (*C.* × *latifolia*—see Fig. 1.9) is apparently a triploid cross between the original lime and the lemon, therefore having the “blood” of four species: the citron, the pomelo, the mandarin and the makrut (or leech-) lime, the citron providing a “double dose” via both parental hybrids.

In modern times deliberate crosses have been made with other species leading to the hypothesized complicated arrangement shown in Fig. 1.10 (modified from Mabberley 2004).

Citrons

Citrus medica L., *Sp. Pl.* **2**: 782 (1753)

Shrubs or small trees. Branches, leaf buds purplish when young. Branches with ca. 4 cm spines. Leaves simple or rarely 1-foliolate, without a basal articulate part of leaflet; petiole short; leaf blade elliptic to ovate-elliptic, 6–12 × 3–6 cm or larger, margin serrate, apex rounded, obtuse, or rarely mucronate. Inflorescences axillary, racemes, ca. 12-flowered, or sometimes flowers solitary, purplish in bud. Flower bisexual or sometimes male by ± complete abortion of the pistil. Petals 5, 1.5–2 cm, pinkish without. Stamens 30–50 (–60). Ovary

Fig. 1.9 'Oranger d'Otaiti' from Risso & Poiteau, *Histoire naturelle des orangers* t. 27 (1819)—lectotype of *Citrus* × *otaitensis* (see Appendix) (*Source* https://gallica.bnf.fr/ark:/12148/bpt6k1512210b/f129.item.zoom)

cylindric, 10–15-locular. Style long and thick; stigma clavate. Fruit oblong or oval, pericarp pale yellow, bumpy to rarely smooth, stripped off with difficulty, fragrant, white or pale yellow and soft within; segments 10–15; sarcocarp colourless, nearly pellucid or pale milky yellow, crisp, acidic or slightly sweet; seeds numerous 9–10 × 4–5 × 3–4 mm, pointed at base, smooth; embryo white. $2n = 18, 20$

Perhaps native in NE India and possibly SW China and/or Myanmar, but original distribution obscured by wide cultivation. See Appendix for full synonymy.

There are many cultivars (one including 'Etrog' [*Citrus medica* var. *conifera* Michel, *C. medica* var. *ethrog* Engl.], an etrog) and cultivar groups to which some of the botanical varietal names in the Appendix (and others published by Risso and subsequent authors) may be assignable

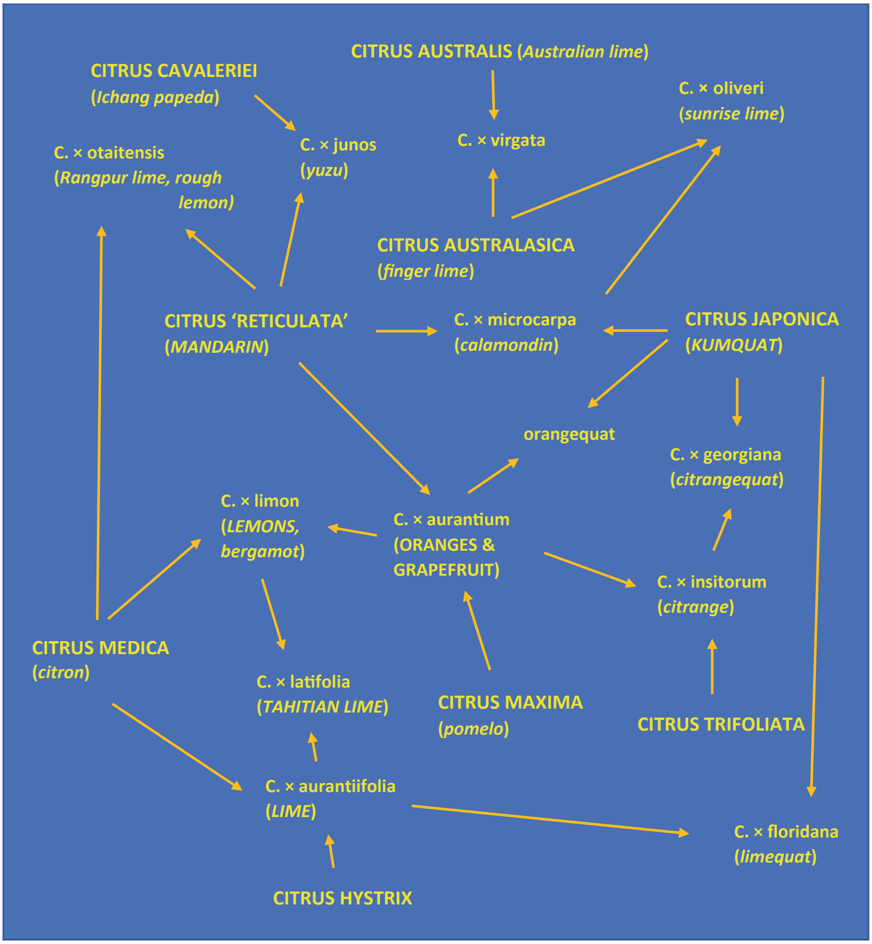

Fig. 1.10 Putative relationship between presumed wild species (in CAPITALS) and commercial cultigens (principal ones in italic *CAPITALS*) through hybridisation (modified from Mabberley 2004)

Commercial Citrus with Citron Parentage Grown in the Mediterranean

Citrus medica is the male parent of many citrus cultigens (see Fig. 1.10), of which the principal seen in the Mediterranean are:

1. ***Citrus* × *aurantiifolia* —(key) limes**
   Hybrids between *Citrus medica* and *C. hystrix* DC. (Zhang and Mabberley 2008; Ollitrault et al. 2020).

There are several cultivars, many best accommodated in cultivar groups, to which some of the botanical varietal names in the Appendix (and others published by Risso and subsequent authors) may be assignable.
N.B. Some 'lumias' often included here may be *Citrus medica* × *C. maxima* (pomelo).

2. ***Citrus* × *floridana* —limequats**

Hybrids between *Citrus* × *aurantiifolia* (*C. medica* × *C. hystrix*) and *C. japonica* Thunb. (kumquat from southern China). For discussion on the synthesis of limequats in F.W. Savage's citrus grove in Eustis, Florida, USA, in 1909, see Swingle and Robinson (1923).

3. ***Citrus* × *latifolia* —Persian or Tahitian (seedless) lime (a 'lemonime'**; cf. Swingle 1943).

A sterile triploid hybrid between *C.* × *aurantiifolia* (*C. medica* × *C. hystrix*) and *C.* × *limon* (*C.* × *aurantium* [*C. maxima* × '*C. reticulata'*] × *C. medica*) (cf. Ollitrault et al. 2020).

4. ***Citrus* × *limon* —lemons**

The parents of the lemon are *Citrus* × *aurantium* (*C. maxima* × 'C. *reticulata'*) and *C. medica*, where backcrosses with either parent give a range of sour to sweet lemons, which go under various names (some listed in Appendix) and are best referred to as cultivar groups, such as the Bergamot Group (Zhang and Mabberley 2008).

5. ***Citrus* × *otaitensis* —rough lemons (including Rangpur lime)**

Hybrids between '*Citrus reticulata*' (mandarin) and *C. medica* (Bayer et al. 2009; Olitrault et al. 2020).
This well-known hybrid was introduced to France in about 1812, but was reported as being grown in England by 1805 under the name 'Citrus limetta sinensis' (Lémon 1829) and was later known as *C. sinensis* (auctt.; see Rev. Hort. 76:80 + t. 31 (1904), non (L.) Osbeck = *C.* × *aurantium* L. Sweet Orange Group), though very often the name '*Citrus sinensis*' used for cultivated plants in Europe (e.g. Pers., Syn. Pl. 2:74 [1806]; Risso, Fl. Nice:82 [1844]) referred to the chinotto (i.e., from China, also formerly known as *Citrus* × *vulgaris* var. *chinensis* Risso and *C.* × *bigaradia* var. *sinensis* Michel).
Of 'chinottos' the one usually seen today in the Mediterranean is *C.* × *aurantium* 'Myrtifolia' (*Citrus* × *vulgaris* var. *myrtifolia* Risso, *C.* × *bigaradia* var. *myrtifolia* Michel,[1] *C. × *myrtifolia* Reider, Ann. Blum. 1: 34 + t. [1825, 'myrthifolia'; corr. Reider op. cit. 5: 170, 1829], *pro sp.*, *C.* × *sinensis* var. *myrtifolia* Risso.

Fig. 1.11 Volkamer lemon (a rough lemon) from Risso and Poiteau, *Histoire naturelle des orangers* t. 40 (1819) – lectotype of *C.* × *volcameriana* (see Appendix). (*Source* https://gallica.bnf.fr/ark:/12148/bpt6k1512210b/f129.item.zoom)

The illustration and description published by Risso and Poiteau (Fig. 1.11) match the Rangpur lime (a rough lemon), sometimes referred to as *Citrus* × *jambhiri*, 'C. limonia' or C. × *volcameriana.*

The Florentine citrons (actually cultivars of C. × *limon*) have also contributed to the non-sexual "graft-hybrid" or chimaera, the "bizzar(r)ia" noticed first in Firenze in 1644 (?1630) by a gardener at the Villa Torre degli Agli, now in the western suburbs of the city, a house that belonged to the wealthy Panciatichi banking family (Fig. 1.12). It was perhaps the first recorded plant chimaera. As with another famous

[1] * = Addition to POWO/IPNI and other databases.

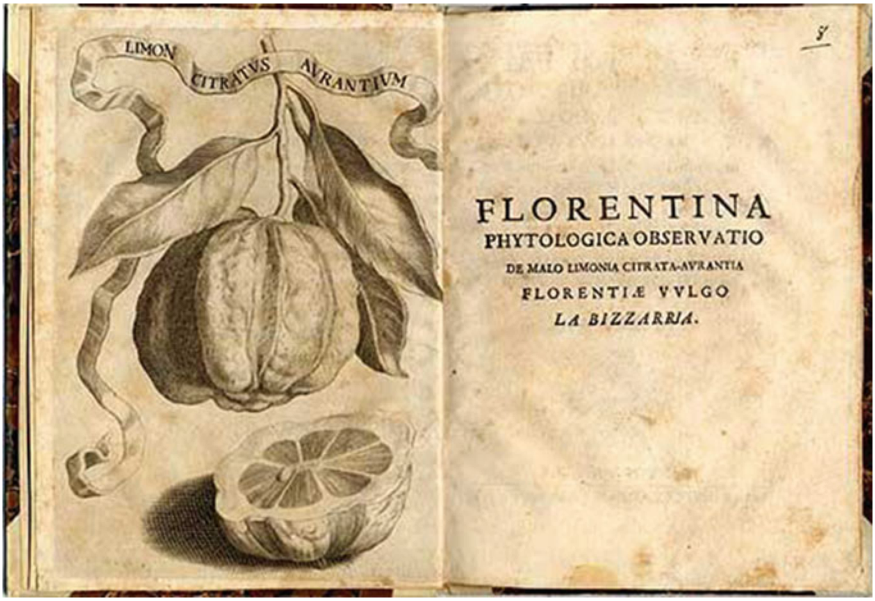

Fig. 1.12 Graft-chimaera, *Citrus* 'Bizzarria', derived from a Florentine citron (scion) and bitter orange (stock). (From P. Nati (1674), *Florentina phytologica obseruatio de malo limonaia citrata-aurantia Florentiae vulgo la bizzarria*, Florence)

graft-hybrid, +*Laburnocytisus adami* (Leguminosae) derived in 1826 from a graft of *Cytisus purpureus* on a laburnum (*Laburnum anagyroides*), a chimaera where the epidermis is from the broom, the rest the laburnum, though sometimes pure laburnum (rarely broom) shoots develop (Mabberley 2017), the bizzaria arose by accident from an old Florentine citron grafted on a sour orange (Nati 1929). The graft seems to have failed, but some tissue of the Florentine citron scion became enveloped by that of the orange. Like the +*Laburnocytisus* then, it is a periclinal chimaera. In 1986 a similar chimaera, *Citrus* (+*Citroponcirus*) 'Hormish', was described where a frost-damaged graft in China led to a similar graft chimaera between a form of '*Citrus reticulata*' grafted on a *C. trifoliata* stock. Other such Chinese chimaeras involving different combinations of grafted citrus have been recorded since.

1.7 Huanglongbing and the Future of the Citron

The importance of understanding the reproductive history of commercial citrus is that, given the close-knit interbreeding group that makes up the genus besides the clonal nature of most of these crop plants, many with *Citrus medica* in their parentage, much of the industry is reliant on a very narrow genetic base. It is therefore very important to work out where the parental species are in wild populations and to maintain the variation there, because a narrow genetic base lays open crop-plants—and the industry and economy based on them—to serious danger (Mabberley 2021). But the threat to the citrus industry and the citron today is not just this. Recently an American website declared:

> Citrus greening disease, also known as Huanglongbing (HLB) is one of the most severe plant diseases in the world. It can affect any variety of citrus trees. Once a tree is infected with the disease, there is no known cure. Although the disease is not harmful to humans, fruits from infected trees are not suitable for consumption because of their green color, misshapen appearance and bitter taste. The disease has devastated millions of citrus trees in the United States
>
> Save Our Citrus website (www.saveourcitrus.org)

Huanglongbing, a Chinese name, meaning yellow shoot disease, is the official name for the disease. It refers to the colour of infected foliage, while, “citrus greening”, the name sometimes still used in America, Africa and more widely in the West, refers to the fact that the fruits of infected plants remain green and are unsaleable. The symptoms of huanglongbing include a blotchy mottling of the leaves and mis-shapen fruits of poor colour and worse flavour, being salty and bitter. Where this bacterial disease is prevalent, citrus trees may not live more than four years and those surviving for five to eight may never bear marketable fruits. Sweet oranges generally have the severest symptoms, while certain commercial mandarins such as ‘Kinnow’ are more tolerant.

The bacteria are spread by psyllids, which feed on the phloem, and multiply in the psyllid body. In feeding, the psyllids inject bacteria into the plant, where the bacteria also multiply and fill the phloem such that materials cannot pass from the leaves to the rest of the plant. Infection can follow as little as 15 minutes’ feeding time, and 100% infection can take place after as little as an hour’s feeding. The disease is spread not only by psyllids but also by marcotting (air-layering), and grafting using infected scions, major sources of infection in Asia. In China, trees propagated in this way decline within three years of planting and provide commercial yields for just one. Because plants have a system of diverting materials around diseased or damaged area until the last few working sieve-tubes cease functioning, the citrus tree can look reasonably healthy. This latent phase can last several years, during which time the tree can, of course, act as a source of bacteria to be spread to yet other plants.

The most widespread vector, the Asiatic citrus psyllid, is now a worldwide pest of citrus. It has been recorded from even the most isolated of all archipelagos, Hawaii. It has a wide range of hosts in Rutaceae, including *Bergera koenigii*, the curry-leaf of Asian cuisine. The adult insects are only three to four millimetres long and can occur in large numbers on the undersides of citrus leaves, being most active as the trees produce new growth. The eggs are laid on the growing shoot-tips; a single female can lay more than 800 in her lifetime. The whole lifecycle can be got through in as little as 15 days in Florida, where there are nine or ten generations a year.

In the host plants, the bacterium (‘*Candidatus* Liberibacter’) is confined to the phloem, different forms of the bacterium being found naturally in different parts of the world—'asiaticus' (*C*Las) in Asia and the cause of the worldwide catastrophe, 'africanus' in Africa (spread by the indigenous African citrus psyllid) and 'americanus' discovered in Brazil in 2004; other forms include 'capensis' found in *Calodendrum capense* (Rutaceae) and 'solanacearum' in potato (Solanaceae). Although huanglongbing was long-considered to have originated in China, it seems highly unlikely that this is the case. The very fact that there is no resistance in edible Chinese species of *Citrus* suggests it has jumped from another kind of plant altogether. According to Nelson et al. (2013), the bacteria associated with huanglongbing originated in Gondwanan Africa in association with indigenous trees in the family Rutaceae and speciated in Africa and on the Indian plate after the break-up of Gondwana.

*C*Laf evolved in Africa to be associated with the African citrus psyllid (*Trioza erytreae*) and Rutaceae such as species of *Calodendrum*, *Teclea*, *Vepris* and *Zanthoxylum* (Nelson et al. 2013). The Asian citrus psyllid would appear to have originated in India, with perhaps *Bergera koenigii* as its original host, though Asian species of *Clausena* are also hosts (Beattie 2020a), and spread almost worldwide from there since the 1800s. Its dispersal to south-east Asia in the nineteenth century (but first recorded in mainland China only in 1934—Beattie 2020b) to the Americas in the 1900s and to Africa in the 2010s (see Ajene et al. 2020). The spread of *C*Las means that the most severe form of the disease now occurs in the Americas besides throughout much of subtropical and tropical Asia east to New Guinea, and west to the islands of the Indian Ocean and, most recently, to Africa (Ajene et al. 2020). Ironically, it has been argued (Beattie 2020b) that the spread can be attributed to the well-meaning plan to reduce scurvy in navies by spreading citrus material—alas infected—for establishment of plantations.

This severe form has prevented the establishment of a modern viable citrus industry in Asia and, even before 1920, was very destructive of the Pakistan industry. Between 1960 and 1970 three million trees were destroyed in Indonesia alone and, by 1983, commercial groves in most parts of Java and Sumatra were abandoned. In the Philippines huanglongbing was largely responsible for the 60% reduction in area planted to citrus between 1961 and 1970, killing in 1971 alone over one million trees in just one province. By 1980 up to 95% of the trees in the northern and eastern provinces of Thailand were affected. It was first recorded in Papua New Guinea in 2002. By September 2004 it was found in Brazil and is now rampant in South and Central America.

The Asian citrus psyllid was first found in the United States in 1998; in August 2005 a pomelo tree in Florida City, south of metropolitan Miami was found to be infected with 'asiaticus'. The psyllid and disease soon reached Louisiana, then Texas, Georgia, Mississippi, South Carolina and Alabama. In August 2008 the psyllid was found in San Diego, California, perhaps coming from Mexico. Today it is found throughout the citrus-growing parts of Florida where the disease is now the most serious threat to the $9 billion Florida industry, which has an annual farm gate value of $1.5 billion.

The usual control would have been pesticides. Indeed, in Asia their (unsustainable) use can lead to trees surviving for up to 15 years in well managed orchards, but such treatments, even with up to 73 sprays every year, often with up to four active ingredients, have failed to prevent spread of the disease. Moreover, intensive insecticide application schedules leads to the selection of insecticide-resistant psyllids, besides devastating natural biological control of the pest by weaver ants (*Oecophylla smaragdina*). There is some hope, though, in that studies, largely by workers at Western Sydney University, Australia, indicate that mineral oils (white oils) used to control other pests and diseases may be as effective as conventional insecticides, without the risk of resistance (see Beattie 2020b).

Some biological control of the Asian citrus psyllid is also possible but introduced parasitoids, first described in India in 1922, have been unable to prevent the spread of the disease in Asia and the Americas. In desperation, all kinds of other ideas have been put forward, including applications of aspirin-like anti-bacterials and various nutrients, because the disease significantly reduces levels of calcium, magnesium and boron, while raising phosphorus levels, ratios allegedly remedied by the nutrient sprays. Tetracyclines and other antibiotics have also been used but, due to cost, phytotoxicity and to humans because of potentially harmful residues, their use is not practical. Thermotherapy based on water-saturated hot air treatments has even been used to eliminate the bacteria from budwood with the idea that shoot-tip grafting can be used to produce disease-free stock.

Today though, nowhere in the world is there an effective management regime in terms of treatment of infected plants or prevention of infection in healthy ones. A further problem stems from the fact that the Asian citrus psyllid attacks many other Rutaceae. Particularly worryingly, *Murraya paniculata,* the ubiquitous ornamental of very many tropical and subtropical towns and cities, the so-called orange jasmine, a plant long-domesticated in China, turns out to be a favoured host for the insect and also a transient one for the bacterium.

In the United States the situation is dire, though only in recent years has the industry admitted it has a major problem, but the 2014 Farm Bill in the United States allotted the first \$23 M of c. \$125 M for research over the subsequent five years. Florida produced 63% of citrus fruits grown there and that industry supported some 76,000 jobs, but yields are falling year on year; since the first report of HLB in Florida in 2005, citrus acreage and production there has decreased by 38 and 74%, respectively (Huang et al. 2021). The local economy is very severely affected as growers attempt to switch to other crops or just abandon the dying citrus—to act as reservoirs for healthy trees nearby. More and more citrus, fresh and juiced, has to be imported from other countries, especially Brazil, but the simple fact is that the orange-juice—and indeed the whole citrus industry worldwide—is imperilled.

So far, the psyllid and therefore the disease has not reached the Mediterranean, but it seems inevitable it will become established there. This is why, as tiresome as it so often seems, quarantine to prevent entry of the bacteria and their vectors, is crucial to the continued wellbeing of crops and growers. But, in the long run, in the absence of effective and acceptable spray regimes or other treatments, a more fundamental solution has to be found—one where deterrents to the insect or disease-resistance can be bred into the crop. Encouragingly, very recent research focused on comparative expression analysis of small RNAs and messenger RNAs between HLB-sensitive cultivars and HLB-tolerant taxa, such that candidate natural defence genes potentially responsible for HLB tolerance were identified. One of these candidate regulators from *Citrus australasica* native in north-eastern Australia, is an antimicrobial peptide (AMP), named stable antimicrobial peptide (SAMP) which has been shown to kill Liberibacter crescens (Lcr), a Liberibacter strain in culture, and to prevent infections of *C*Las and 'solanacearum' in greenhouse trials (Huang et al. 2021).

For the citron this disease is fatal. Indeed, it seems that no citrus, hybrid or wild is completely resistant to it (Mabberley 2015), though some tolerance has been found in, for example, Australian species like *Citrus glauca* and certain hybrids including *C.* × *insitorum* (*C. trifoliata* crossed with commercial mandarin [*C.* × *aurantium*; '*C. reticulata*']) and the Australian 'Sydney Hybrid', *C.* × *virgata* (*C. australis* × *C. australasica*). The evolutionary explanation for such resistance is elusive. Although there are already some selected citrus cultivars that can live for some productive years before succumbing and some of the *C*Las-resistant plants could be used as resistant rootstocks (Alves et al. 2021), an effective scion cultivar breeding program incorporating the germane genes could take many years.

Acknowledgements Thanks are due to George Beattie (Western Sydney University, Australia), for reviewing the section on huanglongbing, to Valery Malécot (Angers, France) for valuable information on Risso's *Citrus* specimens, to John McNeill (Edinburgh) for nomenclatural advice and to Ian Warrender (Palmerston North, New Zealand) for redrawing Fig. 1.10.

Appendix—Formal Classification

(Expanded and updated from Mabberley 1997, 2004, 2022; Zhang and Mabberley 2008).

As the names of citrus crops involving the citron are very much confused in the literature, regrettably so even in modern papers, this synopsis should allow the reader to place correctly germane names encountered there.

Citrus medica—*Citrons*

Citrus medica L., *Sp. Pl.* **2**: 782 (1753) ≡ *C. tuberosa* Mill., *Gard. Dict*. ed. 8: Citrus no. 2 (1768), *nom. superfl.* ≡ *C. fragrans* Salisb., *Prodr. Stirp. Chapel Allerton:* 378 (1796), *nom. superfl.* ≡ *C. medica* var. *vulgaris* Risso & Poit., *Hist. Nat. Orang.*: 194, tt. 96. 97 (1820), *nom. superfl. pro* var. *medica* ≡ *C. cedra* Link, *Handbuch* **2**: 346 (1829) & Risso, *Fl. Nice*: 87 (1844), isonym, ?*nom. superfl.* ≡ *C.* × *limonum* var. *medica* (L.) Risso*, Hist. Nat. Prod. Eur. Mérid.* **1**: 431 (1826) ≡*C.* × *aurantium* L. [unranked] *medica* (L.) Wight & Arn., *Prodr. Fl. Ind. Orient*. **1**: 98 (1834) ≡ *C. medica* subsp. *genuina* Engl., *Nat. Pflanzenfam.* III, **4**: 200 (1896), *nom. superfl. pro* subsp. *medica* ≡ *Aurantium medicum* (L.) M. Gómez, *Fl. Habanera*: 205 (1897);

C. medica var. *proper* Guillaumin in *Agric. Prat. Pays Chauds* n. s. **14**: 118 (1932), *nom. superfl. pro* var. *medica.*

Type: "Habitat in Asia, Media, Assyria, Persia". Type [icon]: 'Citreum' in Tournefort, *Inst. Rei Herb.* **3**: t. 396 (1700) lectotype designated by D.M. Porter in C.E. Jarvis et al. (ed.), *Regnum Veg.* **127**: 34 (1993).

[*Citreum vulgare* Tournef. [*Inst. Rei Herb.* **1**: 621 (1700)] ex Mill., *Gard. Dict.*: Citreum no. 1 (1754), *nom. illeg.*]

Citrus spinosa S.G. Gmel., *Reise Russland* **3**: 278 + t. 22 (1774).

Type: Iran [cult.?], *S.G. Gmelin* (in Herb. Pallas) (**BM**?).

Citrus medica var. *tuberosa* Risso in *Ann. Mus. Hist. Nat.* **20**: 200 (1813) ≡ *C. medica* var. *monstrosa* C. Presl, *Fl. Sicul.*: 183 (1826), *nom. superfl.*

Type: France [cult.], ?not preserved.

? *Citrus lumia* Risso, *Hist. Nat. Prod. Eur. Mérid.* **1**: 414 (1826) ≡ *C. medica* var. *lumia* (Risso) Engl., *Nat. Pflanzenfam.* III, **4**: 200 (1896).

Syntypes: France [cult.], October, *Risso 'No. 37'* (**P** P06137324) and *'39'* (**P** P05471819).

Citrus cedrata Raf., *Sylva Tell.*: 141 (1838).

Type: lost? (**P-DU**?).

Citrus papaya Hassk., *Cat. Pl. Hort. Bog. Alt.*: 218 (1844).

Type: Indonesia [cult.], Java, Bogor, ?*Anon. s.n.* [Hort. Bog. III-G-82] (?**L** holo; **BO** iso].

Citrus crassa Hassk., *Cat. Pl. Hort. Bog. Alt.*: 217 (1844).

Type: Indonesia [cult.], Java, Bogor, ?*Anon. s.n.* (?**L** holo).

Citrus medica var. *bajoura* Bonavia, *Cult. Oranges lemons*: 67 (1890) ≡ *C. medica* subsp. *bajoura* (Bonavia) Engl., *Nat. Pflanzenfam.* III, **4**: 200 (1896).

Type: Not indicated.

? *Citrus kwangsiensis* Hu in *J. Arnold Arbor.* **12**: 153 (1931).

Type: China, Kwangsi, 14 June 1928, *R.C. Ching* [Kwangsi Expedition 6456] (**A** A00044028 holo; **NY** NY00388449 iso).

? Citrus medica var. *alata* Yu. Tanaka in *Trans. Nat. Hist. Soc. Taiwan* **22**: 431 (1932) ≡ *C. alata* (Yu Tanaka) Tanaka, *Syst. Pomol.*: 140 (1951).

Type: Philippines, Mindanao, Todaya, Mount Apo, 1924, *M.S. Clemens s.n.* (**UC** holo).

[*Citrus medica* var. *yunnanensis* S.Q. Ding ex C.C. Huang in *Guihaia* **11**: 8 (1991), *nom. inval.* (ICN Art. 40.6)].

There are many cultivars (one being 'Etrog' [*Citrus medica* var. *conifera* Michel, *C. medica* var. *ethrog* Engl.], the etrog) and cultivar groups to which some of the above botanical varietal names (and others published by Risso and subsequent authors) may be assignable (but for Florentine citrons, see *Citrus* × *limon*). Another cultivar group (Fingered Group) discussed above includes a number of cultivars including:

C. medica var. *digitata* Lour., *Fl. Cochinch.* **2**: 469 (1791) ≡ *C. medica* f. *digitata* (Lour.) Guillaumin in *Agric. Prat. Pays Chauds* n. s. **14**: 119 (1932).

Type: Not preserved?

(N.B. Although Loureiro used the binomial *C. digitata,* he called it a variety of *C. medica*).

Sarcodactilis helicteroides Gaertn.f., *Suppl. Carp.*: 39 + t. 185 [f. 1 'Sarcodactylis helicterioides'] (1805).

Type: 'E Guiana belgica [Surinam]', *Anon. s.n.* (**TUB** holo?).

Citrus sarcodactylis Hoola van Nooten, *Fl. Java* **1**(6): t. 3 (1863) ≡ *C. medica* L. var. *sarcodactylis* (Hoola van Nooten) Swingle, *Pl. Wilson. (Sargent)* **2**: 141 (1914).

Type: "Native of East India." Probably not preserved, in which case the plate would be a good candidate as lectotype.

Citrus × *limonum* var. *cheirocarpa* H. Lév. ex Cavalerie in *Bull. Géogr. Bot*. **21**: 211 (1911).

Type: ? not preserved.

The Buddha-hand or Buddha's hand citron with separated carpels is best treated as a cultivar group. Also to be referred here is *Citrus medica* var. *fructucornuto* Michel (1816). *Citrus limonum* var. *digitata* Risso & Poit., Hist. Nat. Orang.: 192 + t. 95 (1820) and *C. medica* var. *muiliensis* H. Wang & Y. Ding in *Acta Hort. Sin.* **10**: 181 (1983), *nom. nud*., are somewhat intermediate between 'Fingered' and typical *C. medica.*

Commercial Citrus with Citron Parentage and Grown in the Mediterranean

Citrus medica is the male parent of many citrus cultigens (see Fig. 1.10), of which the principal (with commonly used synonyms) are:

1. ***Citrus*** × ***aurantiifolia*** **—(Key) Limes**

Citrus × ***aurantiifolia*** (Christm.) Swingle in *J. Wash. Acad. Sci.* **3**: 465 (1913), *pro sp.* ≡ *Limonia* × *acidissima* Houtt., Nat. Hist. II, 2: 444 (1774), *pro sp.,* non L. (1753), ≡ *L.* × *aurantiifolia* Christm., *Vollst. Pflanzensyst.* **1**: 618 (1777), *pro sp.* ≡ *C.* × *limonellus* Hassk. in *Flora* **25**, Beibl. 2: 43 (1842), *pro sp., nom. superfl.* ≡ *C. medica* f. *aurantiifolia* (Christm.) Hiroe, *Forest Pl. Hist. Jap. Islands* 1: 219 (1974).

Type [icon]: 'Limonellus sive Limon Nipis' Rumpf, Herb. Amb. 2: t. 29 (1741), lectotype designated by B.C. Stone in Dassanayake & Fosberg, *Revis. Handb. Fl. Ceylon* **5**: 424 (1985).

Citrus × *nipis* Michel, *Traité Citronier*: 44 (1816) pro sp.

Type: Nor preserved? Michel includes 'Limonellus sive Limon Nipis' Rumpf, Herb. Amb. 2: t. 29 (1741), type of C. × *aurantiifolia*, in his protologue.

Citrus × *spinosissima* G. Mey., *Prim. Fl. Esseq.*: 247 (1818), *pro sp.* ≡ *C. medica* var. *spinosissima* (G. Mey.) Mart., *Syst. Mat. Med. Bras.*: 30 (1843) ≡ *C.* × *aurantium* L. var. *spinosissima* (G. Mey.) Griseb., *Fl. Br. West Ind. Is.*: 132 (1864) ≡ *Aurantium* × *spinosissima* (G. Mey.) M. Gómez, *Fl. Habanera*: 205 (1897).

Type: Guyana [naturalized], R. Essequibo (=Araunama), 'Arowabisch' Is., *Rodschied 131* (**GOET**).

? Citrus × *mellarosa* Risso, *Hist. Nat. Prod. Eur. Mérid*. **1**: 405 (1826), *pro sp.*
Type: France [cult.], 'primavere', *Risso s.n.* (**P** P05308995).
? C. × *aurata* Risso, *Hist. Nat. Prod. Eur. Mérid*. **1**: 409 (1826), *pro sp.*
Type: France [cult.], not found.
Citrus × *lima* Macfad. in *Bot. Misc*. **1**: 300 (1830), *pro sp.* ≡ *C.* × *aurantium* subsp. *lima* (Macfad.) Guillaumin in *Agric. Prat. Pays Chauds* n. s. **14**: 113 (1932).
Type: Jamaica, not preserved?
C. × *acida* Roxb., *Fl. Ind*. **3**: 390 (1832), *pro sp.* ≡ *C. medica* L. var. *acida* (Roxb.) Hook.f., *Fl. Brit. India* **1**: 515 (1875) ≡ *C. hystrix* DC. subsp. *acida* (Roxb.) Bonavia ex Engl., *Nat. Pflanzenfam*. III, **4**: 200 (1896).
Type [icon]: India, "Cultivated in Bengal", 'Citrus acida', Fig. 1 (*Icones Roxburghianae*) (**K, lectotype designated here**).
Citrus × *notissima* Blanco, *Fl. Filip*.: 607 (1837), *pro sp.*
Type: Philippines, not preserved?
Citrus × *lima* Raf., *Sylva Tell*.: 143 (1838), *pro sp., nom. illeg., non* Macfad. (1830).
Type: lost? (**P-DU**?).
*[2] *Citrus* × *rissoa* Risso in *Hortic. Univ*. **1**: 200 + t. 27 (1839) & *Herb. Gén. Amat*., sér. 2, **2**: 15 + t. (1841), *pro sp.,* **syn. nov.**
Syntypes: France [cult.], *Risso s.n.* (**P** P05309085), Alpes-Maritimes, Beaulieu-sur-Mer, *Risso s.n.* (**P** P05309084), 'fleur janvier', *Risso s.n.* (**P** P05309082).

2. *Citrus* × *floridana* —Limequats

Citrus* × *floridana (J. Ingram & H.E. Moore) Mabb. in Telopea **7**: 337 (1998) ≡ × *Citrofortunella floridana* J. Ingram & H.E. Moore in *Baileya* **19**: 170 (1975).
Holotype: [icon] 'Evstis [sic = 'Eustis'] limequat (No 48798), grown in the greenhouse at Washington, D.C.', *J. Agric. Res*. **23**: [237] t. 4 (1923).
× *Citrofortunella swinglei* J. Ingram & H.E. Moore in *Baileya* **19**: 170 (1975), non *Citrus swinglei* Burkill ex Harms (1931).
Holotype: [icon] 'Tavares limequat' (No 48792), *J. Agric. Res*. **23**: [238] t. 5B (1923).

3. *Citrus* × *latifolia* —Persian or Tahitian (Seedless) Limes

Citrus* × *latifolia (Yu. Tanaka) Tanaka, *Syst. Pomol*.: 140 (1951), *pro sp.* ≡ *C.* × *aurantiifolia* var. *latifolia* Yu. Tanaka in *Agr. & Hort*. **9**: 2346 (1934) ≡ *C.* × *aurantiifolia* subsp. *latifolia* (Yu.Tanaka) S. Ríos & al., *Varied. Trad. Frut*.: 101 (1998).
Type: Not preserved?

4. *Citrus* × *limon* —Lemons

Citrus* × *limon (L.) Osbeck, *Reise Ostindien*: 250 (1765) as '*limonia*', *pro sp.* ≡ *C. medica* L. var. *limon* L., *Sp. Pl*. **2**: 782 (1753) ≡ *C. medica* var. *odoratissima*

[2] * = Addition to POWO/IPNI and other databases.

Andrews, *Bot. Rep.* **10**: t. 609 (1810), *excl. ic. & descr., nom, superfl. pro* var. *limon* ≡ *C. medica* L. f. *limon* (L.) Hiroe, *Forest Pl. Hist. Jap. Islands* **1**: 218 (1974).

Type [icon]:'Limon vulgaris' in Ferrari, *Hesperides*: 191, 193 (1646) lectotype designated by D.J. Mabberley in *Telopea* **7**: 169 (1997).

Citrus × *limonum* Risso in *Ann. Mus. Natl. Hist. Nat.* **20**: 201 (1813), *pro sp.* ≡ *C.* × *limonum* var. *vulgaris* Risso & Poit., *Hist. Nat. Orang.*: 174 + t. 84 (1820), *nom. superfl. pro* var. *limonum* ≡ *C.* × *aurantium* [unranked] *limonum* (Risso) Wight & Arn., *Prodr. Fl. Ind. Orient.* **1**: 98 (1834) ≡ *C. medica* var. *limonum* (Risso) Hook. f., *Fl. Brit. India* **1**: 515 (1875) ≡ *C. medica* subsp. *limonum* (Risso) Engl., *Nat. Pflanzenfam.* III, **4**: 200 (1896).

Type: "Ce lemonier s'élève jusqu'a quatre metres dans notre department; et quoique il soit moins sensible au froid que les varietés suivantes, il est peu cultivé parce qu'il ne donne qu'une petite quantité de fruits." (?not preserved).

Citrus medica var. *florentina* Risso in *Ann. Mus. Hist. Nat.* **20**: 200 + t. 4 [II] Fig. 1 (1813) ≡ *C. cedra* var. *florentina* (Risso) Risso, Fl. Nice: 87 (1844).

Type: France [cult.], ?not preserved, in which case the figure would make an appropriate lectotype.

Citrus × *limetta* Risso in *Ann. Mus. Natl. Hist. Nat.* **20**: 195 + t. 4 (II) Fig. 2 (1813), *pro sp.*

C. × *lumia* var. *limetta* (Risso) Risso & Poit., *Hist. Nat. Orang.*: 144 + t. 69 (1819); *C. medica* var. *limetta* (Risso) Hook. f., *Fl. Brit. India* **1**: 515 (1875); *C.* × *aurantium* var. *limetta* (Risso) Guillaumin in *Agric. Prat. Pays Chauds* n. s. **14**: 115 (1932).

Syntypes: France [cult.], *Risso s.n.* (**P** P05309097, P05309098).

Citrus × *limetta* var. *bergamia* Risso in *Ann. Mus. Natl. Hist. Nat.* **20**: 197 (1813) ≡ *C.* × *aurantium* var. *bergamia* Michel, *Citronier*: 31, t. 26 + Fig. 3 (1816) ≡ *C.* × *bergamia* (Risso) Risso, *Hist. Nat. Prod. Eur. Mérid.* **1**: 403 (1826), *pro sp.* ≡ *C.* × *aurantium* [unranked] *bergamia* (Risso) Wight & Arn., *Prodr. Fl. Ind. Orient*. 1: 98 (1834) ≡ *C.* × *aurantium* subsp. *bergamia* (Risso) Engl., *Nat. Pflanzenfam.* III, **4**: 198 (1896).

Type: France [cult.] (? not preserved).

?Citrus × *aurata* var. *gordonia* Risso, *Hist. Nat. Prod. Eur. Mérid.* 1: 411 (1826) ≡[3]**C.* × *gordonia* (Risso) Risso in *Hortic. Univ.* **1**: 352 + t. 41 (1839) & *Herb. Gén. Amat.*, sér. 2, **2**: 33 + t. (1841), *pro sp.*

Syntypes: France [cult.] 'Citrus Gordon', *Risso s.n.* (**P** P05308992); 'C. Gordon', *Risso s.n.* (**P** P05308993).

Citrus × *bergamota* Raf., *Sylva Tell.*: 141 (1838), *pro sp.*

Type: lost? (**P-DU**?).

Citrus × *pachiderma* Risso, *Fl. Nice*: 87 (1844), *pro sp.*, **syn. nov**.

Type: France [cult], *Risso s.n.* (**P** P05309047 holo).

Citrus × *dimorphocarpa* Lush. in *Ind. Forester* **36**: 346 (1910).

Type: Not indicated, but probably a cultivated plant at Dehra Dun, India (?not preserved).

[3] * = Addition to POWO/IPNI and other databases.

Citrus × *limonimedica* Lush. in *Ind. Forester* **36**: 348 (1910).

Type: Not indicated, but probably a cultivated plant at Dehra Dun, India (?not preserved).

Citrus × *medicolimonum* Lush. in *Ind. Forester* **36**: 349 (1910).

Type: Not indicated, but probably a cultivated plant at Dehra Dun, India (?not preserved).

Citrus × *meyeri* Yu. Tanaka, *Icon. Jap. Citrus Fruits* **1**: 91 (1946).

Type: Not found.

Citrus × *limodulcis* D. Rivera et al., *Varied. Trad. Frut.*: 125 (1998).

Type: Spain [cult.], Murcia, Churra, 1996, *D. Rivera & F. Mendez* (MUB 47,654 holo; MUB iso).

5. *Citrus* × *otaitensis* —Rough Lemons (including Rangpur Lime)

Citrus* × *otaitensis (Risso & Poit.) Risso, *Fl. Nice*: 86 + t. [7] (1844 '*taitensis*'), *pro sp.* ≡ *C.* × *aurantium* var. *otaitensis* Risso & Poit., *Hist. Nat. Orang.*: 66 + t. 27 (1819) ≡ *C.* × *lumia* var. *otaitensis* (Risso & Poit.) Lémon in *Rev. Bot.* **1**: 115 (1829) ≡ *C.* × *limon* var. *otaitensis* (Risso & Poit.) Tanaka in *Sci. Bull., Facult. Agric. Kyushu Univ.* **1**: 107 (1925).

Type: France [cultivated], Paris, Noisette's garden and ?not preserved, so the plate **is here designated as lectotype (see Fig.** 9**)**. Apparently the pot-plant grown as 'Otaheite' for winter decoration in USA etc. Note that the only (undated) specimen in Risso's herbarium is 'Citrus otaitense [sic]', *Risso s.n.* (**P** P02441072) and that, as so often in his flora, Risso 'recycled' his earlier varietal epithets (see for example *C. bergamia* above) as species names, this time inadmissibly replacing the by then archaic 'Otaite' with 'Taite', but in the horticultural literature of the nineteenth century the name was usually rendered *C. otaitensis*. I am indebted to John McNeill (E) for advice here.

Citrus × *bigaradia* var. *volcameriana* Risso & Poit., *Hist. Nat. Orang.*: 91, t. 40 (1819); Ten., *Cat. Orto Bot. Napoli*: 20 (1845) ['Wolkameriana R.'] ≡ *C.* × *volcameriana* (Risso & Poit.) V. Ten. & Pasq., *Comp. Bot.*: 414 (1847), *pro sp.* **Syn. nov**.

Type [icon]: Risso & Poit., *Hist. Nat. Orang.*: t. 40 (1819) **lectotype designated here (see Fig.** 1.11**)**; the illustration and description published by Risso & Poiteau match the Rangpur lime (a rough lemon).

[*Citrus* × *limetta* var. *sinensis* Hort. Angl. ex Lémon, *op. cit.*: 117, *nom. in synon.*]

['*C.* × *limonia*' auctt., non *C.* × *limon* (L.) Osbeck, 'limonia'].

Citrus × *volkameriana* Pasq., *Cat. Ort. Bot. Napoli*: 29 (1867), *pro sp.*, *nom. illeg.*, *non C.* × *volcameriana* V. Ten. & Pasq. (1847).

Type: Italy [cult.], Reggio Calabria and Naples (?**NAP** not seen).

Citrus × *jambhiri* Lush. in *Ind. Forester* **36**: 342 (1910), *pro sp.* ≡ *C.* × *aurantium* subsp. *jambhiri* (Lush.) Engl., *Nat. Pflanzenfam.* III, **4**: 200 (1896) as '*jambiri*'. **Syn. nov.**

Type: Not indicated, but probably a cultivated plant at Dehra Dun, India (?not preserved), *fide* D. J. Mabberley in *Telopea* **7**: 170 (1997).

? Citrus x rangpuriensis Traub, *Plant Life* **29**: 172 (1973).

Type: USA [cult.], California (n.v.).

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Chapter 2
Citron Genomics

Chandrika Ramadugu and David Karp

Abstract Citron, one of the three basic species of the genus *Citrus*, is the progenitor of limes and lemons. Molecular studies elucidate the genetic basis of many unusual traits observed in citrons and other related groups. The genome sequence of a *Citrus medica* cultivar, 'XZ', is now available; at 407 Mb, the citron genome is larger than other sequenced citrus genomes. Genetic analysis has confirmed the paternal contribution of citrons in other sour citrus groups. Unusual fruit shapes observed in citrons can be correlated with the expression of specific genes. Polyembryony observed in citron derivatives is determined by a MITE insertion in the promoter of a gene *CitRWP*, coding for a transcription factor. Citrons typically produce anthocyanins in young leaves and flowers. The *Ruby* and *Noemi* genes are associated with anthocyanin production and fruit acidity in citron and other citrus types. Expression of P-ATPases encoded by genes *CitPH1* and *CitPH5* and a regulatory transcription factor encoded by *CitAN1* are correlated with fruit acidity.

2.1 Introduction

In recent decades the technology and methods used for genetic analysis of citrus have greatly advanced, revealing crucial insights into how citrus species and cultivars are related, how and when they evolved, and the genetic mechanisms responsible for their appearance, chemical composition, and flavor. Although citron (*Citrus medica* L.) is the type species of the genus *Citrus*, citron fruits are of relatively minor economic importance in world citriculture, and few studies have dealt with the genetic relationships of citron cultivars. Most studies initially focused on commercial crops such as orange, mandarin and lemon. However, as long surmised and recently confirmed, citron has played a crucial role as a parent of most of the acid citrus fruits. Partly

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as a result, many studies have addressed citron genomics, the branch of molecular biology concerned with the structure, function, evolution, and mapping of genomes. Although the technical details are complicated, many of the conclusions they impart will interest anyone curious about this most historic and mysterious fruit.

Until about 40 years ago scientists relied primarily on secondary metabolite composition and morphological comparisons of citrus plant parts for reaching taxonomical conclusions. Indeed, both chemotaxonomy (Scora 1975) and morphological "numerical taxonomy" (Barrett and Rhodes 1976) concluded that the ancestors of cultivated *Citrus* belonged to three main taxa, citron, mandarin and pummelo. Subsequent taxonomical studies analyzed leaf isozymes (enzymes; Torres et al. 1978) and karyotypes (size, shape, and number of chromosomes; Guerra et al. 1997). Starting in the 1990s scientists used increasingly powerful and accurate tools to analyze citrus genetics: restriction fragment length polymorphisms (Federici et al. 1998); random amplified polymorphic DNA and sequence characterized amplified regions (Nicolosi et al. 2000); simple sequence repeats (SSR) (Luro et al. 2001; Barkley et al. 2006); SSR and insertion-deletions (indels; Garcia-Lor et al. 2012); single nucleotide polymorphisms (SNP) (Ollitrault et al. 2012b); full sequencing of genomes (Wu et al. 2014); and multiple methods such as nuclear, chloroplastic and mitochondrial markers (Garcia-Lor et al. 2013; Curk et al. 2016). Most recently, scientists have started discovering quantitative trait loci, molecular markers that correlate with observed horticultural or pomological traits.

After an overview of citrus genomics, this chapter surveys the methods and conclusions of the most important citron genomic studies.

2.2 Citrus Genomics Overview

The genetic composition of an organism determines its phenotype, the underlying physiological processes, the essential metabolic pathways, responses to biotic and abiotic challenges, tolerance to environmental factors, and finally, the form and function of its progeny. Understanding the genome of a plant will, in theory, answer several questions regarding the fundamental processes that define the organism. Genomic data integrated with complementary information from the transcriptome, the proteome, and the metabolome is expected to eventually provide a more comprehensive picture of functional genetics. Often, gene function is assumed based on the correlation of a specific phenotype with the presence of a gene, its transcript, and bioinformatic prediction of its function based on homology searches (Gmitter et al. 2020). In citrus, only a small percentage of the genome codes for proteins; very little is known about the role of intergenic sequences in gene function. A fuller understanding of the genome will require years of study using biological specimens. Knowledge of the genomes will be valuable in understanding the biology of the species and subsequent utilization of the sequence information to develop improved cultivars.

Genomic sequences of several representative citrus species are now available in public databases The collinearity and synteny (conservation of blocks of genes within chromosomes of closely related individuals) between species facilitate comparative genomic studies. Correlation of horticulturally valuable traits with candidate genes and their expression profiles are expected to provide opportunities for crop improvement through genomic selection. The next phase of citrus genomics appears to be very promising; technological advances leading to superior sequencing approaches, availability of multiple genome sequences of related organisms, and improvement of bioinformatics methods will contribute significantly to the understanding of the genomes. Progress in CRISPR-mediated genome editing techniques will enable the modification of candidate genes associated with important traits like juvenility and disease resistance (Peng et al. 2017; Zhu et al. 2019; Jia and Wang 2020). Linking phenotypic characters with genome sequence variability will provide valuable tools for marker-assisted selections, sequence-based crop improvement and innovative methods for plant breeding (Ollitrault 2019).

2.3 Sequencing Genomes of Major Citrus Groups

The first complete citrus genome sequenced was from a haploid 'Clementine' mandarin (Wu et al. 2014). The International Citrus Genome Consortium involving researchers from United States, France, Italy, Spain and Brazil collaborated and generated the first citrus genome that was made public in 2011 (Talon and Gmitter 2008; Aleza et al. 2009; Gmitter et al. 2012; Ollitrault et al. 2012a; Germana et al. 2013). Most cultivated citrus varieties have a high level of heterozygosity which may lead to complications in the genome assembly process. A haploid clone of 'Clementine' derived from induced gynogenesis (a procedure to rescue plantlets derived from the maternal tissue) was considered optimal for generating the first citrus genome sequence. Supporting information provided by genetic linkage maps and expressed sequence tag (EST) resources were useful in improving the assemblies and for providing annotations (Ollitrault et al. 2012b). Another major accomplishment was the sequencing of a doubled haploid line of 'Valencia' sweet orange derived from anther culture; the parental diploid genome was later mapped to the haploid reference genome (Xu et al. 2013). Exponential growth in the development of sequencing and analysis techniques has contributed to dramatic advances in the field of genomics. Shotgun Illumina sequencing combined with long-read single-molecule sequencing approaches is valuable in improving the quality of the scaffolds and genome assemblies.

In recent years, several commercial citrus cultivars have been sequenced by multiple research groups. A high-quality genome of a haploid pummelo was reported by Wang et al. (2017) based on single-molecule sequences on the PacBio RSII platform. In addition to de novo sequencing, several citrus accessions were re-sequenced by shotgun paired-end reads using the Illumina platform. About 36 nearly

Fig. 2.1 Sequence read archives (SRA) of three phenotypically diverse citrons pictured here are available https://www.citrusgenomedb.org/. Genome-wide short reads were aligned with 'Clementine' reference sequence. **a** 'Buddha's Hand' citron. **b** '*Etrog*' citron. **c** 'Yunnanese' citron

complete citrus genome sequences are available through public databases (https://www.citrusgenomedb.org/). Genomic information for many of these is obtained from sequence read archives (SRAs are genome-wide short reads generated by high-throughput sequencing methods and aligned to the reference genome—in this case, the haploid 'Clementine' sequence). Sequence information for three citron accessions—'Buddha's Hand' citron, 'Etrog' citron, and 'Yunnanese' citron—is included in the citrus genome database (Fig. 2.1).

The first complete *Citrus medica* genome, sequenced using PACBIO RSII and Illumina platforms and assembled de novo, was reported by Wang et al. (2017). This draft genome of *C. medica* cultivar 'XZ' from China is about 407 Mb, larger than the *Citrus* genomes belonging to other subgroups (https://www.citrusgenomedb.org/organism/5945). The sequences were submitted by Huazhong Agricultural University, Wuhan, China. Links to the draft genome sequence of *Citrus medica* cultivar 'XZ' can be obtained from public databases at https://www.ncbi.nlm.nih.gov/nuccore/MKYO00000000. *Citrus medica* genome codes for 32,579 genes (in comparison, the number of predicted genes for 'Clementine' mandarin is 24,533, for pummelo 30,123 genes, and for sweet orange 29,655 genes). Citron genome has 66% alignment with the 'Clementine' genome and 61% with the pummelo genome (Wang et al. 2017). The additional genes in citron may be associated with species-specific traits.

Genome sequences of several citrus accessions at various stages of completion are also available from GenBank (https://www.ncbi.nlm.nih.gov/genome/browse#!/overview/citrus). Annotation of the genomes is inferred using comparative analysis with other plant genomes, direct transcriptomic data, and additional supporting information. The quality of a genome usually improves over time as more de novo assembled sequences become available, and as RNAseq data and genetic maps are incorporated.

2.4 Citron is One of the 10 Ancestral Citrus Species, and a Parent of Many Acid Citrus Types

Before genomic analysis of representative citrus species was possible, it was assumed that there were three (or, according to some researchers, four) basic ancestral species from which all other citrus cultivars and hybrids are derived. The three basic species identified were: *Citrus medica* (citron), *Citrus maxima* (pummelo), and *Citrus reticulata* (mandarin) (Scora 1975; Barrett and Rhodes 1976). A fourth species that may have contributed to the development of other species was identified as a papeda (*Citrus micrantha*) (Garcia-Lor et al. 2012, 2013; Ollitrault et al. 2012b). Hybridization among the progenitor species was assumed to be responsible for the development of all other citrus types, a view that is now considered to be too simplistic. Based on phylogenomic studies conducted using about 300,000 nuclear SNPs across the genome, about 10 ancient progenitor species are identified: *Citrus medica*, *C. maxima*, *C. reticulata*, *C. micrantha, C. ichangensis* (Ichang papeda), *C. japonica* (or *Fortunella japonica*, the kumquat), *C. mangshanensis* (Mangshan wild mandarin), *C. glauca* (or *Eremocitrus glauca*, Australian desert lime), *C. australis* (*Microcitrus australis*, Australian round lime) and *C. australasica* (*M. australasica*, Australian finger lime) (Wu et al. 2018). Seven of the 10 progenitor species are from Asia, and three originated in Australia. Citron still retains its position as one of the basic, ancestral species. Future analysis of additional complete genomes of wild citrus genotypes may uncover other species that may be regarded as ancestral types.

Within the past decade scientists using whole genome sequencing and other advanced methods have determined the ancestry of many important citrus cultivars, and many of the minor types. The parentage of all the major citrus types for which citron was either a parent or a grandparent are listed in Fig. 2.2.

2.4.1 Genetic Studies Using Markers Derived from Nuclear and Chloroplast Sequences

As one of the ancestral species, citron has contributed towards the development of many commercially significant cultivars. Earlier studies conducted with limes and lemons using molecular markers indicated that citron is usually the male parent in most natural hybrids belonging to the acid citrus group (Nicolosi et al. 2000; Araujo et al. 2003; Carvalho et al. 2005; Barkley et al. 2006). Since the chloroplast (cp) genome is generally maternally inherited, detection of cp markers is informative about the probable maternal parentage of hybrids. Since most citrons are self-compatible, hybrids with citron as the maternal parent are not common (Scora 1975). CpDNA is not subject to recombination and is useful to understand phylogenetic relationships at lower taxonomic levels.

The first sequenced cp genome in citrus was from *Citrus sinensis*, the ‘Ridge Pineapple’ cultivar (Bausher et al. 2006). Comparison with cp genomes of related

Citron as a parent

Lemon (*C. limon*): ♀sour orange (*C. aurantium*) × ♂citron (*C. medica*) (Nicolosi et al. 2000; Gulsen and Roose 2001; Curk et al. 2016; Wu et al. 2018)

Limetta (*C. limetta*): ♀sour orange (*C. aurantium*) × ♂citron (*C. medica*); same parents as lemon, "but with a higher proportion of *C. reticulata*" (Curk et al. 2016)

Lime, small-fruited (Mexican, West Indian, Key; *C. aurantifolia*): ♀small-flowered papeda (*C. micrantha* or similar) × ♂citron (*C. medica*) (Ollitrault et al. 2012b; Garcia-Lor et al. 2013; Curk et al. 2016)

Alemow (*C. macrophylla*): ♀small-flowered papeda (*C. micrantha* or similar) × ♂citron (*C. medica*) (Nicolosi et al. 2000; Ollitrault et al. 2012b; Curk et al. 2016)

Rangpur lime (*C. limonia*): ♀sour mandarin (*C. reticulata*) × ♂citron (*C. medica*) (Federici et al. 1998; Gulsen and Roose 2001; Curk et al. 2016; Wu et al. 2018)

Rough lemon (*C. jambhiri*): ♀sour mandarin (*C. reticulata*) × ♂citron (*C. medica*) (Scora 1975; Barrett and Rhodes 1976; Federici et al. 1998; Nicolosi et al. 2000; Curk et al. 2016; Wu et al. 2018)

Volkamer lemon (*C. volkameriana*): ♀sour mandarin (*C. reticulata*) × ♂citron (*C. medica*) (Curk et al. 2016)

Sweet lime (*C. limettiioides*): ♀(mandarin [*C. reticulata*] × pummelo [C. *maxima*]) × ♂citron (*C. medica*) (Curk et al. 2016)

Meyer lemon (*C. meyeri*): ♀(mandarin [*C. reticulata*] × pummelo [*C. maxima*]) × ♂citron (*C. medica*) (Curk et al. 2016)

Citron as a grandparent

Lime, large-fruited (Bearss, Tahiti, Persian; *C. latifolia*): ♀lemon (*C. limon*) x ♂small-fruited lime 2n (*C. aurantifolia*); resulted from the fertilization of a haploid ovule of *C. limon* by a diploid gamete of *C. aurantifolia* (Curk et al. 2016)

Bergamot (C. bergamia): ♀sour orange (*C. aurantium*) x ♂lemon (*C. limon*) (Curk et al. 2016).

Fig. 2.2 Often a father, never a mother: citron's progeny plants led to the identification of cp sequences conserved across genera, location of indels, and characterization of repeat and variable regions. The information was utilized in the design of molecular markers for understanding the phylogenetic relationships of different citron species. The *matK* gene in the cp genome encoding maturase protein has been used for DNA barcoding in phylogenetic studies (Penjor et al. 2013; Mahadani and Ghosh 2014).

Carbonell-Caballero et al. (2015) sequenced cp genomes of 34 citrus accessions including four citrons ('Buddha's Hand', 'Mac Veu de Montagne', 'Humpang' and 'Corsican') and several hybrids with citron parentage. This study identified 3.0 indels per kb for the chloroplast genome, including 216 single nucleotide variants and 61 indels.

Another study by Zhang and Bai (2020) reported a sequence of the cp genome of *Citrus medica* (Nanjing Forestry University accession number 20171017ivia_322). The total length of this cp genome was 160,031 bp; a large single-copy region (87.5 Kb) and a smaller single-copy region (18.5 Kb) are separated by two, 27 Kb long inverted repeats. A total of 134 genes were identified (89 protein-coding, 37 tRNA, and 8rRNA genes). Introns (segments of a gene that do not code for protein and are removed before translation of the gene) were observed in 20 genes, including 12 protein-coding genes.

The sequence variation in the introns of cp genes is utilized in citron phylogenetic studies (Luro et al. 2012; Ramadugu et al. 2015; Yang et al. 2015). Rates of nucleotide substitution in chloroplast often vary from nuclear DNAs (Wolfe et al. 1987); markers discriminating closely related varieties have been developed for selected regions of the cp genome. Analysis of cp genomes is useful to understanding the history of domestication, evolutionary aspects, genetic variability, chloroplast inheritance patterns, and maternal ancestry of hybrid cultivars (Raubeson and Jansen 2005; Li et al. 2010; Carbonell-Caballero et al. 2015; Luro et al. 2019). Mitochondrial markers were also utilized to study maternal citrus phylogeny.

Taxa belonging to the genus *Citrus* are generally diploid with nine sets of chromosomes (Krug 1943); a small number of horticultural varieties are triploid or tetraploid (Curk et al. 2016; Rouiss et al. 2018). Carvalho et al. (2005) conducted a chromosomal comparison of 10 limes, lemons and citrons using chromomycin A3 (CMA) and 4–6-diamidino-2-phenyl indole (DAPI) stains. The heterochromatic blocks (marked by banding pattern) and karyotype (the number and visual appearance of the chromosomes in the cell nuclei) indicated a close relationship between the four lemons included in the study and the papeda ancestry of a lime. The study showed that *Citrus medica* was cytogenetically homozygous and the other nine hybrid accessions were heterozygous with citron parentage (Carvalho et al. 2005).

Curk et al. (2016) utilized 123 cytoplasmic and nuclear markers including SNP and indel markers to study 133 citrus accessions belonging to the acid fruit group to study diversity, genetic structure, and the origin of limes and lemons. It was concluded that citron was the male parent for the limes and lemons included in the study. The maternal phylogeny of triploid limes 'Tahiti' and 'Tanepo' and triploid 'Madagascar' lemon was determined based on mitochondrial and chloroplast markers. The inclusion of a wide variety of accessions in this study made it possible to identify the exact maternal and paternal ancestry of several limes and lemons (Curk et al. 2016).

In northeast India many wild and cultivated forms of citron have been documented (Bhattacharya and Dutta 1956; Kumar et al. 2014; Gogoi and Basumatary 2017). Along with Yunnan Province in China and northern Myanmar, the northeastern part of India has the most diversified citron germplasm (Deng et al. 2020). Determining genetic variability in naturally occurring populations of citron is valuable in centers of origin such as India and China. Identification of diverse germplasm is required for developing conservation strategies (Malik et al. 2013). Bharbhuiya et al. (2016) analyzed 219 citrons from four wild and eight domesticated populations in northeastern India using five microsatellite markers. Not surprisingly, high genetic variation was observed in the citron populations from this major center of diversity for citron. The informative SSR markers used for the study showed an average of 13.40 alleles per locus; mean heterozygosity varied from 0.22–0.54 in the wild populations and 0.44 to 0.73 in domesticated groups.

Ramadugu et al. (2015) analyzed citron samples from Yunnan Province in China and the Citrus Variety Collection in Riverside, California, USA (Mediterranean citrons). In this study with 47 citrons, substantial heterozygosity and genetic diversity was documented using 23 microsatellite markers, and SNP markers in nuclear and cp genes. Population structure analysis (Pritchard et al. 2000; Falush et al. 2003; Evanno et al. 2005) revealed three clusters with significant genetic distance between individuals in each cluster (0.535, 0.219, and 0. 318, respectively). Fixation index values (a measure of population differentiation due to genetic variability) in the three clusters were 0.0012, 0.499 and 0.486. Cluster one had non-fingered wild citrons from China, cluster two included fingered and non-fingered citrons from China, and cluster three comprised of non-fingered citrons from diverse locations including Israel, Italy, Morocco, and the US (Fig. 2.3). Pure citrons had a significant level of homozygosity; however, considerable heterozygosity was recorded in several citrons. Earlier studies did not report much variability among citron accessions (Federici et al. 1998; Bayer et al. 2009). This was probably due to the small sample size of citrons in these studies and the choice of markers used for analysis.

Yang et al. (2015) reported substantial genetic diversity among citrons from southwest China and Tibet. They studied 56 accessions using 77 SSR markers; heterozygosities ranged from 0.36 to 0.49. Simple sequence repeats are characterized by codominant inheritance and a high level of polymorphism. Yang et al. reported 387 alleles, with about 5 alleles per locus. Polymorphism information content (PIC) value ranged from 0.12 to 0.83, with an average value of 0.45. A high level of genetic differentiation was reported, probably because of the geographical regional adaptation of accessions, long evolutionary history, and the choice of discriminating markers used for analysis. Yang et al. hypothesized a common ancestor for the fingered and non-fingered citrons included in their study.

In *Citrus* various biological processes including apomixis, vegetative propagation, and interspecific recombination have resulted in hybrids with mosaics of large genome fragments from different species (Curk et al. 2016; Wu et al. 2018). Several molecular tools are now available for analysis of citrus genomes. Mikeal Roose developed Affymetrix Axiom arrays by mining for SNPs in 30 resequenced genomes [including four citrons, three citron hybrids (lemons and limes), and citrus relative genera *Fortunella*, *Poncirus,* and Australian limes]; two versions of the SNP array were designed with 1.5 million and 56,000 SNPs (Eck et al. 2016). In a different study, using mined SNP data from about 40,000 loci distributed across the genome, Ahmed et al. (2019) developed a phylogenomic analysis method to understand the level of introgression in complex citrus hybrids with mosaic genomes; this study included six citron accessions from the Corsican germplasm collection. Using simple sequence repeat data from citron and seven other citrus and related species, Duhan et al. developed a comprehensive microsatellite marker database (*citSATdb*) containing 1,296,500 putative SSR markers that are useful for studying genetic diversity and population structure in *Citrus* accessions (Duhan et al. 2020).

2.5 Disease Resistance in Citrons

Crops grown in "monoculture" are known to be vulnerable to pathogens and can result in disease outbreaks (Bové 2006; King and Lively 2012). A bacterial disease, citrus huanglongbing (HLB) has devastated citriculture in many parts of the world and has caused immense financial damage (Hodges and Spreen 2012). Based on a long-term field study conducted with about 83 accessions of citrus and citrus relatives, Miles et al. (2016) reported that accessions with citron in their parentage appeared to be more tolerant of citrus HLB. The seedling trees in this study consisted of 65 citrus

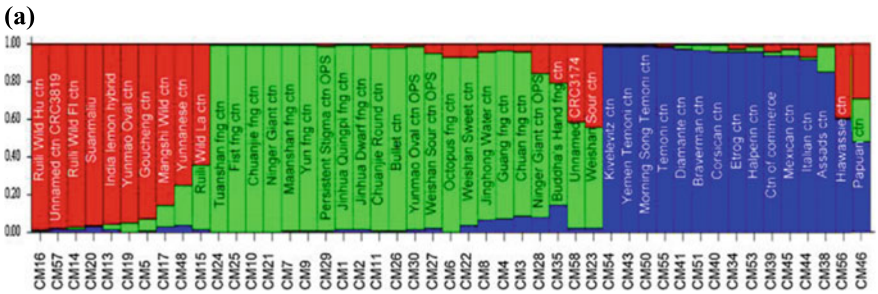

Fig. 2.3 **a** Population structure analysis of 47 citrons using data from 23 microsatellite markers. Three major populations were inferred. Y axis represents probable admixture in each accession. Cluster 1—non-fingered wild citrons from China (red), including many likely hybrids. Cluster 2—fingered and some non-fingered citrons from China (green). Cluster 3—non-fingered citrons from Israel, Italy, Morocco, United States, etc. (blue). Overall proportion of membership in the three inferred clusters were: 0.240, 0.449, and 0.311. Abbreviations used: ctn (citron), fng (fingered), OPS (open pollinated seedling). **b** Neighbor joining tree showing relationships of the citrons represented in the population structure diagram in panel A. Bootstrap support values are indicated on the branches. (Reproduced with permission from Ramadugu et al. 2015)

(b)

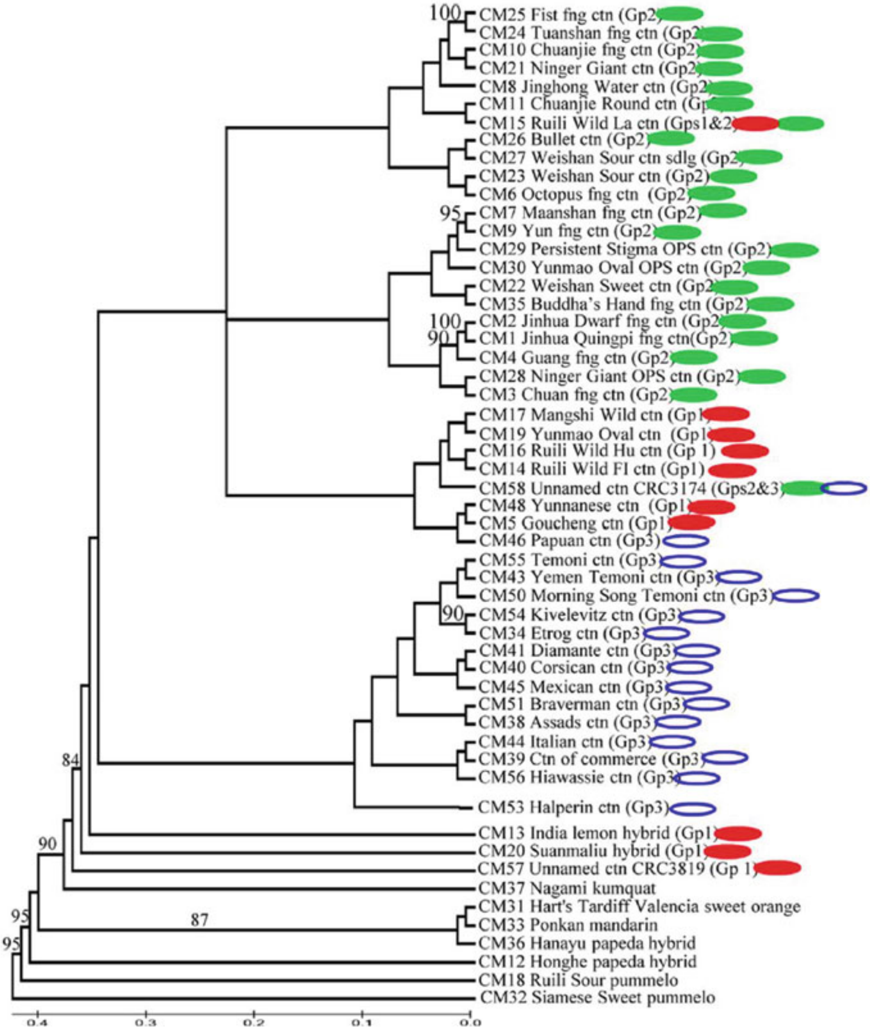

Fig. 2.3 (continued)

accessions, including pure citrons, limes, lemons, mandarins, papeda, pummelo, sour oranges, and grapefruit. The bacterial pathogen titer and blotchy mottle symptoms characteristic of HLB were significant in the citron group (Ramadugu et al. 2016). Yet, several citrons and hybrid species with citron parentage showed significant tolerance to citrus HLB as measured by canopy size, growth parameters, overall health, and longevity. In a linear regression analysis, the percentage of citron in the accession correlated significantly with HLB tolerance rating (Miles et al. 2016). Citrons may confer HLB tolerance to progeny and may be useful as parental species in breeding trials. Identification of genes associated with HLB resistance and incorporation of disease resistance traits in commercial citrus will be possible with genomic data. The advances in the field of genomics will help develop solutions and prevent disease epidemics that threaten citrus cultivation worldwide.

2.6 Polyembryony

Apomixis is a form of asexual reproduction that is common in many cultivated citrus types and results in progeny that are identical to the maternal parent (Kotlunow 1993). Citrons are monoembryonic, and hence apomixis is not known in this group (Hodgson 1967). However, many hybrids with citron parentage—like limes and lemons—exhibit nucellar polyembryony. Understanding the genetic basis of mono- or polyembryony has been the subject of many studies due to its importance in citrus cultivation. Large-scale production of seedlings identical to the parental genotype is an essential feature of plants used for rootstocks in the nursery industry. However, for breeding purposes, monoembryonic parents are preferred since genetic variability is essential to generate improved genotypes. Up to three quantitative trait loci correlated with the polyembryonic trait have been reported (Iwamasa et al. 1979; Kepiro and Roose 2010; Raga et al. 2012).

Recent analysis of many citrus genome sequences (including a citron genome) has contributed towards understanding the molecular basis of polyembryony. Wang et al. (2017) sequenced four citrus species including primitive species, wild types, and cultivated types showing mono- or polyembryony. Genome sequences of four monoembryonic types (citron, pummelo, *Atalantia*, and a papeda) were compared with previously published sequences of 'Clementine' and sweet orange. Analysis of six complete genomes, together with a population of 124 individuals resulting from a cross between a monoembryonic pummelo and a polyembryonic mandarin, resulted in the identification of an 80 Kb region on chromosome 4 with 11 candidate genes putatively associated with polyembryony. Three of these 11 genes, *EDA24, AGL2,* and *ACR4* have been previously associated with flower and embryo development in *Arabidopsis* (Gifford et al. 2003; Dreni and Zhang 2016). In citrus, these three genes were differentially expressed in mono- and polyembryonic types. In addition, a specific gene, *CitRWP* was highly expressed in the ovules of polyembryonic cultivars. Gene *CitRWP* encodes an RWP-RK transcription factor implied to have a role in the regulation of egg cells (Koszegi et al. 2011). A MITE insertion (miniature inverted-repeat transposable element) in the promoter region of *CitRWP* showed a strong correlation with the polyembryony phenotype. The specific MITE insertion was detected in 213 polyembryonic accessions and absent in 573 monoembryonic progeny segregating for the polyembryony trait. The inclusion of the citron genome sequence in this analysis contributed towards understanding the molecular basis of polyembryony (Wang et al. 2017) (Fig. 2.4).

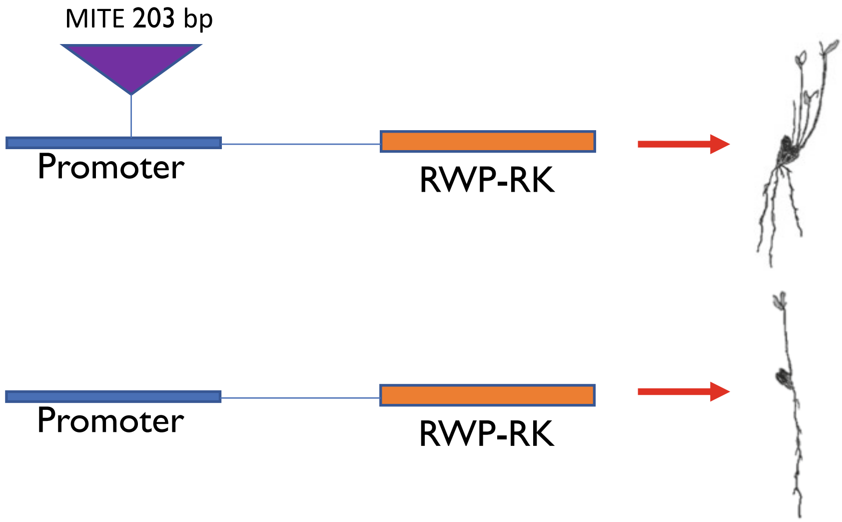

Fig. 2.4 Molecular basis of polyembryony. The gene CitRWP on chromosome 4 codes for a transcription factor RWP-RK. Presence of a 203 bp MITE insertion (miniature inverted-repeat transposable element) in the upstream promoter region is correlated with polyembryony phenotype (n = 58; top panel). Monoembryonic varieties (n = 66; bottom panel) lacked the MITE insertion. (Cartoon based on Wang et al. 2017.)

2.7 Anthocyanin Production and Acidity in Citrons

Citrus plants belonging to the acid group (citrons, limes, and lemons) produce anthocyanins in their young leaves and flowers, a characteristic not shared by most mandarins and pummelos. The acidity of citrus fruits, along with the sweetness, determines fruit quality. Molecular mechanisms underlying the anthocyanin pathway and its correlation with fruit acidity have been investigated recently (Fig. 2.5). Anthocyanin biosynthesis, modification, and transport are known to be associated with regulatory proteins including MYB (myeloblastosis) transcription factors (TFs), basic helix-loop-helix TFs, and WD40-repeat proteins that together belong to the MBW (MYB-bHLH-WD) transcriptional complex (Quattrocchio et al. 1993; Kobayashi et al. 2004; Schwinn et al. 2006).

In *Citrus*, the *Ruby* gene encoding a MYB TF was shown to be associated with the accumulation of anthocyanins. In a study involving 69 accessions belonging to various citrus groups and close relatives (including four citrons, ten lime varieties, and five lemon accessions), Butelli et al. (2017) analyzed the *Ruby* locus and reported six types of deletions, six insertions of transposable elements, translocation events and several point mutations in the *Ruby* gene and its promoter. In plants showing these aberrations, there were varying effects on anthocyanin accumulation that could be directly associated with *Ruby*. Two *C. limon* accessions were compared for pigment production, presence of genomic fragments, and transcripts associated

Gene	Function	Type of gene	Function	Reference
Ruby	Transcription factor (Myb)	Wild type	Accumulation of anthocyanin	Butelli et al. 2017
		Deletions, insertions, transposable elements, translocations or point mutations in the *Ruby* gene and its promoter	Anthocyanin accumulation affected	
Noemi	A bHLH Myc transcription factor	Wild type	Acidic fruits with anthocyanin.	Butelli et al. 2019
		Deletion (of 1313 nucleotides) or insertion of retrotransposons	Reduced expression of *Noemi* resulting in increased pH of juice, lower anthocyanin.	
CitPH1, *CitPH5*	P-ATPases	Wild type	Higher level of expression results in hyperacidification	Strazzer et al. 2019.
		Inactivating mutations in CitAN1	Lower levels of expressions results in non-acidic fruits	
CitAN1	Transcription factor (Myc)	Different mutations	Regulates expression of *CitPH1* and *CitPH5* resulting in loss of acidity	

Fig. 2.5 Genes regulating anthocyanin production and fruit acidity

with the *Ruby* locus. 'Femminello' lemon has purple pigmentation and a functional *Ruby* gene, while the bud sport derived from it, 'Zagano Bianca', has no pigmentation in the leaves or flower buds and has a major deletion in the *Ruby* locus. A Copia-like retrotransposon insertion in the *Ruby* gene reported in blood oranges was highly correlated with the development of strong pigmentation in the fruits (Butelli et al. 2012). In finger lime (*Microcitrus australasica*), transposons belonging to the SINE (short interspersed nuclear elements) family were associated with anthocyanin production in the fruit. Similar SINE transposons were observed in the Chinese box orange plant, *Severinia buxifolia*, which has highly pigmented fruits (Butelli et al. 2017).

In a follow-up study, Butelli et al. (2019) studied citrus accessions having a wild-type *Ruby* gene, yet lacking pigmentation. Two other associated traits commonly observed in these plants were the absence of proanthocyanidins in the seeds (characterized by the absence of a chalazal spot on the inner seed coat) and a substantial loss of acidity in the fruit juice. These plants were described as having the "acidless" phenotype. A bHLH MYC transcription factor, *Noemi*, was shown to be a major determinant of fruit acidity. In a comparative study conducted using two types of citron, the role of *Noemi* was described; 'Poncire Commun' is a cultivar that can synthesize anthocyanins, proanthocyanidins and has juice with a pH of about 2.5; 'Corsican' citron is genetically close to 'Poncire Commun' (Luro et al. 2012) but has the acid-less phenotype with a juice pH of 5.5. Sequences of the *Ruby* gene, two additional genes that encode the WD-40 class of proteins (the bHLH gene MYC2 and a gene encoding a different bHLH protein that was named *Noemi*) were analyzed. The only difference between the pigmented, acidic 'Poncire Commun' and the anthocyanin-less, acidless 'Corsican' was a deletion of 1313 nucleotides in the 3' terminus of *Noemi*. This deletion was homozygous in 'Corsican' and heterozygous in 'Poncire Commun'. The resulting protein is predicted to have a deletion of 275 amino acids, the entire bHLH domain that is known to be essential for interactions with other proteins (Wen et al. 2018). Analysis of the progeny of 'Poncire Commun' showed that anthocyanin-producing seedlings of 'Poncire Commun' had at least one wild type allele of *Noemi*. Supporting evidence for the role of *Noemi* was obtained from an analysis of 'Assads' citron, 'Yemen' citron, and 'Greek' citron, which were heterozygous for the 3' deletion of *Noemi*; 'Yemen' and 'Greek' citron are acidless etrog-type citrons. Two Chinese fingered citron cultivars with white flowers and green leaves, 'Qingpi' and 'Aihua', were homozygous for the *Noemi* deletion. The presence of this deletion in Chinese fingered citrons indicated that the gene modification responsible for the acidless phenotype is ancient and probably originated before the arrival of citrons in the Mediterranean region. Correlation between a functional *Noemi* gene, synthesis of anthocyanins, and acidity of the juice was demonstrated in 33 citrus types belonging to different groups (Butelli et al. 2019).

In a separate study, Strazzer et al. (2019) identified molecular mechanisms that determine fruit acidity. Citrus fruits with low acidity express *CitPH1* and *CitPH5*, two interacting P-ATPases that constitute a vacuolar pump which acidifies intracellular compartments and transports protons across the plasma membrane. Two vacuolar proton pumps generate a steep pH gradient across the tonoplast (the membrane around the vacuole of a plant cell), causing transport of citrate into the vacuole of juice vesicles resulting in hyperacidification. Genes *CitPH1* and *CitPH5* were expressed at high levels in sour fruits and at low levels in non-sour fruits. A MYC transcription factor, *CitAN1*, regulates the expression of *CitPH1* and *CitPH5*, resulting in loss of acidity. The studies were conducted in 'Faris' lemon that produces sour or non-sour (sweet) fruit on different branches of the same tree providing an opportunity to compare acidic fruits (pH 2.5) with non-acidic types (pH 5.1). Extension of this study to other low pH lemons ('Frost Lisbon', 'Shaub', 'Amber') and high pH lemons ('Faris Sweet', 'Millsweet', and other sweet lemons) confirmed the gene expression patterns. Data obtained from citron hybrids (lemons) was useful to understand the molecular mechanisms involved in fruit acidity.

2.8 Genes Determining Fruit Shape

Citrons often have unusual morphological characteristics such as a persistent style (pitam), fingered fruit shape (usually accompanied by solid albedo lacking in locules or pulp), acidless pulp, and locules empty of pulp (Ramadugu et al. 2015; Karp and Hu 2018). The genetic-physiological bases of these peculiar, fascinating phenotypes observed in citrons have not yet been fully elucidated (Goldschmidt 2017), but scientists have begun to make a start.

Multiple genes belonging to gene families *SUN*, *OVATE*, *YABBY*, and *FAS* are implicated in determining fruit shape in tomato and other crops (Rodriguez et al. 2011). Several genes known to be determinants of fruit shape were identified by PCR amplification in fingered citrons (Liao et al. 2018). From the *SUN* gene family (Pan et al. 2017), *CmsSUN20* was amplified from fingered citron. From the *OVATE* gene family (Liu et al. 2002; Tsaballa et al. 2011), genes *CmsOVATE*, *CmsOFP7,* and *CmsOFP12* were identified; from the *YABBY* gene family, the following genes were recognized: *CmsYABBY5*, *CmsCRC*, *CmsINO*, *CmsYAB2*, and *CmsYAB1*. Gene expression studies of these fruit-shape determining genes in several citrons will be useful in understanding the basis for the unique fruit shapes observed.

Pan et al. (2020) conducted transcriptome analysis of fingered citrons at different developmental stages. As the fruit turned from green to yellow, expression levels of the following genes associated with the flavonoid biosynthetic pathway gradually increased: phenyl ammonia lyase (*PAL*), chalcone isomerase (*CHI*), flavonoid 3′-monooxygenase (*CYP75B1*), zeta-carotene desaturase (*ZDS*), 4-coumarate isomerase coenzyme A ligase (*4CL*) and flavonol synthase (*FLS*).

Some fingered citrons are parthenocarpic, developing fruit without fertilization. In one fingered citron cultivar, Liao et al. (2017) reported obligate parthenocarpy, which is usually caused by male or female sterility and results in fruits that are completely seedless. Molecular analysis revealed that the mRNA expression levels of the auxin-related genes *IAA9*, *AUCSIA,* and *PIN4* were down-regulated after anthesis. Low transcription of *CmsIAA9* was correlated with parthenocarpic fruiting in fingered citron.

Growers of fingered citrons have long recognized that the development of “open” or “closed” fingers (Fig. 2.6) appeared to be dependent on temperatures during fruit development. The molecular mechanism began to be elucidated when Chen et al. (2019) studied the expression of genes involved in carpel development in fingered citrons. The promoter for *CRABS CLAW* (CRC), a gene associated with carpel and nectary development, was first discovered in *Arabidopsis*. The gene *CmsCRC* is implicated to have a role in regulating the spreading of fingers in ‘Qingpi’ citron exposed to cold temperatures. Typically, the fingers stretch out, but they roll up to form a fist when cultivated at temperatures below 20 °C during flower formation. This difference in fruit shape may, therefore, be correlated with the *CRC* gene expression pattern.

2.9 Perspective

Many of the studies reviewed in this chapter date from the past decade, but many topics remain to be addressed: the phylogenetic relationships of citrons in China,

Fig. 2.6 Fingered citrons with open and closed fingers at maturity. **a** ‘Octopus’ open-fingered citron. **b** ‘Chuan’ citron with closed fingers

India, Southeast Asia, and Indonesia; the linking of specific fingered citron cultivars to their non-fingered parents or relatives; genes linked to the characteristic shape of citron cultivars, or the persistence of the pitam; and the possible epigenetic influence of grafting citron on diverse rootstocks. As much as we have learned about citron genomics in recent decades, it seems likely that a deeper understanding will emerge before long, with important implications both for citron and for citrus as a whole.

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Chapter 3
Phytochemistry of the Citron

Yoram Eyal

Abstract Citron (*Citrus medica*) is considered as one of the four ancestral *Citrus* species and has been in use for thousands of years as a natural source for both aroma and insect repelling compounds. Citron leaves, fruit peel and flesh contain a variety of metabolites of the phenylpropanoid family (coumarins, furanocoumarins, flavonoids including anthocyanins) and isoprenoid family (mono- and sesquiterpenes, carotenoids, limonoids) involved in a variety of ecological functions. Chemotaxonomy of citron in the context of the *Citrus* genus demonstrates a metabolic profile different from pumelo, mandarin, oranges and grapefruit, but resembling lemon, in agreement with the available genetic and genomic data.

3.1 Introduction

The citron (*Citrus medica* L.) is considered as one of the ancestral *Citrus* species (alongside pumelo, mandarin and papeda) and has been used for thousands of years as a medicinal plant as well as a source for extracting aroma and pest-repelling compounds (Alvarez Arias and Ramon-Laca 2005; Gabriele et al. 2009; Panara et al. 2012). The pharmacological/health related properties, as well as other human uses of the citron that are not ritualistic, stem mainly from the secondary metabolite composition of the fruit, which is the focus of this chapter.

3.2 Phenylpropanoids

Flavonoids are the dominant group of phenylpropanoids in most *Citrus* species, yet in citron coumarins appear to dominate (as a reference for the ratio of the major phenylpropanoids in citron: the flavedo contains 77% coumarins vs. 21% flavonoids) (Berhow et al. 1998), and limettin is the dominant coumarin in citron

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as well as in lemon (Dugrand-Judek et al. 2015) (Fig. 3.1). The coumarin umbelliferone serves as a precursor for the biosynthesis of furanocoumarin plant defense compounds in some *Citrus* species, including grapefruit. These compounds have been established as the underlying cause of "grapefruit-drug interactions", whereby the blood/cellular levels of statins and other prescription drugs are affected by consumption of grapefruit. In citron (and similarly in lemon), significant accumulation of furanocoumarin compounds of the three known clusters has been documented in the peel {mainly oxypeucedanin and oxypeucedanin-hydrate of the bergapten cluster; mainly phellopterin, byakangelicol and byakangelicin of the isopimpinellin cluster; mainly heraclenin and heraclenol of the xanthotoxin cluster} (Dugrand-Judek et al. 2015) (Fig. 3.1) but levels of all these compounds in the pulp were found to be very low.

The dominant group of flavonoids in most *Citrus* species are the flavanones that accumulate in large quantities in young leaves and fruit and are gradually diluted as the leaves expand and the fruit grows (Bar-Peled et al. 1993). Accordingly, it has been assumed that flavanones have a role in citrus in plant defense, mainly in young tissue. Citron is the exception as it accumulates much lower levels of flavanones than most other *Citrus* species and instead accumulates higher levels of flavones (mainly diosmin) and flavonols (mainly rutin) in young leaves and fruit (Berhow et al. 1998; Roowi and Crozier 2011; Menichini et al. 2011; Venturini et al. 2014)

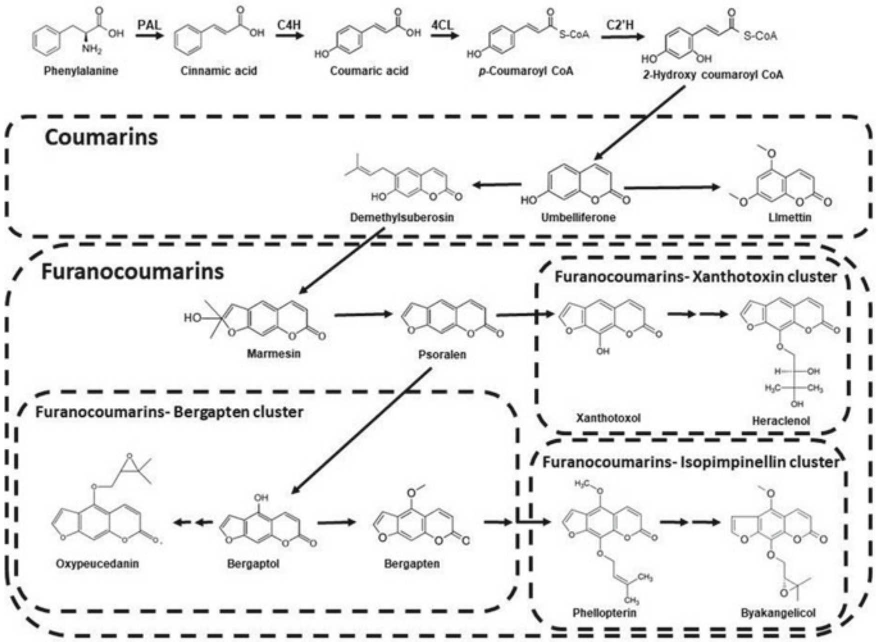

Fig. 3.1 Coumarin and furanocoumarin biosynthesis pathway in citron. Compounds shown are end-products typically accumulating in citron or pathway junction intermediates

(Fig. 3.2). The evolutionary significance of this unique flavonoid profile of citron is not known and may reflect different requirements to cope with the environment in the geographical origin of citron. Alternatively, flavanones, flavones and flavonols may have overlapping or redundant roles as defense compounds.

Flavonoids accumulate in citrus as glycosides consisting of monosaccharide or disaccharide moieties. The latter most commonly consist of the disaccharide rutinose (rhamnose-1,6-glucose), which results in tasteless compounds typical of mandarins, or the disaccharide neohesperidose (rhamnose-1,2-glucose) which may result in bitter compounds typical of grapefruit (Fig. 3.2). In citron the flavonoid-glycosides are all

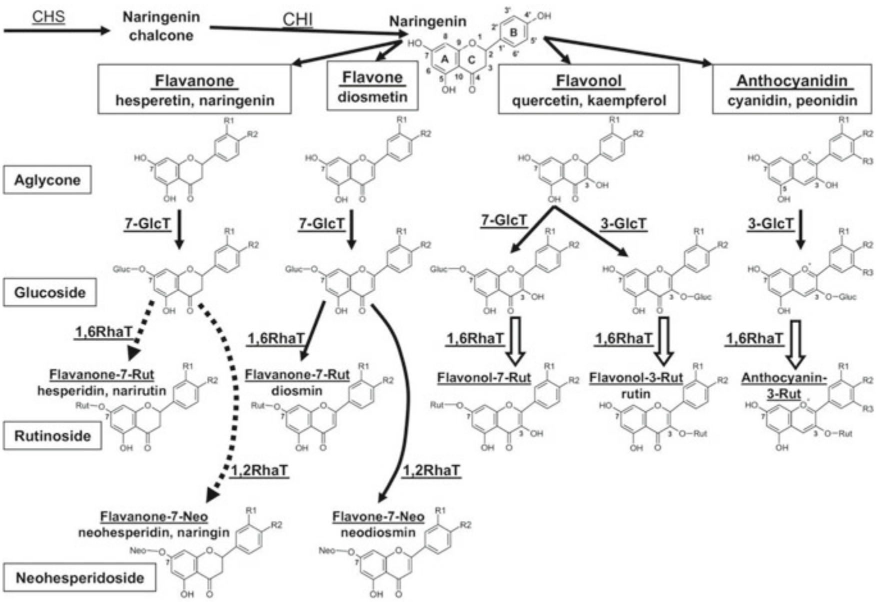

Fig. 3.2 Biosynthesis of flavonoids in citrus. Three molecules of malonyl-CoA and one of *p*-coumaryl-CoA are condensed in a reaction catalyzed by chalcone synthase to create naringenin chalcone. A stereospecific ring closure isomeration step catalyzed by chalcone isomerase converts the chalcone to the flavanone naringenin. The latter serves as a junction in the pathway and is converted to other flavanones (e.g., hesperetin), to flavones (e.g., diosmetin) to flavonols (e.g., quercetin, kaempferol) or to anthocyanidins (e.g., cyanidin, peonidin) (flavonoid subgroups are boxed). In citrus, flavanones are glucosylated at position 7 to create flavanone-7-*O*-glucosides, such as naringenin-7-*O*-glucoside, by a 7GlcT (7-*O*-glucosyltransferase). The latter serves as a substrate for the bitterness determining step (labeled by dashed-line arrows) catalyzed by either a 1,6 rhamnosyltransferase (1,6RhaT) to yield tasteless 7-*O*-rutinosides (e.g., hesperidin, narirutin; Lewinsohn et al. 1989) or a 1,2RhaT rhamnosyltransferase (1,2RhaT) to yield bitter 7-*O*-neohsperidosides (e.g., neohesperidin, naringin). Flavone branched-chain glycosylation follows the same enzymatic pathway leading to either 7-*O*-rutinosides (e.g., diosmin) or 7-*O*-neohsperidosides (e.g., neodiosmin). Additional flavonoids, flavonols (e.g., quercetin, kaempferol) and anthocyanidins (e.g., cyanidin, peonidin), are subject to either 3-*O*-glucosylation or 7-*O*-glucosylation followed by 1,6RhaT catalyzed branched-chain rhamnosylation (labeled by empty arrows) (from Frydman et al. 2013)

tasteless and most contain a rutinose moiety, while modification with neohesperidose is entirely absent (Berhow et al. 1998). Accordingly, the enzyme catalyzing rutinose modification is expressed in citron, while the enzyme catalyzing neohesperidose modification is entirely absent (Frydman et al. 2004, 2013). The majority of flavonoid-glycosides in citrus, such as rutinose and neohesperidose modifications, occur as O-linked glycosylations (i.e., sugar linked to the flavonoid skeleton via an oxygen atom), yet C-linked glycosylations (i.e., sugar linked directly to a carbon atom of the flavonoid skeleton) have been documented. Citron has been shown to contain both O-linked glycosylations (e.g., rutin, diosmin) and C-linked glycosylation (e.g., diosmetin-6,8-di-C-glucoside and diosmetin-6-C-glucoside) (Roowi and Crozier 2011).

Anthocyanins are an additional subgroup of flavonoids that have a typical accumulation pattern in different *Citrus* species. Citron and lemon are unique in the genus *Citrus* in accumulating anthocyanins (mainly the red pigmented cyanidin-rutinoside) in very young leaves, buds and fruitlets (Frydman et al. 2013; Frydman et al. unpublished results). Anthocyanin accumulation in young leaves is typical of many species in the plant kingdom and has been suggested to assume roles in plants defense (Karageorgou and Manetas 2006); quenching of light/fluorescence returning from the leaves may prevent perception of the leaves by pests, thus lowering infestation. Alternatively, leaf anthocyanins may attract predators of pests that feed on young leaves. The species-specific pattern of flavonoid accumulation in citron young tissue (i.e., anthocyanin accumulation which is typical only in citron and lemon vs. high flavanone accumulation which is typical for most *Citrus* species excluding citron and lemon) may represent different strategies for plant defense that vary based on geographical origin. Others have suggested that an additional role for anthocyanins is the photoprotection of young tissue from excess light by quenching (Karageorgou and Manetas 2006) or as a means to lower light harvesting under stress due to a combination of cold nights and high daylight radiation. Nevertheless, it is difficult to explain why citron would be the only ancestral *Citrus* species to require additional photoprotection for young tissue, unless conditions that prevailed during its speciation were more extreme than they are today.

3.3 Isoprenoids

3.3.1 Terpenes

Monoterpenes (C10) and sesquiterpenes (C15) are the major volatiles synthesized in all *Citrus* species (Fig. 3.3), including citron, and are major factors in the unique aroma/flavor of each *Citrus* species/variety. Terpenes are synthesized and stored in essential oil glands located in the fruit peel, the flower corolla and the leaves, as well as in small quantities in the juice sacs as oil droplets, and have diverse ecological functions. Terpenes accumulating in citrus flowers (such as the monoterpenes linalool

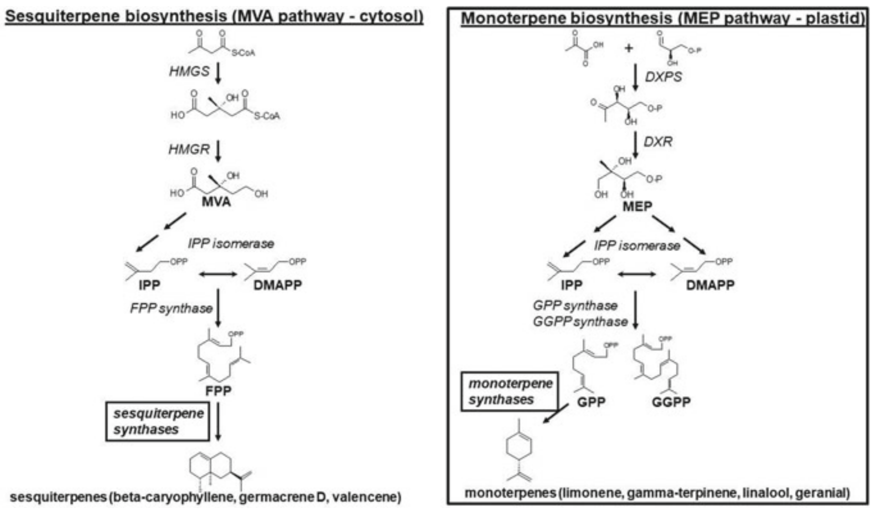

Fig. 3.3 Volatile terpenes biosynthesis pathways in citrus. Monoterpenes (C10) are synthesized by monoterpene synthases of the plastid-localized MEP (methylerythritol phosphate) pathway via the precursor GPP (geranyl pyrophosphate). Sesquiterpenes (C15) are synthesized by sesquiterpene synthases of the cytosol-localized MVA (mevalonic acid) pathway via the precursor FPP (farnesyl pyrophosphate)

and geranial) appear to assume a role as pollinator attractants and are very effective in attracting bees. Terpenes present in leaves and fruit peels throughout development (such as the monoterpene limonene) appear to have a role in plant defense, while terpenes accumulating in citrus peels at the late stages of fruit maturation may function as attractants of fruit-eating animals for the purpose of seed dispersal (Sharon-Asa et al. 2003). The unique aroma of mature citron fruit is determined by the composition of the terpenes in the fruit peel essential oil which consists of over 60 volatile compounds (Gabriele et al. 2009; Venturini et al. 2014; Chhikara et al. 2018). These include limonene (60%; lemon-like odor), gamma terpinene (25%; herbaceous-citrusy odor) and geranial (sweet, citrusy, lemon odor).

3.3.2 Limonoids

Limonoids of the tetranortriterpene family are known to be responsible for the "secondary bitterness" in citrus juices, bitterness caused by oxidation of these compounds as a result of exposure to atmospheric oxygen when the juice is squeezed out of the juice sacs (Roy and Saraf 2006). Citron was found to contain the limonids—limonin and nomilin, which accumulate in seeds, peel and pulp. These compounds are attributed as having biological activity against a variety of insects as well as pharmacological activity as antibiotic or anti-viral compounds (Roy and Saraf 2006).

3.3.3 Carotenoids

The pulp of the citron is relatively poor in carotenoids compared with mandarin and orange (total carotenoid count of citron pulp is less than 1% of that in mandarin pulp) and consists mostly of beta-cryptoxanthin (Fanciullino et al. 2006). The levels of carotenoids are similarly low in lemon pulp (Kato et al. 2004; Fanciullino et al. 2006; Kato 2012). While data are lacking regarding the precise composition of carotenoids in the citron flavedo, based on the similar color it is likely similar to the composition in lemon, in which the most abundant carotenoid is the colorless phytoene. The yellow color results from a mixture of all-trans violaxanthin, lutein and beta-cryptoxanthin (Kato 2012).

3.4 Chemotaxonomy of Citron

The increasing availability of plant genome sequences has revolutionized the field of plant taxonomy (for available citrus genomes see Rao et al. 2021). Nevertheless, the "dry" sequence data and annotations do not always provide the complete evolutionary picture when studying genetically close-knit genera like citrus. Inheritance of singular/minor sequence changes, which may have a crucial effect at the encoded enzyme activity level and the resulting metabolite profile, may be overlooked by computerized sequence-based phylogeny. Thus, the study and documentation of plant metabolites (phytochemistry) and their metabolic pathways continue to impact plant taxonomy and evolution research in the genomic era.

Plant chemotaxonomy, the use of phytochemistry in plant taxonomy (Hegnauer 1986), was established in the twentieth century based on phytochemistry research initiated in the eighteenth century, but flourishing since the 1940s with the advent of paper chromatography and other analytical methods. Chemotaxonomy based on the carotenoid profile (Fanciullino et al. 2006) roughly divides the genus *Citrus* into three groups: (1) oranges and mandarins; (2) citron and lemon; and (3) pumelo and grapefruit. A chemotaxonomic analysis based on the composition of volatiles yielded similar results and places the citron, rough lemon and lemon in one group (Liu et al. 2013). Chemotaxonomy based on the flavonoid profile further demonstrates the close relation between citron and lemon; (1) the dominant flavanones in both citron and lemon are hesperidin and eriocitrin (Berhow et al. 1998); and (2) citron and lemon are unique in the genus *Citrus* in accumulating high levels of anthocyanins (mainly cyanidin-rutinoside) in young leaves, buds and fruitlets.

Chemotaxonomy based on the coumarin/furanocoumarin content also supports the genetic relation between citron and lemon. Although levels of coumarins and furanocoumarins are significantly lower in lemon compared to citron, the specific composition of metabolites of these groups in citron and lemon is strikingly similar (Dugrand-Judek et al. 2015). Overall, chemotaxonomy studies support the notion that citron is one of the parents in a cross that derived lemon. This conclusion is also supported by genomic sequence data.

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Part II
Cultivation and Production

Chapter 4
Selected Aspects of Commercial Production in Etrog Orchards

Assaf Avtabi and Joshua D. Klein

Abstract Etrog fruits are grown in only a few of the many countries that produce citrus. The fruits are unusual among citrus in that the vast majority of the crop is valued only for its external appearance, and is produced and sold to a particular ethnic-religious market. Etrog trees must be grown in frost-free areas with little wind and good soil drainage. The trees are easily rooted and established from cuttings, although there is a danger of transmission of disease by this method. Trees can also be grown from seed, which mitigates disease transmission. However, seed-derived trees are not always identical to the mother plant. Trees are best established in Spring, for religious (counting of the orla years) and horticultural (gaining strength before Winter) reasons. Etrog trees are usually trained to a trellis system for ease of access to fruit, and are grown on raised beds for ease of rooting, with trickle irrigation for directed fertilization, and under shade cloth to protect the trees and especially the sensitive fruit from solar damage. Maintenance of fruit quality requires repeated spraying of various compounds, but spraying is minimized later in the season to avoid peel stains that make the fruit unmarketable. A unique spray treatment is the use of Picloram early in the season for retention of the style ("pitam" in Hebrew), which enhances marketability of the mature fruit. Although etrog trees flower three times a year, selective drought in the Spring is recommended to suppress the early wave of flowering, which often produces less-marketable fruit. Etrog fruit are highly variable in shape, and not all shapes are accepted commercially. Commercial orchard yields are maintained for 12–14 years, after which the yield decreases, partly because of tree age and partly because of heightened sensitivity to disease.

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4.1 Introduction

> "Soon we will start the harvest… I'll pick and you follow me, take the etrog from my hand, and place it carefully on the bed of flax" (etrog grower to his young wife).
>
> "You hold the etrog by its belly, not by its head, lest the pitam break. You don't hold it by its bottom, either, where it is separated from the tree, because that spot is very delicate."
>
> Her husband crawls under the tree, shears in his hand. "Perfect, perfect, come to me my prince," he calls to the etrog that is hanging demurely on a small branch at the base of the tree. "Do you see it? Have you ever in your life seen such a perfect thing? Look at its shape, the delicate crevices on its body, the ideal color."

This selection from *The Season*, by Neumann (2014), gives the reader an indication of the special relationship between the grower and the etrog fruits he labors to produce. The following chapter is devoted entirely to the etrog, which across the generations has been the subject of many discussions surrounding how a fruit worthy of a *bracha* (blessing) should look. As is often the case with halakhic discussions, the rabbinic authorities were frequently divided, sometimes by their individual personal knowledge of the fruit, and sometimes by virtue of their geographic distance from the etrog orchards. This meant that their knowledge of the etrog tree was based only on information found in books that they had read. Indeed, few people truly know from first-hand knowledge how the exotic etrog tree grows and how it is distinguished from other citrus trees; certainly not Jewish people in the Diaspora, and indeed not even many of those living in Israel. It is not an easy tree to grow, and it is doubtful that any other fruit tree grown in Israel requires such a complicated regime of horticultural care. Indeed, despite the fact that the etrog tree has been grown and the halakhot (Jewish laws) of the trees have been discussed for many generations, there has not been a thorough presentation of commercial etrog production in Israel until the present time, with the exceptions of a booklet by Moshe Gorelik and a brief chapter by Joshua Klein (Gorelik 1968; Klein 2014). Needless to say, much of the information presented includes specialized discussions on botany, horticulture, soils, and climate. Since the etrog is also a ritual object, the relevant religious laws (halakhot) of commerce and agriculture must also be considered, because the etrog is grown commercially and the competition in the market is fierce. The present chapter cannot take all these elements into account, however, and can only present a few of the many challenges that etrog growers must recognize and overcome in order to produce "fruit of the goodly tree" (Lev. 23:40) for the populace that observes the commandment of the Four Species during Sukkot.

Etrog trees, like other citrus, can be grown in the middle-latitudes between 35° north and 35° south. Unlike other citrus such as oranges, grapefruits, lemons and other easy-to-peel fruit that are grown on large tracts of land around the world, etrogim are grown in only a few countries. Even in those countries, etrogim are grown on less than 0.1% of the land devoted to citrus. Growing etrog citrons for religious use requires large investments in money and knowledge and has many more possibilities for failure than other citrus crops. It is important to stress this, since every year after the Tishrei holidays there are those who fear that they have missed a great economic opportunity by not growing etrogim, whose individual price in the case of "*mehudar*" (extraordinarily beautiful with rigorously documented origin) fruit can equal the farm-gate price of as much as a tonne of other fresh citrus fruit. It should be emphasized that the marketing window for etrogim is very narrow, since the fruit is only used for the seven days of the Sukkot holiday, and the supply of etrogim in Israel already is greater than the demand.

It is not surprising, therefore, that the etrog market is extremely competitive, and that marketing requires extraordinary professional and commercial skill. Etrog trees are unusual commercially, since trade in their fruit does not rely on flavor or culinary quality, but solely on external appearance. Grower financial return in marketing other fruits depends on fruit quality and on seasonal yield. Commercial competition in the etrog market revolves around the fruit's external quality, in addition to the reputations of the growers, distributors, and marketers as well as the perceived prestige of the etrog variety being marketed. Achieving the consumer-desired quality requires the commercial etrog grower to attain perfection in growing, distribution, and marketing.

Currently, etrog growers in Israel do not grow fruit intended primarily for consumption or industrial use, aside from a small amount of fruit that is kept on the trees for those who wish to make the "shehecheyanu" blessing on Tu B'Shvat, or for a small amount of candied fruit. These latter comprise a tiny amount of overall production.

This chapter is based on the first author's vast experience as an extension agent and advisor to etrog growers in Israel and abroad. Any information not included because of space limitations in the current volume will appear in a future volume devoted solely to etrog growth and production in Israel, a highly-specialized topic that differs in many respects to the production of other tree-fruit crops.

4.2 Establishing an Etrog Orchard

4.2.1 Selection of Land

The parcel of land selected to grow etrogim should not have low winter temperatures and should be without frosts, high winds, or sandstorms. Land with good air drainage will be free of frost, and good soil drainage will avoid flooding and associated soil diseases. In general, it is best to plant etrog trees in light-to-medium soils, such as the hamra or hamra-sand soils of the Sharon and coastal plain regions of Israel. However, careful use of drip irrigation-fertigation offers the supply of deficient nutritional elements, and the neutralization of elements that are in excess in the soil, such that it is possible to grow premium etrogim on loess soils in the Negev and in marginal soils in other areas of Israel.

Etrog trees are planted on raised beds, similar to other citrus trees. This allows proper drainage, which is especially important in etrog production since the trees are not grafted onto rootstocks and have to produce their own root system. Etrog trees are particularly sensitive to salinity in soils and in irrigation water, growing best in soils that are pH neutral or slightly acidic. There are not many regions in Israel with such soil, but this can be compensated through management of irrigation and fertilization. With proper agrotechnology, even soils that are slightly basic can be made to produce commercial crops of quality etrogim.

Commercial etrog production is an intensive procedure, requiring expertise in a range of techniques such as optimal irrigation and maintenance of strict sanitation of the fruit such that it is free of biotic and abiotic sources of injury. The electrical conductivity of the soil should be checked before planting. If it is less than 1 dS m^{-3}, it is not considered saline and is appropriate for planting etrog trees. If it is more than 3 dS m^{-3}, the soil is too saline for planting. Intermediary values will require investigating and correcting/neutralizing the sources of salinity. Most soils in the central part of Israel (hamra or hamra-sand and similar) are appropriate for planting etrog trees, but northern and southern soils are less suitable and should be treated as necessary before planting.

4.2.2 Preparation and Planting of Etrog Saplings

Most etrog saplings that will provide fruit for the Four Species are produced vegetatively by rooting cuttings (asexual propagation), but a minority are germinated from seeds (sexual propagation). Each method has its advantages and disadvantages. The Israeli Plant Health Authorities require by law (Israel Ministry of Agriculture 1991) that any mother plant providing propagation material be officially certified free of disease. Despite this law, many etrog trees are propagated without such oversight, because of the "commercial secrets" of the growers regarding many of their sources and methods. This secrecy can result in the inadvertent spread of diseases to non-etrog citrus groves (see also Chap. 7 "Diseases of the Etrog Citron and Other Citrus Trees" in this volume). The common current practice is for growers to source propagation material from exemplary trees in their own or others' orchards which produce fruit of the desired quality. In the absence of governmental oversight, it behooves growers to do the right thing for themselves and for their neighbors by going to an authorized laboratory to check propagation material for the presence of viral diseases, *mal secco*, and other diseases that initially can only be detected in the laboratory.

4.2.2.1 Propagation from Cuttings

A cutting is a section of a branch that is taken from the mother plant, rooted, and subsequently grows to become a sapling that develops into a tree identical to the mother tree (Goldschmidt 2006). Thick and thin cuttings root equally well, with thin cuttings able to root even if only 2–3 cm long, as long as there are at least a few leaf buds present. Growers, however, find it more convenient to use longer cuttings. In order to limit transpiration and to conserve internal moisture, it is best to retain only the topmost two leaves on a cutting, and to cut those leaves in half laterally. This, in turn, will induce formation and activity of endogenous rooting hormones needed to establish the cutting (Avtabi and Zigel 2009). It is best practice to transfer the cuttings to a rooting medium immediately after removing them from the mother tree. If this is not possible, the cuttings must be disinfected before being placed in double plastic bags at 5–8 °C. Prepared cuttings are inserted in the rooting medium to more than half their length and are maintained in shade at 28–30 °C at high humidity, which can be achieved by use of sprinklers. Care must be taken that the humidity is not so high that it causes rot at the exposed base of the cutting. Rooting is usually easy even for hobbyists who want to produce only a few trees and do not have the facilities of plant nurseries. Figures 4.1, 4.2, 4.3 and 4.4 illustrate the detailed rooting procedures.

There are many advantages to growing etrog trees from cuttings, among them saving water—the time from taking the cutting from the mother plant, rooting, growing, transplanting in the orchard and getting the first yield is at most three years (see further in Sect. 4.2.2.3 Planting Etrog Saplings below). More importantly, vegetative propagation ensures that the resulting tree will produce fruit similar to that of the mother tree, and that consumers will get exactly the type of fruit that they want for the Four Species.

There are, however, disadvantages to vegetative propagation, chief among them transmission of viruses and other diseases that may be found in the mother plant. The diseases might not only be established in the new plantings but could also be transmitted to nearby established groves, even those of other citrus varieties. Seed-derived trees, in contrast, are rarely infected with transmissible virus diseases. Vegetative

Fig. 4.1 Etrog cuttings in a heated rooting bed with a misting system to maintain moisture

Fig. 4.2 Etrog cuttings of the 'Hazon Ish' variety, in small (200 mL) plastic pots filled with a light rooting medium (perlite)

Fig. 4.3 Bare-root etrog cuttings

Fig. 4.4 Rooted etrog cutting in a small (125 mL) flexible container (left) and etrog cuttings rooted in 2 L plastic bags for direct transplanting to the orchard (right)

propagation also requires more skill than planting seeds, as well as requiring heated propagation tables, but these technicalities can be overcome by collaborating with professional nurseries that supply citrus and other fruit trees. It is necessary to ensure the phytosanitation of the trees in the mother orchard, which must be examined and certified by the Plant Protection Authority of the Ministry of Agriculture, as is done with all fruit trees in Israel.

4.2.2.2 Seed Propagation

Seed propagation of etrog saplings is easy and is especially practiced by those who take the etrogim that their rabbis used, remove the seeds, and place them in soil in pots. The resulting seedlings can be transplanted into private gardens or commercial orchards.

The main disadvantage of this method is that the seedlings are not necessarily similar genetically. Seedlings may vary in vigor, in time of flowering, and in fruit shape. A more serious consideration is that seedlings take a year longer than cuttings to begin producing fruit, since they first undergo a non-flowering "juvenile" period that is absent in vegetatively-propagated plants (Avtabi and Levi 2002).

Nonetheless, seed-derived trees have an advantage over vegetatively-propagated saplings in that they are free of many disease organisms. There is also the possibility that the inherent genetic variability of the seeds will result in the appearance of a tree that has better characteristics or that bears fruit that are even better than the ones found on the mother plant.

4.2.2.3 Planting Etrog Saplings

The best time to plant etrog saplings is in the spring, but some growers delay planting until just before 15 Av, because of the calculation of the *orla* years (see next paragraph). These later plantings are often done under time pressure and in a disorganized manner, which often results in poor survival rates of the trees because of the high temperatures at the time of planting. Even if trees planted in late summer acclimate initially, they are often not sufficiently established to survive the low temperatures and high moisture of winter, which results in trees that do not develop as well as those that are planted earlier in the spring (Avtabi 2012).

Counting the years of *orla* must be taken into account when planning new plantings of trees. Trees planted by 15 Av are considered by Rosh HaShana (1 Tishrei) to have completed the first year of *orla* (i.e., within 45 days of planting). Delaying planting until close to 15 Av, in addition to the difficulties noted earlier, makes it hard to replace saplings that do not initially survive, since they will be planted later than the deadline for "earning" one year of *orla* in only 45 days. This delay also makes it hard for *mashgichim* (kosher supervisors) to separately label substitute trees that are planted just after 15 Av. Thus, for both religious and horticultural reasons, it is best to plant in the spring.

Fig. 4.5 Etrog sapling with a full and healthy root system, which will assure satisfactory tree development in the orchard (left); etrog tree with a twisted root (center); and young etrog tree with a twisted root that is delaying development of the tree. In extreme cases this can lead to tree decline (right)

It is important to pay close attention to the legal standards regarding citrus saplings (Israel Ministry of Agriculture 1991) when considering the quality of etrog saplings, even though the standards do not relate to etrog trees directly, but rather concern citrus saplings produced through grafting rootstocks and scions (Fig. 4.5).

Like other citrus trees, etrog trees need a steady supply of water from the time of planting. It is therefore important to install an irrigation system and to check that it is working properly before beginning planting. The planting hole must be sufficiently deep that two-thirds of the root ball is covered by soil. The sapling is placed in the hole with the upper one-third of the root ball exposed (Fig. 4.6). This prevents excessive moisture accumulating, which could cause collar rot in the future. The sapling should be watered thoroughly before planting so as to maintain integrity of the root ball during planting, which ensures survival of the sapling. Soil should be used to make a hillock (Fig. 4.6) to cover the above-ground portion of the root ball. As etrog acreage in Israel has increased in recent years and as farm machinery has modernized, the accepted spacing of etrog trees has become 6 m between rows and 4 m between trees within a row (42 trees per dunam or 420 trees per hectare). However, different varieties of etrog may mandate different spacings. After planting, growers often cover the lower trunk with plastic or cardboard to protect it from rodents and other gnawing animals, as well as from herbicides (Fig. 4.7). In windy areas, the saplings are anchored to a pole and are planted at a slight angle in the direction of prevailing winds. Plastic triangular windbreaks that protect against wind and against sunburn can also be used (Fig. 4.8).

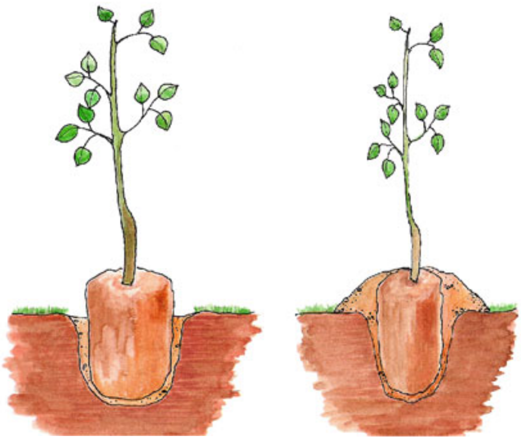

Fig. 4.6 Planting the sapling in a prepared hole. (Left) Edge of the boll and root junction are above lip of the hole; (right) soil covers the entire boll/root junction

Fig. 4.7 Two different plastic shields used to protect the trunks of young trees from gnawing animals and from drift of weedkilling compounds

4.2.2.4 Planting Etrog Saplings Directly in the Orchard and the Care and Cultivation of Young Trees

Since etrog cuttings root relatively easily, they are sometimes planted directly in the orchard, avoiding the nursery stage. This method saves money in the short term but extends the period in which the grower must deal with trees in the orchard, rather than treating them in the compact confines of the nursery. Production of premier etrogim mandates that constant attention is paid to the tree, the branches, and the fruit, starting from when the tree is in the nursery. The tree is shaped initially by removing lateral

Fig. 4.8 Triangular windscreens protect young saplings from strong winds and extreme sun

branches and tying the central spindle branch to a support pole. The aim is to create a strong tree with a central axis, from which grow three to four lateral branches that bear the foliage and fruit. Secondary branches of etrog trees are long and twisted, with some hanging down and others growing straight up, leading to a very tangled tree. This shrubby and tangled growth habit makes it difficult to maintain the quality and beauty of etrog fruit, since they are liable to be injured by limb rubs or punctures. In addition, the vigorous growth of external branches causes shading and ultimately desiccation of internal branches. Consequently, branches of young trees are spread and tied to a framework or trellis of wooden strips/boards or metal cables (Fig. 4.9). Doing this early in the tree's development allows the formation of a vase-like tree shape, whose interior has few leaves or branches. This allows penetration of sunlight and spray materials to the interior of the tree. Exposing the tree interior to sunlight allows development of short woody branches that produce healthy leaves and many flowers.

Trellises can be made out of many materials, as long as they can support the tied branches at the proper height for access by orchard workers and associated machinery. The framework itself is usually 1.5 m from the tree trunk. The upper branches are often trained to cover the orchard alley between two rows of trees, forming a tunnel (Fig. 4.10). Fruit that develops on these "tunnel" branches benefit from more direct sunlight and are often quite beautiful. The tunnel must be kept thin, however, so that sunlight can penetrate from above and that spray material can escape from below. Spray penetration is enhanced by removing extraneous large and small branches at the sides of trees next to the orchard alleys, especially on the north side of the trees, if possible. This sculpting of the tree allows better access to the branches that bear the fruit on the tree's interior.

Etrog trees grow best, with plentiful flowers, if branches are exposed to sunlight. However, exposure of the fruit to direct sun can result in damage such as etrogim that

Fig. 4.9 Scaffolding is erected in the second year after planting. Lower branches will be tied to the lower boards to form a "goblet" or "vase" tree shape. Later, the upper branches will be tied to the upper boards

Fig. 4.10 Interior view of screenhouse, which protects the fruit against sunscald. Note the tunnel-like effect of overlapping branches from adjacent rows

are deformed (squat), asymmetrical, or have burn marks on the peel. This damage can be prevented by erecting shade nets over the trees. Shade nets also help maintain overall fruit quality, in addition to increasing the amount of "water etrogim," which are fruit that set during May–June. Initial work in this subject was carried out with R. Avraham Ludmir of Hadera, who worked at the Center for Israeli Etrogim Company (Avtabi 1975). Shading with netting enhanced the overall yield of fruit, especially for "water etrogim," as well as enhanced survival of the pitam, along with more and greener leaves. The use of shade nets is now standard in etrog orchards (Fig. 4.11). Black shadecloth is placed 1.5 m above the tops of the trees, both to avoid damage from contact with the trees below and to improve light diffusion. Support structures for the shadecloth should be made of metal of sufficient strength to withstand winds and stormy weather, while at the same time affording ease of removal and replacement of the fabric, depending on the season. The shadecloth should be removed to expose the trees to direct sunlight during the flowering season but must be returned again later to protect the newly-set fruitlets and developing fruit.

Fig. 4.11 Screenhouse in an etrog orchard. In addition to shade from above, shade is provided at the sides of the structure, with appropriate openings to allow access by tractor-drawn machinery

The degree of shading is dependent on the etrog variety being grown and on the amount of solar radiation in the growing area. In the center of Israel, shading of 30–40% is sufficient, but in warmer regions the degree of overhead shading should be increased, depending on the temperature and the amount of radiation. In areas with strong winds, netting is also placed along the sides of the orchard that are most exposed to wind.

4.3 Irrigation and Fertilization of Commercial Etrog Orchards

Etrog orchards require the highest-quality irrigation water, with a very low chloride content. If desalinated water is used for irrigation, it is important to replace any mineral elements that are missing. Etrogim can also be grown with recycled water of the highest purification level. Depending on the region, etrog trees are irrigated similarly to other citrus trees. Thus, if 500–750 cm of water per dunam (5000–7500 cm per hectare) are sufficient for a mature orchard in central Israel, much more than that is required in southern Israel. The amount of water and the frequency of irrigation depend on the soil type, local climate, tree size, natural and artificial (e.g. shadecloths) environmental conditions, and water availability and quality. Local evaporation rates should be taken into consideration as well.

Mineral nutrition is as important as irrigation for maintenance of etrog orchards. Consistent supply of essential elements is critical during all growth periods, with care taken to avoid mineral deficiencies and, equally to avoid over-supply that can cause salinization of the soil.

Unlike other citrus crops that have standard fertilization rates depending on leaf mineral analysis (Israel Ministry of Agriculture 2014), optimal nutrition standards have not yet been developed for etrog trees. Citrus leaf analysis in Extension Service laboratories can therefore provide only general recommendations for etrog tree nutrition.

Etrog trees require a relatively high amount of nitrogen such that the leaf N concentration reaches 3%, while ‘Shamouti’ oranges, for example, require only 2% N by leaf analysis (Avtabi and Bran 1977). Nitrogen fertilization should be stopped or at least reduced towards the harvest season, so that the peel color will turn from green to yellow more readily. In chalky soils (more than 10% limestone), it is necessary to add chelated iron early in the spring, since otherwise it is not naturally found in the soil. Magnesium, manganese, zinc, and other microelements can be supplied with foliar sprays (Avtabi and Bran 1977). Because etrog trees flower, set, and grow fruit relatively quickly, it is important to apply foliar sprays early in the spring. It is almost impossible to spray later during the main fruiting season (barring treatments against insects and diseases) because of the danger of causing marks on the fruit peel. Spraying is recommended from the end of March or the beginning of April, as well as in the fall after harvest.

4.4 Droughting Etrog Trees to Induce Flowering

Etrog trees flower over a long period, from the end of winter until the end of summer. Individual flowers can even be found blooming during the winter. Flowering takes place in flushes. Usually, the first flush takes place in the month of Nissan (springtime), with fruit set taking place during Iyar (four to six weeks later) and ready to harvest during Sivan-Tamuz (late spring-early summer). These fruits are called *bikker* and are usually not sufficiently attractive to be sold for ritual use. Growers prefer fruit from the later flushes of flowering that occur during Iyar, Sivan, and even Tamuz—“water etrogim”—because they are aesthetically (and therefore religiously) pleasing. These fruits often have a *gartel* (Yiddish for “belt,” a physiological phenomenon possibly induced by infection with viroids), with a narrow waist, a delicate peel, and juicier pulp, especially if grown under shadecloth. Later flowering is economically advantageous because of the shorter period of growth and shorter time needed for storage before marketing.

Selective droughting of etrog trees in the spring will result in a delay in most of the flowering (as opposed to lemons, where droughting is employed in the summer for the same purpose). Induced drought by restricting irrigation causes plant stress, which in turn induces enhanced flowering. The length of the drought period can be determined by an experienced grower, who examines leaves every morning for signs of drought stress. Once drought stress is noted in the tree, irrigation must be resumed. In sandy soils droughting can take place over days or weeks, while in loess and heavier soils it can occur from the end of the rainy season (February–March) until the end of April–beginning of May (two months). This is an extreme treatment, which must be employed after studying the specific characteristics of each region, variety, soil, and climate. Once flowering commences, the flowers and fruitlets must be protected from physical injury caused by contact with leaves, branches or thorns, as well as from insects and diseases.

4.5 Treatments for Pitam Maintenance

The pitam is the tip of the etrog fruit; it is the stigma that is retained from the style of the flower. Other citrus fruits also retain the stigma, but only in etrog fruits is it of commercial significance, since it is considered a beautifying and even sanctifying element of the fruit (see also Chap. 13 "'Fruit of the Goodly Trees': The Talmudic Discourse on the Etrog Citron" in this volume). Retention of the pitam is a physiological phenomenon with a genetic basis, since only some varieties retain the pitam naturally, while in other varieties it abscises at the beginning of fruit development and expansion. Growers whose clientele prefer an etrog with a pitam grow varieties with higher degrees of natural pitam retention.

There are also hormonal treatments that can induce pitam retention (Goldschmidt 1970). Picloram, the material recommended for this treatment, acts as a weed killer at high concentrations but, at 3–5 ppm, has become the standard treatment used for etrogim that do not naturally retain the pitam. Picloram is usually applied at full bloom directly to the flower with a handheld sprayer. Growers have also attempted overall spraying of trees with large mechanical sprayers. When successful, this method saves time and money compared with spraying by hand. However, there have been cases of tree and leaf damage similar to that caused by weed killers when the entire orchard is sprayed rather than selected fruitlets. The method used will thus be dictated by local conditions and the variety being grown.

4.6 Treatments for Fruitlets and Young Fruits

The treatment that enhances pitam retention also causes retention of the stamens, which dry out and stick to the base of the fruitlets. Dried stamens can cause scratches on the peel of young fruit, thus affecting their quality. Once dry, therefore, stamens should be removed delicately by hand as early as possible during fruit development. Fruitlets should be protected from coming into contact with leaves, branches and thorns, by tying them securely to branches or to the guy-wires that support the tree. If a few fruits develop together as a cluster, they should be separated by placing sponge or another soft material between them (Fig. 4.12). Sometimes it is necessary to thin some of them in order to avoid bruising from fruits pressing on each other.

There is great variability among etrog fruits, compared with other citrus. Fruit from the same cluster that grew at the same location on the tree and at the same time, can still have different shapes. When separating fruitlets from each other, all fruit that are damaged or that have a non-traditional (non-commercial) shape should be

Fig. 4.12 A cluster of six fruits that are separated with polystyrene to prevent fruit damage

removed. Separating fruit from each other and from branches, thorns, and leaves is carried out throughout the fruit's growing period until harvest.

4.7 Commercial Considerations and Calculations in Establishing an Etrog Orchard

As emphasized at the beginning of this chapter, etrog growing requires a large investment, commensurate with opportunities for good returns on that investment as well as the danger of monetary losses. Potential growers should know that they will be dealing not only with a sensitive and damage-prone fruit, but also with a clientele that is very strict about purchasing only certain types of fruit from certain cultural and horticultural backgrounds. It is doubtful that one can convince customers to purchase a fruit that has all the desired external characteristics if it does not also have the desired background of traditional source and use. Some of the arguments that rocked the Jewish world regarding the kashrut of certain sources and varieties of etrog are discussed in the chapter on the controversy surrounding etrogim originating from Corfu (see also Chap. 20 "The Corfu Etrog Citron Polemic" in this volume). Although technical and religious information is supplied by experts who visit the orchards, etrog commerce is complicated and sales do not depend only on experts in horticulture and in halakha. Many aspects of tradition and personal connection are involved in etrog production and especially marketing. Growing etrogim commercially is one of the most challenging and complicated branches of agriculture in Israel; the details provided in this chapter only hint at what a novice needs to know to begin growing independently.

4.8 Yield

In Jewish law, the first commercial yield of a fruit tree is called "*neta revai*" (literally "fourth from planting"). In the case of commercial etrog orchards, this is the third chronological year from planting, which is actually the fourth halakhic year of the tree if it was planted before 15 Av. The orchard can yield anywhere from a few dozen to a few hundred marketable fruit per tree. Etrog trees bear plentifully for a number of years from the beginning of commercial yield. However, the fruit quality decreases as the trees mature. Over many years of observation, it has become apparent that the commercial productivity of etrog trees is affected by disease (especially *mal secco*) and by the biological age of the tree, such that infected orchards are commercially unviable when they are 12–14 years old. In regions without *mal secco*, orchards can be productive for twice that length of time.

4.9 Conclusions

In this short chapter, only a few of the many topics that concern etrog growing, from selecting propagating material through commencement of yield, have been discussed. The grower must be present in the orchard throughout the season. Every tree must be observed for health, and for response to heat and drought in summer and to frost in winter. Any deviation from the norm can cause fruit to be downgraded in quality, and even a slight decrease in a single aspect of quality can cause a pedantic consumer to reject outright this special fruit. The information presented in this chapter does not in any way substitute for personal and specific advice by qualified extension agents and advisors. Rather, it is intended to give a glimpse into some of the complicated technical aspects of growing this unique crop.

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Chapter 5
Preserving Etrog Quality After Harvest: Doctrine and Practice

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Abstract Citron (*Citrus medica* L.) fruits ("etrog" in Hebrew; plural "etrogim") are used ritually in the Jewish holiday of Sukkot (Tabernacles) and can command as much as US$100 per fruit, depending on quality. The etrog is unique among citrus fruits in that only the external attributes are of commercial importance. Maintaining physical fruit quality mandates the use of protective cushioning on the tree, at harvest, and in packaging to avoid scratches, puncture marks or damage to the stem or pedicel (pitam). Growers use a wide range of chemical treatments post-harvest to reduce to a minimum the possibility of disfiguring insect or disease infestations. Most etrog varieties are highly susceptible to chilling injury if stored at less than 12 °C. Etrogim lose water readily during storage, so fruit are stored and almost always marketed in plastic bags that limit water loss. Peel color is regulated with applications of ethylene or gibberellin, depending on whether specific markets prefer fruit that are green or yellow.

5.1 Introduction

The methods used in the treatment and handling of fruit after harvest are designed to ensure a supply of high-quality fresh produce over a long period of time. Fruit quality after harvest is dependent on the quality at harvest, the storage methods used, and the natural storage life of the fruit itself. Breeding new fruit varieties usually emphasizes maintenance of internal fruit characteristics such as flavor, sweetness,

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aroma, and texture, as well as external color and shape. Other consideration in fruit breeding include earliness or lateness of ripening, and resistance to diseases and insects. Over the years there has been a change in consumer purchasing habits: fruit used to be purchased shortly after harvest for immediate consumption or for use in preserves that could be stored for a long time, whereas now many temperate-zone and subtropical fruits can be stored for months at a time.

The etrog citron is a fruit of a different sort. Consumers are not concerned with flavor, and only have some interest in aroma. Primary consumer concerns are external: the color and shape of the fruit, with some interest in a pleasant aroma, and no interest in the flavor of the flesh or juice. The fruit stem must also be strongly attached, and in some varieties the presence of a persistent pitam (stigma and style) is desirable. The fact that the etrog is not marketed as an edible commodity has influenced the development of particular methods of postharvest treatment and storage for fruit that are kosher.

Etrog fruits can be stored for longer periods than most citrus. Etrog merchants over the centuries developed methods for maintaining fruit quality despite the long distances involved in marketing etrogim to Jewish communities that were quite distant from the regions where the fruit were grown. These great distances mandated high prices for etrogim to cover the costs involved in transporting quality fruit to those who wanted to observe the Four Species commandment. Etrog merchants developed unique methods of wrapping, packaging, and storing the fruit, all to enable long-distance shipping, long before other citrus fruit were similarly marketed.

Postharvest treatments for storage of citrus crops have been used commercially for over 100 years (Reuther 1967). Thiabendazole (Kellerman et al. 2014) and intermittent warming (Cohen et al. 1994) to prolong storage, avoid chilling injury, and maintain quality in lemons, and oiled or chemically treated papers were used to individually wrap and protect grapefruits and oranges for nearly a century (Eckert and Eaks 1989; Reuther 1967). Degreening of oranges and lemons with ethylene to attract consumers is also a well-established practice (Grierson and Newhall 1960). Postharvest treatments to prevent fungal, bacterial, and insect attack in storage are carried out universally, usually employing thiabendazole, imazalil, and sodium ortho-phenyl-phenol (SOPP) in various combinations (Erasmus et al. 2015). Growers who produce organic produce can use physical methods of pest and pathogen removal and protection such as a hot water brushing machine (Porat et al. 2000; Fallik 2011), biological methods such as applications of protective yeast cultures (Droby et al. 1998), or combinations of microorganisms and physical treatments such as salts, UV light, or temperature (Talibi et al. 2014). Some citrus fruit can be stored for up to eight months after harvest, depending on variety and storage conditions. Consumer demand for fresh citrus is steady throughout the year (Gao et al. 2011). In contrast to oranges, lemons, grapefruits, and other citrus fruit, consumer demand for etrogim is limited to a specific time of year. Therefore, the standard paradigms for fruit production and storage are not relevant, and etrog-specific methods must be developed.

Citrons, like lemons, have two major flushes of flowering, one in early spring (February/March) and one in the summer, with a lesser intermediary flush in late spring (Klein 2014). Etrogim from the early flush can be harvested in late June/early

July, although the quality of these *bikker* ("early", in Arabic) fruit is often considered inferior because of irregular shape and peel texture. Fruit from the *tenne betten* (intermediary flush) are harvested in July. *Me'ah* (literally, "water") fruit of the later flush (so called because growers often irrigate the orchards more heavily to get the fruit to marketable size in time for the Sukkot holiday) have superior quality and are harvested from late July up until the holiday itself. The market for etrogim is exclusively in early fall, with a very minor confectionery market, mostly using fruit that was too small at the time of Sukkot, but which later reaches sufficient size to be processed and marketed as sugar-infused slices for Tu B'Shvat, the "New Year of the Trees", in mid-January (Klein 2014). The storage period required for the vast majority of etrogim is therefore limited to a maximum of four months, from late June at the earliest to early October at the latest.

Etrogim are stored either on the grower's property, or more frequently in storage rooms near the main wholesale markets of Bnei Brak and Jerusalem. Some fruit are shipped overseas to major markets in Europe (Paris) or North America (New York, Los Angeles) and arrive as early as four weeks before the holiday, while in most cases fruit are sent by air closer to the time of the holiday itself (Kirschenbaum, personal communication). Etrogim were sent by ship and by horse-drawn cart from Calabria (Italy), Greece, and pre-state Israel when Jews were spread more thinly in the Diaspora and lived in areas where etrog trees could not be readily grown (northern and central Europe, Russia, North America). Etrogim are quite tolerant of shipping conditions, as evidenced by their slow rate of water loss and their ability to retain fruit shape despite water loss of up to 10%. This allowed growers to ship the fruit long distances even when specific postharvest storage and shipping treatments had not yet been developed.

Consumer demands regarding the quality of etrogim are stringent, and they are willing to pay relatively high prices for fruit that meet their standards. Growers invest large sums to produce high-quality fruit, with an enormous amount of hand labor involved in production, harvesting, and packing compared with other citrus fruits.

Production and marketing of etrog citrons demands expensive manual labor, starting from growing the fruit, continuing to the punctilious selective harvest, and on to postharvest treatments. Etrog fruits are extremely sensitive to physical and physiological damage. In addition, customers often have extremely high expectations and demands for external fruit quality, such as uniform color (either medium-light green or yellow) and absence of even slight physical damage. This results in growers using unique methods of tying, padding, and physically protecting fruit from damage due to contact with other fruit, branches, leaves, and thorns before harvest. Growers also use many more chemical treatments before and after harvest than are used with other citrus.

5.2 Treatments to Prevent Water Loss

Even slight physical pressure can result in unsightly marks on etrog peel within twelve hours or less, which means that fruit must be harvested with great care. The marks become more pronounced over time, and can ultimately become weakened, water-soaked, and a host site for pathogens. Etrogim often grow in clusters of three to seven fruit (Fig. 5.1), although some grow at the end of long flexible stems that move in the slightest breeze (Fig. 5.1). Growers often thin excess fruit at different stages of development, removing those that will develop into less than perfectly shaped fruit in the future.

In order to maintain the remaining fruit in acceptable condition during the growing season, fruit-bearing branches are often tied with twine to a frame surrounding the tree (see also Chap. 4 "Selected Aspects of Commercial Production in Etrog Orchards" in this volume). Tying prevents excessive movement due to wind and helps reduce the incidence of blemishes caused by other fruit, limbs, thorns, and leaves. Growers often place small protective foam cushions between two high-quality fruit that grow in a cluster, or put stockings of expanded polystyrene on the fruit itself (Fig. 5.1) in addition to tying the stem, especially if adjacent fruit would otherwise touch and rub against each other (Klein 2014). Fruit are clipped from the tree with a 1–2 cm long stem, and are placed directly (and carefully) in citron-shaped flexible foam inserts (ten or twelve etrogim in a single layer per box) for transport to the packing house (Fig. 5.2).

Aside from avoiding pressure and puncture injury, the most important physical aspect of postharvest treatment and protection of etrogim is the prevention of water loss from the fruit. Etrog peels are quite rigid, which allows for maintenance of fruit shape even if there has been significant water loss. This is particularly the case with the fruit harvested from the early (*bikker*) flush of flowering, although such fruit are not always marketed. In contrast, fruit harvested from the second (*me'ah*) major flush of flowering often achieve their size by intensive irrigation before harvest. The size of the fruit is therefore due to water-induced swelling of the cells, rather than to the accumulation of dry matter. Such fruit can lose water after harvest, and in extreme cases, individual fruit with >10% water loss can actually appear slightly shriveled.

Many types of citrus fruits are coated before storage with natural or synthetic wax (Gassner et al. 1969), in order to prevent water loss as well as fungal attack (Hagenmaier and Baker 1994). However, there is a religious concept of *hatzitza* (physically intervening material), whereby the Four Species must be held directly in the hand without an intervening layer or object, such as *tefillin* (phylactery) straps or a cloth (Sukka 37a, Shulchan Aruch 451:7). Therefore, many religious authorities recommend not using etrogim that have been coated with wax.

At the packing house, harvested fruit are divested of their individual expanded polystyrene protective sleeves, if they were used in the orchard, before being sorted and graded. Etrogim are usually very dusty upon arrival from the orchard, and the peel can also have remnants of bird or insect droppings, scale insects, insect eggs, and other items that detract from the fruit's appearance. Fruit are therefore washed

Fig. 5.1 Etrog fruit in need of protection from thorns (top), single fruit protected by an expanded polystyrene sleeve (middle), and multiple etrog fruits separated by pieces of expanded polystyrene to protect against limb, leaf, or self-abrasion

Fig. 5.2 Citrons harvested directly into cartons with foam inserts that can hold ten to twelve fruit in coddled comfort. Note that the insert below has ample room for the pitam (the residual style that for many is the "ne plus ultra" of etrog beauty)

Fig. 5.3 'Urdang' etrogim after four months storage at 12 °C without (right) and with (left) plastic bags

in diluted soapy water with delicate brushes upon arrival at the packing house. After this thorough cleaning, fruit are treated with postharvest fungicides and pesticides, before they are placed individually in plastic bags and then in a polystyrene sock or in a foam-lined box (Fig. 5.3).

Bagged fruit can be stored and shipped in foam-lined trays or in individual protective expanded polystyrene socks which are placed in single layer cartons of 10–12 fruit. Fruit that are harvested, bagged and placed in foam-lined trays relatively early in the season are often placed in polystyrene socks and repacked in individual cardboard retail boxes closer to the Sukkot holiday. These individual single-fruit boxes can then be packed in multiple layers of up to twenty-five fruit total in a single carton, which is then placed in a plastic bag for shipping and storage.

Although plastic bags can prevent water loss, they can also cause undesirable effects. At temperatures greater than 4 °C, fruit tend to "sweat" in enclosed storage. If fruit are stored in plastic that is highly impermeable to water vapor (as is the case with polyethylene, the most common plastic used for such bags), the humidity will rise in the bag and water droplets will form on the fruit, providing an excellent substrate for any pathogens. This is why growers are very careful to treat etrogim with postharvest fungicides and pesticides. In addition to being a barrier to water vapor, plastic bags can limit gas exchange between the fruit and the ambient environment. As the fruit consumes oxygen in the bag's atmosphere through respiration, CO_2 accumulates. If enough CO_2 accumulates, the fruit can switch to anaerobic respiration and begin producing ethanol and acetaldehyde, which at high levels can cause physical damage to the fruit (Prange and DeLong 2006). If pathogens accumulate, the fruit can sustain physical damage that results in the generation of wound ethylene (McManus 2012), which in turn will trigger fruit yellowing or even abscission of the stem or pitam, which disqualifies the fruit from ritual use. A low-level accumulation of CO_2 can also simulate the effect of ethylene, resulting in fruit yellowing and stem or pitam abscission, although high levels of CO_2 can inhibit ethylene action (Sisler and Wood 1988). If stored in appropriate bags, the gases do not reach concentrations that induce physiological activity in the fruit, and the fruit remains green (Fig. 5.4).

Etrog fruits are very susceptible to physical damage. The mere act of handling etrogim after harvest induced elevated amounts of CO_2 and ethylene in both

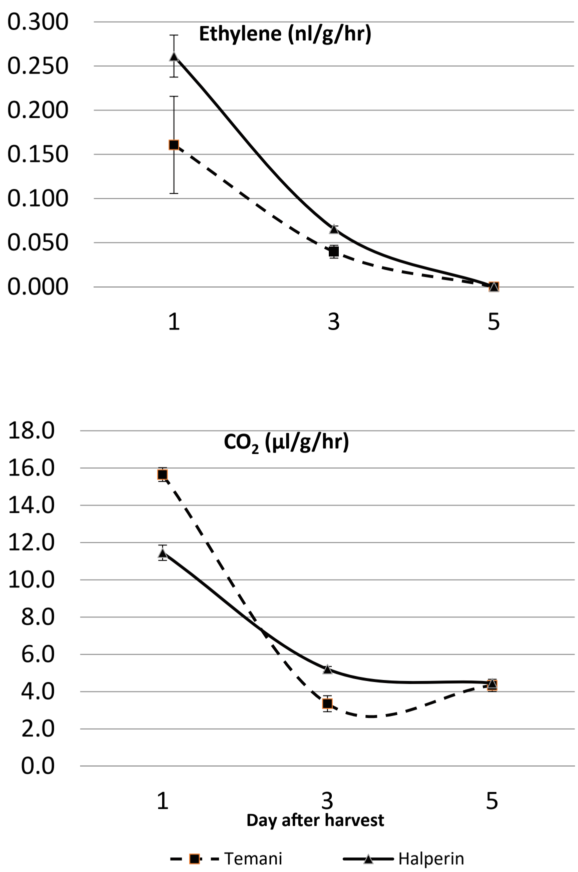

Fig. 5.4 Ethylene and CO_2 production by 'Yemenite' (Temani) and 'Chazon Ish' (Halperin) etrogim in the first five days after harvest. Fruit were sealed in jars for four hours each day to measure accumulated volatiles

'Yemenite' and 'Chazon Ish' (Halperin) fruit (Fig. 5.4). Even though the gases did not reach concentrations that would induce physiological activity in the fruit, it is possible that a mild knock or a moderate squeeze to the fruit could induce formation of damaging amounts of CO_2 and ethylene.

Most growers use inexpensive high-density polyethylene bags to store fruit. It is not unusual for the humidity inside the bags to promote callus formation on the cut pedicel. In extreme cases, rootlets may form (Fig. 5.5). Growers and shippers always clip the stem to remove the calli rootlets before marketing the fruit, whose quality is not affected by these growths. Copper is a cofactor in the response of plants to ethylene (Rodriguez et al. 1999). Treating etrogim with 10 ppm copper chloride immediately after harvest induces degreening of the fruit and significantly reduces callus formation, possibly by chemo-mechanical injury that prevents induction of new tissue while inducing ethylene formation (Klein et al. 2013).

Fig. 5.5 'Urdang' etrogim that were stored at 18 °C for two months: on the right, fruit stored without bagging, visible drying of the stem; on the left, fruit stored in a bag, with visible rootlet formation on callus tissue

Hot-water brushing is a relatively new postharvest treatment that is designed to remove postharvest pathogens from the surface of fruit, leaf, and root crops (Fallik 2011). Treatment can also reduce fruit shrinkage due to postharvest water loss through the skin, as well as decrease chilling injury in susceptible crops (Fallik 2011). While most fruits can easily withstand the gentle brushing and rolling movement that is associated with any fruit treatment on a conveyor belt, the volatile oil glands on etrog peels are particularly sensitive to pressure. Etrogim treated with hot-water brushing at 45 °C, a mild method which has been successfully used in a range of tropical and subtropical fruit including citrus (Fallik 2011), led to skin browning (Klein and Fallik, unpublished). Brushing fruit at the relatively low temperature of 38 °C did not curb water loss over 12 weeks of storage, and even slightly increased chilling injury in 'Yemenite' etrogim (Table 5.1).

Microperforations in plastic bags limit water and gas (CO_2) transmission and absorption (O_2) between stored produce and the atmosphere, thus protecting the produce from water loss and extending storage and shelf life (Rodov et al. 2010). However, an extensive series of experiments (Klein et al. 2016) found that there was no effect of storage in microperforated bags on etrog color, freshness, or extension of storage life.

Fruits are usually stored at the lowest temperature that is appropriate for them. Many tropical and subtropical fruits are susceptible to chilling injury if stored at

Table 5.1 Weight loss (%) in etrogim after hot-water brushing at 38 °C post-harvest and subsequent storage at 16 °C for six or twelve weeks. Weight loss is averaged over four etrog varieties (Halperin (aka Chazon Ish), Urdang, Calabri, and Yemenite (aka Temani)); chilling injury and stem rot are from 'Yemenite' fruit only (1 = minimum, 5 = maximum)

Treatment	Weight loss (%)		Chilling injury (1–5)	Stem rot (1–5)
	6 weeks	12 weeks		
Control	7.2	12.1	2.3	1.1
Hot water brush (HWB) (38 °C)	7.2	12.7	2.9	1.1
Sealed in plastic bag	5.5	10.1	1.7	1.7
HWB + bag	5.1	9.6	1.9	2.2

temperatures lower than 10–12 °C for longer than six weeks (Wang 1990). Chilling injury begins with the breakdown of cell membranes, and becomes evident on a larger scale with sunken areas on the fruit peel, which become discolored and soften. The softening is often hastened by opportunistic fungi that colonize the weakened tissue and then spread to other areas of the fruit. Chilling injury can be reduced by holding fruit at 16–17 °C for short periods before storage (Chaudhary et al. 2014). However, this method was not successful in 'Yemenite', 'Urdang', 'Moroccan', 'Calabri', and 'Hazon Ish' etrogim, all of which had commercially unacceptable degrees of chilling injury despite pre-storage treatment. Chilling injury in etrogim is characterized by browned sunken areas in the peel and by the orange color of physically-undamaged peel (Fig. 5.6). The etrog variety least susceptible to chilling injury is 'Calabri', which is also the variety that is less genetically related to other types of etrogim (Nicolosi et al. 2005; Shapovalov 2011). 'Yemenite' etrogim are most susceptible to chilling injury, along with the genetically close 'Moroccan' variety (Nicolosi et al. 2005; Shapovalov 2011). Many growers use air conditioners in insulated rooms to store fruit at around 20 °C before shipment, but some now hold the fruit at 17–18 °C, despite the extra cost of electricity, to maintain superior quality (especially reduced water loss) for a longer period of storage.

5.3 Regulating Peel Color in Etrogim

After fruit shape, the color of etrogim is the most important quality parameter that influences customers. Many customers in Israel prefer fruit that are light green in color (Hue angle around 110–115). According to the Talmud (Sukka 31a), an etrog that is "as green as a leek," which seems to be a deeper green color (Hue > 120), is not acceptable for religious use. Other customers in the Diaspora prefer fruit that are already yellow (Hue angle around 85–90). Because etrogim from the last flush of flowering ripen on the tree only towards the end of autumn, it is imperative that growers are able to manage color development in the harvested fruit. For approximately 120 years, ethylene has been considered the plant hormone most responsible for ripening, especially for causing a change in citrus peel color from green to yellow or orange (Grierson and Newhall 1960). This change occurs naturally, but can take place much more slowly than marketers would like. Commercial use of ethylene for active degreening of citrus began approximately 100 years ago, using kerosene lamps for gas, despite the risk of explosions (Abeles et al. 1992). Much has been learned since then about the physiology, biochemistry, and molecular biology of ethylene production and action in plants (McManus 2012). Apples are a natural source of ethylene, especially rapidly ripening varieties such as 'Golden Delicious'. Until relatively recently, etrog growers would place 'Golden Delicious' (but not the slow-ripening 'Granny Smith') apples in non-airtight containers, such as leather suitcases, with green etrogim, in order to induce yellowing of the peel (M. Friedmann, personal communication). In airtight containers, CO_2 can accumulate in the atmosphere, in turn inhibiting ethylene formation and decreasing the rate of degreening, although

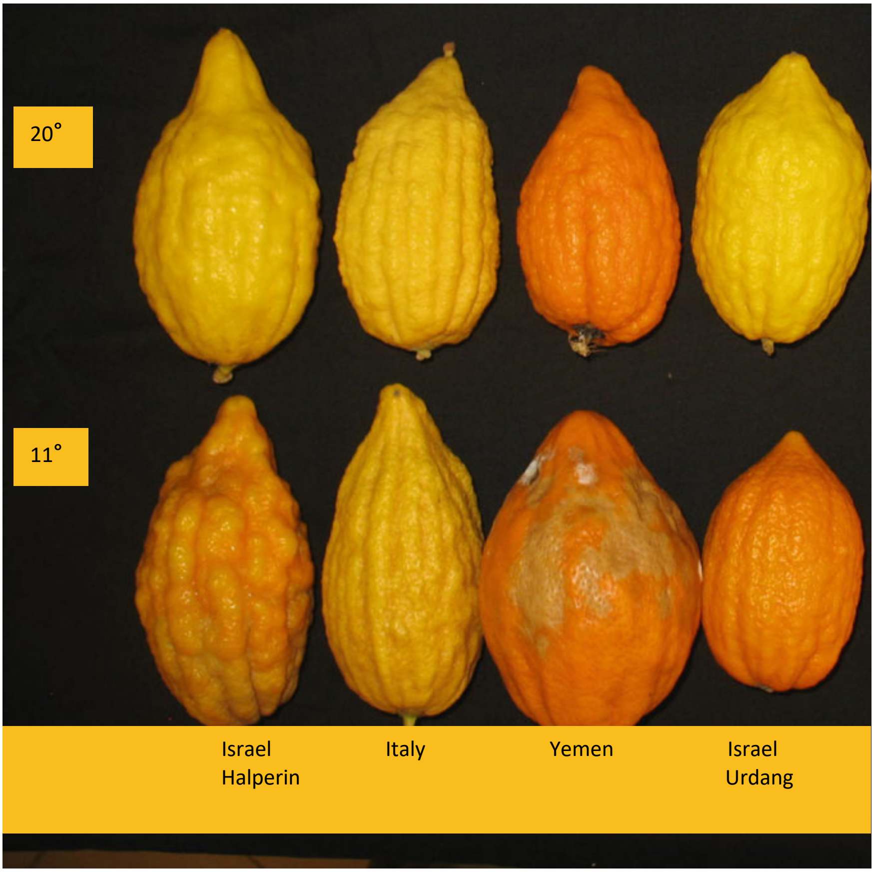

Fig. 5.6 Chilling injury in etrog citrons. From right to left: 'Urdang', 'Yemenite' (labelled Yemen), 'Calabri' (labelled Italy), 'Chazon Ish' (Halperin). Fruit were stored for four months at 20 °C (above) or 11 °C (below). 'Yemenite' etrogim age rapidly and turn orange, even at 20 °C

growers were not aware of the physiological mode of action of ethylene (Abeles et al. 1992).

Most modern etrog growers have small, insulated degreening rooms near their packing house, into which they stream ethylene from a gas cylinder outside the room. The temperature, exact concentration used, and the period of exposure depend on initial peel color and on variety, as some varieties such as 'Yemenite' turn yellow very quickly, while 'Calabri' needs more time. Great care must be taken that the fruit are not overdosed with ethylene, because the hormone can also cause both the stem and the pedicel (pitam) to fall off, rendering the fruit not kosher for ritual use. Most growers jealously keep the precise combination of ethylene concentration and exposure time used in degreening a secret, but it is generally known that exposure to 5 ppm ethylene for 12–24 h at 20 °C will initiate yellowing of etrog peel.

While there is a definite large market for yellow etrogim, especially in the Diaspora, most Israeli customers prefer etrogim that are light to medium green in color. Rather than induce degreening, the goal of growers for the Israeli market is to limit ripening-related color change in the peel. This is done by dipping fruit in solutions of gibberellin (usually GA_3, the most common commercial form of the hormone), which counteracts induction of chlorophyllase activity by endogenous or exogenous ethylene (Fujii et al. 2008), thus reducing the rate at which peel color changes from green to yellow. With proper timing and dosage, fruit will arrive at the market at the desired commercial light green color. Fruit are also treated with GA to prevent senescence-related abscission of the stem after harvest, thus maintaining the kosher status of the fruit.

The "bell-curve" phenomenon is observed with GA treatments in many crops (Aharoni 1989; Klein et al. 2013), including etrogim. Treatment with lower or higher hormone concentrations than optimal will not diminish, and may even hasten, etrog peel yellowing. Placing fruit in plastic bags can also delay color change during extended storage, probably by allowing sufficient accumulation of CO_2 to inhibit the activity of endogenous ethylene in inducing chlorophyllase activity (Azoulay-Shemer et al. 2008). However, the storage temperature seems to have more effect on color change than the presence or absence of a plastic bag (Klein et al. 2013).

During the *shmita* (sabbatical) year (Leviticus 25:36) in Israel, agricultural activities that improve the yield of fruit trees are forbidden. The fruit in the orchards that set and grew during the sabbatical year are considered common property by Torah law. Many religious consumers are wary of acquiring etrogim that grew in Israel during *shmita*, and prefer to use either fruits grown outside of Israel or fruits grown under special religious supervision ('*otzar beit din*') in Israel. The supervising committee is responsible for administering orchard activities such as spraying, irrigation, and fertilizing, as well as organizing fruit distribution for consumers and setting a price that is dependent only on the costs of production and distribution, regardless of fruit quality.

In principle, it is possible to store etrogim at controlled temperatures in plastic bags, which maintains external quality and also moisture in the interior of the fruit. Thus, there is no concern that year-old fruit would dry out and be unsuitable for religious use (Sukka 31a, Shulchan Aruch 648:1). Such a storage method was suggested as a means for growers to provide non-*shmita* fruit for the Sukkot holiday immediately after the end of *shmita*, and would allow farmers to charge market prices (Fig. 5.7). However, not all etrog varieties store equally well for a long time, and the percent of fruit that can survive for an entire year (especially 'Yemenite' and 'Moroccan') is not large.

The etrog is one of the three ancestors of all citrus fruits (Barkley et al. 2006), and as such is an ancient fruit with a rich botanical history. It is not known how or if the Jews stored etrogim for use during Sukkot in ancient times, but it is known from the Talmud that the fruits could get very large (Sukka 36a) and sturdy (Sukka 48b) by the time of the holiday, and that they had attained a certain degree of ripeness sufficient for them to be eaten (Sukka 36a). In the centuries since the Temple period, Jews have spread across the globe and the etrog has accompanied them in appropriate

Fig. 5.7 Mr. Eliezer Gorelick, an etrog grower from Kfar Habad, Israel, photographed in October 2014 with 'Calabri' etrogim that were just harvested (green fruit on the table, from September 2014) or that had been held in a polyethylene bag (in his hand) at ambient temperature in his office for one year (the yellow fruit, from September 2013)

climates (Isaac 1959; Nicolosi et al. 2005). In regions where the fruit could be grown, a lively etrog commerce developed (see also Chap. 19 "The Etrog Citron Trail to the North: Genoa and Trieste" and Chap. 20 "The Corfu Etrog Citron Polemic" in this volume). The modern methods of postharvest technology that have developed from centuries of trade in etrogim have been put to the service of this ancient fruit, so that Jews everywhere can be certain of obtaining a quality etrog for the observance of the commandment of the Four Species.

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Chapter 6
Citron Arthropod Pests in the Mediterranean, Their Origin and Notes on Their Biology and Management

Zvi Mendel, Assaf Avtabi, and Giuseppe Eros Massimino Cocuzza

Abstract All arthropods associated with citron (*Citrus medica*) are also known on other citrus species and there is marked similarity between the key pests of citron and lemon. The pests discussed are mainly related to the situation in Israel and in Santa Maria del Cedro in Italy. The 28 reviewed species are: eight mites (*Aceria sheldoni*, *Aculops pelekassi*, *Brevipalpus californicus*, *Eutetranychus orientalis*, *Panonychus citri*, *Phyllocoptruta oleivora*, *Polyphagotarsonemus latus*, *Tetranychus urticae*), three thrips (*Chaetanaphothrips orchidii*, *Frankliniella occidentalis*, *Scirtothrips dorsalis*), one leafhopper (*Asymmetrasca decedens*), one whitefly (*Aleurocanthus spiniferus*), two planthoppers (*Diaphorina citri*, *Trioza erytreae*), five aphids (*Aphis craccivora*, *Aphis gossypii*, *Aphis spiraecola*, *Myzus persicae*, *Toxoptera aurantii*), scale insects (*Aonidiella aurantii*, *Coccus hesperidum*, *Icerya purchase*, *Parlatoria pergandii*, *Planococcus citri*), one fruit fly (*Ceratitis capitate*), five fruit moths (*Apomyelois ceratoniae*, *Cryptoblabes gnidiella*, *Phyllocnistis citrella*, *Prays citri*, *Thaumatotibia leucotreta*) and one woodborer (*Anoplophora chinensis*). These are considered major pests. Since any arthropod infestation or injury to the fruit renders it non-kosher, citron orchards require a strict pest management regime. The citron fruits are more susceptible than most other commercial citrus varieties to mites and sucking insects, to the citrus flower moth and to the citrus bud mite, but to a much lesser extent to fruit flies.

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6.1 The Origin of Citron Arthropod Pests

Citrus are considered to be the most arthropod-colonized of all fruit trees. Avidov (1961) listed 76 arthropod species associated with citrus in Israel, followed by grapevine with 57 species. The diverse entomofauna associated with citrus trees in their new habitats worldwide is mostly comprised of invasive species. Global trade, which has been expanding since the 1800s, coupled with climate change in the last decades, are the driving forces for the introduction of species from their native ranges (Seebens et al. 2017). Most of the insects associated with citrus are polyphagous. Bodenheimer (1951) analyzed the fauna of citrus in Israel, and indicated that among the 110 species, mostly insects, only three of them could be defined as strictly monophagous. This suggests that only a few species were initially introduced with citrus plants that had been moved from their area of origin. This pattern has not changed much since, and the proportion of monophagous species on citrus remains low. Most non-native species assigned to woody plants in Europe and the Mediterranean region originate from Asia, and especially from China (Roques et al. 2020). This applies to citrus pests in Israel and in other areas with a predominance of Hemiptera and in particular, scale insects. Xylophagous insect species associated with citrus trees in their new areas present a rather minor contribution to their fauna. For example, wood or bark borers represent only about 2.6% of the citrus fauna in Israel (Avidov 1961) and 1.6% in California, USA (Ebeling 1959). In both areas, those borers are indigenous and of minor economic importance. In contrast, wood-borers such as long-horned beetles are severe pests of citrus in their region of origin (Sachan and Gangwar 1982; Wang et al., 1996; Smith et al. 1997).

The *Citrus* genus probably originates from Yunnan province in China, as many of its species have been discovered in that area (Gmitter and Hu 1990). Thus, we may infer that the typical monophagous arthropods of citrus, as well as those with a wider plant-host range, which thrive on citrus and have established themselves on citrus in its new areas, naturally occur in that area of origin. Most of the citrus pest communities are similar among the citrus-producing countries of the Mediterranean basin, although the relative importance of individual species may vary among areas and change with time (Franco et al. 2006; Garcia-Marí et al. 2018). All arthropods associated with citron (*Citrus medica*) are also known as typical insect pests of other citrus species, and of many of the selected citrus cultivars. The citron was the first citrus species to reach the Mediterranean region, followed by lemon about four centuries later. Thus, it can be inferred that the first typical arthropods associated with citrus came with citron. The indigenous area of citron is northeastern India, where its closely related wild types are recognized (Tolkowsky 1938; Hodgson 1967). Citron was very likely brought to the Mediterranean region in the first millennium BCE (Hodgson 1967). *Citrus indica*, an endangered wild species growing in northeastern India (Malik et al. 2006), is the closest genetically related species to citron among the major citrus species (Bayer et al. 2009). However, information on the insect fauna of wild citron is lacking. Nevertheless, a cluster representing the Mediterranean citron is thought to have been originally introduced from India (Ramadugu et al. 2015). The earliest possible date of citron cultivation in the Mediterranean is the 5th or fourth century BCE (Lipshits et al. 2012; Langgut et al. 2013). Lemon (*Citrus limon*) is probably the closest citrus species to citron. Its origin is unknown. The original fruit was a hybrid between a male citron and a female sour orange (Curk et al. 2016) and it is thought to have first grown in northeastern India (Gulsen and Roose 2001). There is marked similarity between the key pests of citron and lemon. Furthermore, among the major common citrus crops, lemon and citron share a high susceptibility to *Phoma tracheiphila*, the causative agent of Mal secco disease (Nigro et al. 2011). Although almost all citrus species are susceptible to this fungus, lemon is likely to be the most affected crop (Perrotta and Graniti 1988), followed by citron (Solel and Salerno 2000).

Herein, the discussed insect pests of citron are mainly related to the situation in Israel. Nevertheless, information accumulated from Santa Maria del Cedro in the province of Cosenza, Calabria, Italy (Dr. Francesco Perri, pers. comm.), as well as from China (Karp and Hu 2018), and Brazil, is also mentioned.

6.2 Mites

Members of four mite families are known to feed on and damage citrus: Tetranychidae (spider mites), Tenuipalpidae (false spider mites), Eriophyidae (rust and gall mites) and Tarsonemidae. Others, such as the Tuckerellidae and Tydeidae, are occasionally reported to inflict some damage (Gerson 2003). Up to 104 phytophagous species have been reported to damage citrus leaves, buds and fruit, but only a dozen can be considered major pests, requiring control measures (Ferragut et al. 2013). The control of citrus mites is becoming more difficult, due to a combination of factors. Firstly, major pests are rapidly becoming resistant to most of the synthetic chemicals that are currently used for control. Secondly, consumers, especially those in the European Community, are becoming less tolerant of pesticide residue on fresh edibles (Gerson 2003). Thirdly, whereas spider mite management may rely on protective biological control agents, this is not the case with rust and bud mites (Eriophyidae). Finally, in Israel, the pest representatives of the Tenuipalpidae and Tarsonemidae families on citron are less important. Overall, mites are important pests of citron in the Mediterranean region (see below) and in Brazil (Juliana Freitas-Astúa, pers. comm.).

6.2.1 Aceria sheldoni *(Ewing)*

The citrus bud mite *A. sheldoni* (= *Eriophyes sheldoni;* Eriophyidae) (Fig. 6.1a) is highly specific to *Citrus*. It is a key pest of lemon in most Mediterranean countries (Franco et al. 2006; Garcia-Marí et al. 2018), but it is rarely a pest of other citrus crops. Although it is considered a major pest of citron in other areas (Morton 1987), it is not a significant pest of citron in Israel. The mite feeds on leaf axil buds and developing blossoms, causing the formation of multiple buds and abnormal growth of the subsequent leaf foliage or fruitlet (Meagher 2008) (Fig. 6.1b). It develops throughout the year, mostly in milder and more humid regions, with peaks in the spring and autumn. Dispersal occurs during the spring growth of most citrus trees, and during growth flushes of lemons. The high susceptibility of lemon and citron, coupled with the apparently unremarkable effect of natural enemies on populations of Eriophyidae, suggest that citron may not be the original host of this mite. Nevertheless, it is one of the earliest specific pests of citrus to reach the Mediterranean as it has been known in the area for almost four centuries (Jeppson and de Peitri-Tonelli 1953).

6.2.2 Brevipalpus californicus *(Banks)*

The citrus flat mite *B. californicus* (Tenuipalpidae) (Fig. 6.1c) is found on most continents, displaying an extensive host range. It may cause economic damage, mainly on citrus (CABI 2020; Gerson and Applebaum 2014). Its area of origin is not clear. The mite feeds on the aboveground parts of all citrus species and varieties, preferring limes and bitter oranges. On fruit, the mite often occurs in rind depressions. Feeding results in yellow–brown spots on the leaves around puncture wounds and in the fruit skin, the latter tending to crack at the damaged sites (Gerson and Applebaum 2014). It is considered a minor pest of citron. Mites of the genus *Brevipalpus* are known to transmit Citrus leprosis virus (CiLV) infecting citron cultivars in Brazil.

6.2.3 Eutetranychus orientalis *(Klein)*

The oriental spider mite *E. orientalis* (Tetranychidae) (Fig. 6.1d) is found in eastern Mediterranean countries, the area from India to China, and in most of Africa. Its origin is presumably the Near East (Ferragut et al. 2013). However, Bodenheimer (1951) suggested that its native area may not be the eastern Mediterranean, as it was first discovered in Israel (then Palestine) in 1922 and was found only in the Jordan Valley. The oriental spider mite may develop on over 200 host plant species, mostly dicotyledons. The mite colonizes the upper side of leaves, where its eggs are deposited along the midrib. It is the most persistent citrus pest in Upper Egypt and an occasional serious pest in central and southern Israel. It is not found on any other subtropical fruit trees in Israel. The damage on citrus develops as stippled yellow-gray spots that cause leaf wilting and drop (Bodenheimer 1951; Kaspi et al. 2017). On Israeli citron, this mite, as well as *Panonychus citri*, often occur in much greater numbers than in other citrus crops in open orchards, under management that relies heavily on synthetic insecticides. There is little doubt that the microclimate under the shading nets used in typical citron cultivation also contributes to its frequent occurrence.

Fig. 6.1 Mites **a** Adult *Aceria sheldoni* [ER]; **b** Young lemon fruit deformed by *Aceria sheldoni* [EP]; **c** Adult of *Brevipalpus*? *californicus* [EP]; **d** Adults of *Eutetranychus orientalis* [ER]; **e** Adult of *Panonychus citri* [ER]; **f** Adults of *Tetranychus urticae* [ER]; **g** Adult of *Phyllocoptruta oleivora* [ER]; **h** Adult drawing of *Phyllocoptruta oleivora* [BH]; **i** Unripe citron fruit damaged by *Phyllocoptruta oleivora* [AA]; **j** Ripe citron fruit damaged by *Phyllocoptruta oleivora* [EP]; **k** Adult and eggs of *Polyphagotarsonemus latus* [EP]; **l** Lemon fruits damaged by *Polyphagotarsonemus latus* [GC]; **m** Lemon fruits damaged by *Aculops pelekassi* [GC] [*Photo credits* Photographer initials, details in the acknowledgement section]

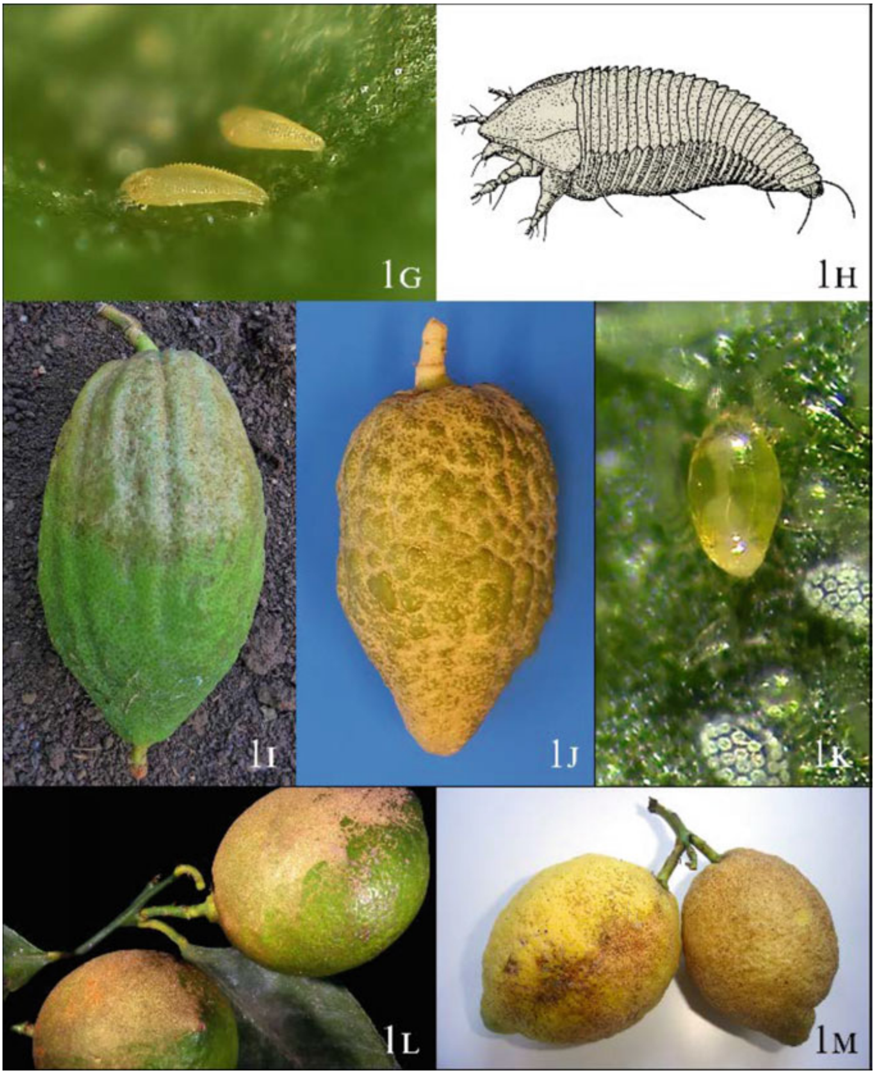

Fig. 6.1 (continued)

6.2.4 Panonychus citri *(McGregor)*

The citrus red mite *P. citri* (Tetranychidae) (Fig. 6.1e) occurs wherever citrus is grown. It appears to be native to the Far East (Ebeling 1959). It has been known in Israel since the late 1970s and occurs mostly along the coastal plain (Gerson and Cohen 1989). It has spread to and colonized all of the production areas worldwide, causing significant damage and crop losses (Ferragut et al. 2013). Its feeding causes stippled spots that combine to cause yellow or silvery areas on the leaves (Swirski et al. 1986). It is mostly recognized as an occasional pest on citrus in Mediterranean countries (Franco et al. 2006) but is ranked among the top important pests of lemon and clementine in the area (Garcia-Marí et al. 2018). Although the citrus red mite has been recorded on many host plants, it is very rare on non-crop plants, suggesting that it maintains its population mainly on citrus trees (e.g., Ohno et al. 2011). It is probably of south Asian origin, with links to members of the *Citrus* genus. This mite is considered a significant pest of citron in both Israel and China.

6.2.5 Phyllocoptruta oleivora *(Ashmead)*

The citrus rust mite *P. oleivora* (Eriophyidae) (Fig. 6.1g, h) probably originated in Southeast Asia (Quayle 1938) and develops chiefly on citrus (Bodenheimer 1951). Nevertheless, it may also be found on other closely related Rutaceae (Vacante and Gerson 2012). It is a tropical species present in all citrus-growing areas of the world where humidity is high (Hoy 2011). It is considered a major pest in eastern areas of the Mediterranean basin (Israel, Turkey), but it is less important or absent in other countries in the region (Franco et al. 2006). The mite is a major pest of all citrus cultivars, especially lemons, rough lemons and tangerines. Yothers and Mason (1930) described the puncturing of the epidermal cells that leads to typical injury (Fig. 6.1i, j). When the epidermal cells are destroyed early in the season before the fruit mature, damage to the peel, termed rusting, produces cracks that give the fruit a rough texture and a brown-black color; the destruction of the epidermal cells spreads, resulting in fractures as the fruit enlarges (Demard and Qureshi 2020). Unless controlled, it can reduce yield by 70–100% (Vacante and Gerson 2012). The citrus rust mite is one of the key pests of citron in Israel and Brazil (Juliana de Freitas Astua, pers. comm.).

6.2.6 Polyphagotarsonemus latus *(Banks)*

The broad mite *P. latus* (Tarsonemidae) (Fig. 6.1k) is highly polyphagous and usually constitutes a minor pest of citrus. Its origin is unclear. The mite occurs on ornamentals and vegetables under protected cultivation in temperate-climate countries, attacking these and many perennial crops in the warmer parts of the world. The mites aggregate on the shaded parts of young leaves and on smaller fruit. In citrus, the broad mite damages mostly the yellow varieties; others are attacked only in greenhouses, mostly on young leaves, in buds and on small fruit (Gerson 1992). Lemon fruits damaged by the mite are shown in Fig. 6.1l. In the Mediterranean region, citrus is known to be affected in Greece, Israel, Italy and Turkey. In infested plants, pharate females are transported upwards by the males; insects, especially whiteflies, may facilitate their dispersal (Palevsky et al. 2001). The mite is often observed on the young foliage of citron causing deformed leaves, with no economic significance. In Brazil, where it is also called white mite, it is a key pest of citron (Juliana de Freitas Astua, pers. comm.).

6.2.7 Tetranychus urticae *Koch*

The two-spotted spider mite *T. urticae* (Tetranychidae) (Fig. 6.1f) was originally described based on European specimens. It is considered to be a temperate-zone species, but it is also found in subtropical regions. It is one of the most harmful spider mites (Fasulo and Denmark 2009). Highly polyphagous, it has been reported in over 1000 host-plant species. The mites usually colonize and feed on the lower sides of leaves, where they suck out the cell contents (Vacante and Gerson 2012). Although the mite occurs on citrus in all Mediterranean countries, its presence in commercial citrus groves is usually insignificant. However, in some countries, such as Algeria, Italy and Spain, it may be a key pest, mainly on lemon (Franco et al. 2006). In Israel, its impact is mainly in shaded areas of nurseries (Eric Palevsky, pers. comm.); its occurrence in citron orchards may be related to the typical management under shade. Consequently, it is considered a major pest of shaded citron orchards in the Israeli coastal plain and in Calabria. It is suggested that in the latter area, the typical hot and humid summers favor the mite populations.

6.3 Thrips

The phytophagous thrips on citrus in the Mediterranean region are oligophagous or polyphagous and belong to the Thripidae (Thysanoptera, Terebrantia) (Marullo and De Grazia 2012). Teks and Tunc (2009) recorded 36 thrips species on citrus in Antalya, Turkey. However, most of the members of this rich fauna are associated with the flowers. Franco et al. (2006) listed eight thrips pests on citrus in the Mediterranean region, none of which was labeled as a major pest (see also Garcia-Mari et al. 2018). A few species are important in certain areas, such as *Pezothrips kellyanus* in Turkey (Teks and Tunc 2009) and Sicily (Perrotta and Conti 2008), or *Chaetanaphothrips orchidii* on grapefruit in Israel. Adult thrips often enter closed or semi-closed buds, and the eggs are laid in the parenchyma tissue, concealed within these buds. The thrips' developed left mandible serves to cut into the food tissue; saliva is injected and the feed is taken from ruptured cells. This feeding behavior destroys the plant tissue, resulting in distinctive silvery or bronze scarring on the fruit or leaf surface (Chisholm and Lewis 2009). Thrips may feed opportunistically and have broad diets, in terms of food type, with the nutritional advantage of being able to supplement their feed with pollen (Kirk 1995). The attack on citrus fruit is often a consequence of weeding, which eliminates the herbaceous plants on which the thrips thrive. Due to their small size and cryptic habits, thrips are successful invaders. Three thrips species, *Chaetanaphothrips orchidii*, *Frankliniella occidentalis* and *Scirtothrips dorsalis*, have reportedly invaded the Mediterranean region (Mound 2002), often causing serious injury on citron fruitlets and young fruit in Israel.

6.3.1 Chaetanaphothrips orchidii *(Moulton)*

The anthurium thrips or orchid thrips, *C. orchidii*, (Fig. 6.2a) originated in Southeast Asia, where other members of the genus occur (Pitkin 1977). These thrips have invaded many areas and were found in Europe in the early 1980s (Kudo 1985). In Israel, they were first detected in 1992, infesting organic citrus orchards in the Western Galilee (Izhar et al. 1997). Orchid thrips feeds in places where citrus fruit come into contact with twigs, leaves, or other fruit, especially when the fruit are found in clusters (Childers and Frantz 1994). In Israel, higher proportions of damaged lemon fruits have been recorded in the lower part of the tree (Goane et al. 2013) and in avocado many damaged fruits have been found (Izhar et al. 1997). The thrips is a minor pest of citron, probably because of the typical fruit management, which meticulously prevents contact between fruit and foliage. This thrips is highly polyphagous, but citron or other citrus may be included in its list of indigenous hosts in South Asia.

6.3.2 Frankliniella occidentalis *(Pergande)*

The western flower thrips *F. occidentalis* (Fig. 6.2b) is naturally abundant in many wildflowers throughout western North America, from Mexico and southern California through Canada (Morse and Hoddle 2006). Since the 1970s, with the emergence of global trade in ornamental greenhouse plants, it has successfully invaded many countries and has become one of the most impactful agricultural pests (Mound and Teulon 1995). This thrips invaded Israel in 1986 (Argaman et al. 1989). It is highly polyphagous, with at least 250 plant species from more than 65 families listed as suitable target plants for reproduction or feeding (Reitz et al. 2020). In addition to feeding on pollen and plant tissue, adult *F. occidentalis* can supplement their diet with high-protein resources by feeding on other herbivores, such as spider mite eggs and thrips larvae (Trichilo and Leigh 1986; Van Rijn et al. 1995). This thrips is very abundant in citrus orchards in the Mediterranean region, but it is usually not considered a significant pest there (Marullo and De Grazia 2012). This may be related to the diverse biotypes of *F. occidentalis*, which consist of monophagous and polyphagous strains among the invasive forms (Mound 1997). The thrips was first noticed on citrus in Turkey in 2002, and it then spread to all districts, becoming the most abundant species on lemon and mandarin. However, it does not seem to cause damage (Teks and Tunc 2009). It rarely inflicts injury on citron fruit in Israel or Italy.

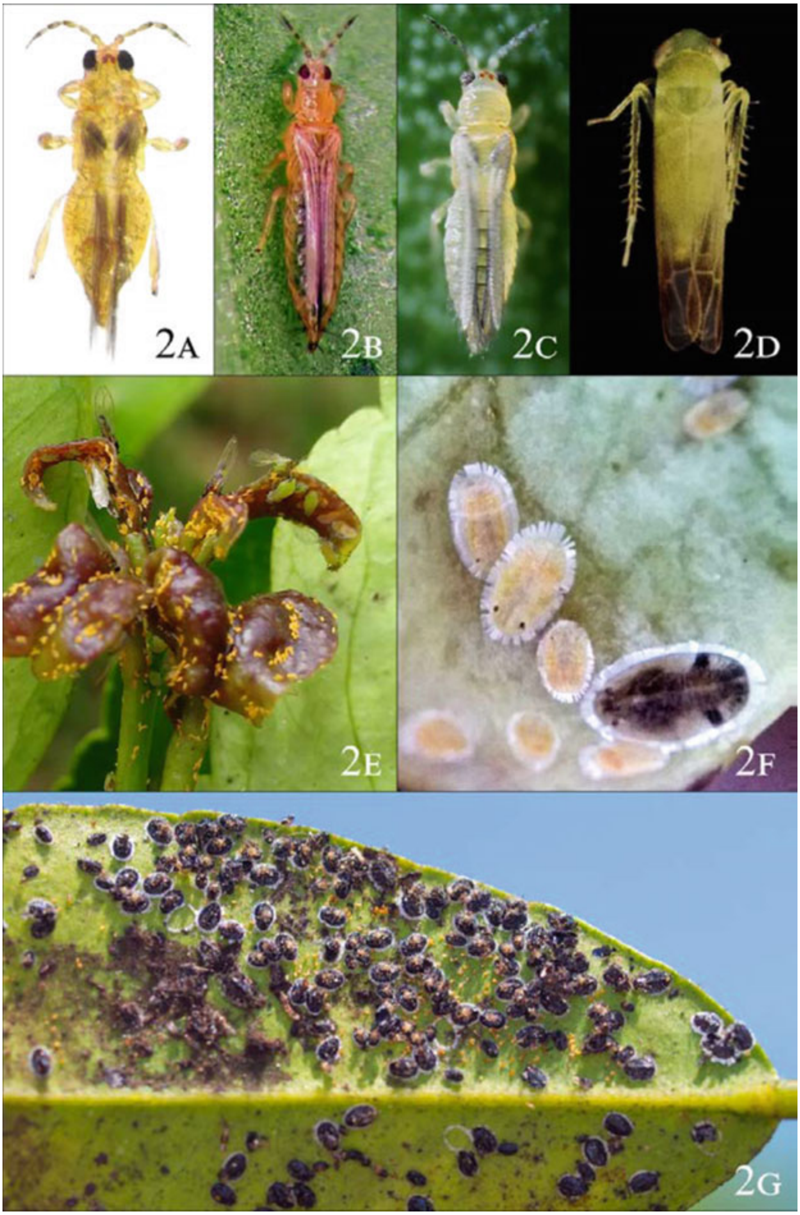

Fig. 6.2 Thrips, leafhoppers, plant hoppers and whiteflies. **a** Adult of *Chaetanophothrips orchidii* [AP]; **b** Adult of *Frankliniella occidentalis* [AP]; **c** Adult of *Scirtothrips dorsalis* [LO]; **d** Adult of *Asymmetrasca decedens* [MW]; **e** Adults and many (yellow) eggs of *Trioza erytreae* (there are also aphids close to the upper right corner) [AG]; **f** Nymphs of *Trioza erytreae* [AG]; **g** Leaf heavily infested with *Aleurocanthus spiniferus* [GC] [*Photo credits* Photographer initials, details in the acknowledgement section]

6.3.3 Scirtothrips dorsalis *Hood*

The chilli thrips or yellow tea thrips, *S. dorsalis* (Fig. 6.2c), is an extremely successful invasive species that has expanded rapidly from Asia since the late twentieth century. It is gradually achieving global distribution and is known as a widespread pest on many crops in the countries between Pakistan, Japan and Australia (Mound and Palmer 1981). The chilli thrips may severely damage the many plant species on which it feeds, the main damage due to severe distortions of young leaves (Marullo and De Grazia 2012). The adults migrate to citrus orchards from other host plants surrounding the orchards (Masui 2007). Although this thrips causes significant damage on citrus in the Mediterranean region, it only occasionally damages young citron fruit in Israel.

6.4 Leafhoppers

There are over 60 leafhopper species (Hemiptera: Cicadellidae) associated with citrus (Hermoso de Mendoza and Medina 1979; Nielson 1985). Leafhoppers lay their eggs in plant tissues; they feed on the leaf parenchyma, sucking out excessive amounts of sap and thereby reducing or destroying the plant's chlorophyll. Leafhoppers may also cause indirect damage to citrus by transmitting plant pathogens.

6.4.1 Asymmetrasca decedens *(Paoli)*

The current distribution of *A. decedens* covers the Mediterranean, Middle East and India. It frequently occurs in the Mediterranean region on a large number of plant species. The adult (Fig. 6.2d) and nymphs feed on the leaves, which turn yellow, and may cause severe growth reduction (Atakan 2009; Baspinar et al. 2011). It is a minor pest of citron, invading the orchards in early summer, but it may also build up its populations on weeds associated with the citrus trees.

6.5 Whiteflies

Franco et al. (2006) reported nine species of whitefly (Hemiptera: Aleyrodidae) on citrus in the Mediterranean, but only two species, *Aleurothrixus floccosus* and *Dialeurodes citri*, were considered serious pests, in a few areas. A tenth species, which does pose a threat, *Aleurocanthus spiniferus*, was reported by Porcelli (2008), and later included among the top 10 arthropod pests of several citrus varieties in the Mediterranean region (Garcia-Marí et al. 2018).

6.5.1 Aleurocanthus spiniferus *(Quaintance)*

The orange spiny whitefly *A. spiniferus* (Fig. 6.2g) is indigenous to tropical Asia and was first discovered in Japan on citrus. Later, another population developing on and damaging tea plants (but not citrus) was found in Japan, assumed to have originated in China (Kasai et al. 2010). The species has since spread across many citrus-producing areas worldwide (Gyeltshen et al. 2005). *Citrus* spp. are the main hosts of economic importance, but it may also be found in woody vegetation of different families. Recently, the species was found for the first time on *Citrus medica* in the Mediterranean region (Nugnes et al. 2020). Immature leaves are preferred for egg laying. Infestation starts from the new twigs in spring (Argov et al. 2012). This whitefly excretes copious amounts of honeydew, which favors the development of a thick cover of sooty mold (Porcelli 2008). This highly destructive whitefly is still unknown in Israel and on citron in the Mediterranean. However, the orange spiny whitefly is considered a significant pest of citron in China (Karp and Hu 2018). In Italy, the only natural enemy that showed some activity in the containment of this whitefly was the predator *Delphastus catalinae* (Coccinellidae; Coleoptera) (Nugnes et al. 2020).

6.6 Aphids

More than 25 aphid species have been recorded on citrus worldwide. Many are probably only accidental visitors, and others are of low economic importance. The most abundant species in the Mediterranean region are in the subfamily Aphidinae (Uygun et al. 2012). The five species recorded on citron in Israel are *Aphis craccivora*, *Aphis gossypii*, *Aphis spiraecola*, *Myzus persicae* and *Toxoptera aurantii*. In Italy, the main species on lemon are *A. spiraecola* and *T. aurantii*, whereas the other mentioned species are extremely rare (Cocuzza 2019). They are active during the winter and spring, in February through May, and their population steeply declines in the summer. The susceptibility of citrus varieties to these aphids is related to the intensity of their young vegetative flush. Thus, young trees are more vulnerable than adult trees. The pruning intensity in fully developed orange or grapefruit orchards is lower than that for lemon or citron and, therefore, the latter are more susceptible to aphid attack (Y. Drishpoun, pers. comm.). Cocuzza (2019) recently provided an identification key available for rapid recognition of the main citrus aphids.

6.6.1 Aphis craccivora *Koch*

The cowpea aphid *A. craccivora* (Fig. 6.3a) is usually anholocyclic, although sexual forms have occasionally been observed. It develops on many host plants, especially legumes (Uygun et al. 2012). This aphid species displays a cosmopolitan distribution. Its colonies are found on young vegetative flushes of citrus and other non-legume trees. It is more frequently found in citron orchards adjacent to open vegetable settings. In Israel, aphids in general are common in citron orchards, and significant damage, when it occurs, may be inflicted during the blossom period.

Fig. 6.3 Aphids. **a** Colony of *Aphis crassivora* [AL]; **b** Colony of *Aphis gossypii* [GC]; **c** Adult and nymphs of *Aphis spiraecola* [GC]; **d** Deformed leaves by *Aphis spiraecola* [GC]; **e** Adult and nymphs of *Myzus perssicae* [ER]; **f** Colony of *Toxoptera aurantii* [GC] [*Photo credits* Photographer initials, details in the acknowledgement section]

6.6.2 Aphis gossypii *Glover*

The cotton aphid *A. gossypii* (Fig. 6.3b) is highly polyphagous, reproducing year-round. It does not usually display host alternation. This pest is distributed world-wide and is found on a variety of agricultural crops in the families Cucurbitaceae, Rutaceae and Malvaceae. As regards citrus, the aphid performs better on grapefruit than on sweet orange, mandarin or lemon (Satar et al. 1998). It is found on the young foliage of different citrus trees, including citron. It has been suggested that the aphid escapes effective restriction by natural enemies due to chemical treatments (Hermoso de Mendoza and Moreno 1989). Swirski et al. (2002) suggested that as a pest of subtropical fruit trees, no further chemical control is needed for its manage-ment. The cotton aphid was mainly responsible for the spread of the Citrus tristeza virus (CTV) in the Mediterranean basin (Davino et al. 2013) although *Aphis gossypii* was originally unknown on citrus. In Italy, until the 1950s–1960s, the species was considered an occasional pest of citrus.

6.6.3 Aphis spiraecola *Patch*

The origin of the Spirea aphid *A. spiraecola* (= *Aphis citricola*) (Fig. 6.3c) is consid-ered to be the Far East (Blackman and Eastop 1984). Its native habitat is most probably located in subtropical areas, as its development threshold is around 2.5 °C (Wang and Tsai 2000). This low temperature requirement allows the aphid to develop during the winter under the Mediterranean climate. Although the aphid is highly polyphagous, its strong association with different citrus cultivars suggests that citrus may be one its original hosts. Nevertheless, the intrinsic rate of increase of the aphid is lower on *Citrus* spp. than on non-citrus ornamental plants (Tsai and Wang 2001). The latter authors found that, among the tested citrus species, the aphid's lowest performance was on rough lemon (*Citrus jambhiri*), a cross between mandarin orange and citron. The Spirea aphid is one of the most abundant species on citrus in the United States and has been known there since the early twentieth century (Yokomi and Tang 1995). It has been recorded in the Middle East since the late 1960s, and was first found in Israel in 1970, becoming a major pest of citrus (Porath et al. 1974). One or two aphids per leaf are sufficient for slight leaf curl (Fig. 6.3d), whereas heavy infesta-tion induces serious curling (Ebeling 1959), foliage contamination by honeydew, and the subsequent development of sooty mold (Gerson and Applebaum 2015). *Aphis spiraecola* is also a minor vector of CTV (Yokomi and Garnsey 1987). In Israel, the aphids occur mainly during the spring, where hot dry winds (khamsin) cause a steep decline in their populations (Zehavi and Rosen 1987). The Spirea aphid is considered an impactful pest in Israeli and Chinese citron orchards.

6.6.4 Myzus persicae *(Sulzer)*

The green peach aphid *Myzus persicae* (Fig. 6.3e) is ubiquitous (Uygun et al. 2012). Like other members of the genus *Myzus*, it is mainly associated with the Rosaceae. Its primary hosts are *Prunus* spp. This aphid is probably indigenous to the Western Palearctic where members of the *Prunus* genus grow and it develops on a large number of cultivated and wild plant species (Bodenheimer and Swirski 1957; Avidov and Harpaz 1969). However, it has been recorded in all citrus areas of the world (Ebeling 1959). It is a minor pest of citron, occurring on the young flush during the spring. Large colonies may slightly deform the leaves, and soil them with honeydew. However, this aphid seldom reaches high population levels, due to the activity of its natural enemies. Its occurrence in citron orchards is mainly related to migratory individuals from neighboring non-citrus plants.

6.6.5 Toxoptera aurantii *(Boyer de Fonscolombe)*

Members of the *Toxoptera* genus feed on vigorously growing shoots of a variety of mostly woody dicotyledonous plants and are usually accompanied by ants. Three species, *T. aurantii*, *T. citricidus* and *T. odinae*, are widespread and well-known agricultural and horticultural pests of woody and crop plants (Qiao et al. 2008). The black citrus aphid *T. aurantii* (Fig. 6.3f) is anholocyclic throughout its distribution, occurring in all tropical and subtropical regions and infesting a large number of plant species (Uygun et al. 2012). It may have originated in Southeast Asia (Milesian archipelago), where it is a pest of many plant species (Bodenheimer 1951). While it is known elsewhere, it is chiefly mentioned as a citrus pest (Ebeling 1959). In contrast to the other abovementioned aphids, it may be found on the leaves of older citrus shoots. It is considered a minor pest of citron.

6.7 Scale Insects

Scale insects (Hemiptera: Coccoidea) are among the most severe pests of citrus worldwide. On Mediterranean citrus, these insects are represented by four families, Diaspididae, Coccidae, Pseudococcidae and Margarodidae. Among the 26 scale insect species of citrus in Israel, 23 are highly polyphagous and their origin is initially unrelated to that of *Citrus*. Only five species are considered significant pests of citron, *Aonidiella aurantii*, *Coccus hesperidum*, *Icerya purchasi*, *Planococcus citri* and *Parlatoria pergandii*.

6.7.1 **Aonidiella aurantii** ***(Maskell)***

The red scale, known as California red scale in the USA, *A. aurantii* (Diaspididae) (Fig. 6.4a) is considered a highly polyphagous species (García Morales et al. 2016). Nevertheless, its economic importance is chiefly related to citrus and to a much smaller extent, roses. In Israel, it is also a pest of avocado in the Jordan Valley. According to DeBach (1962), the red scale is considered indigenous to Southeast Asia, which includes most of the native habitat of the genus *Citrus*. The spread of citrus plants made it a citrus pest in vast areas worldwide (CABI 2019). The red scale develops successfully on all aboveground parts of the citrus tree. Injury is caused by toxins injected into the feeding tissue and includes yellowing of foliage and defoliation, dieback of twigs and small branches, but mainly culling of infested fruit (Bodenheimer 1951; Ebeling 1959). The red scale has been the subject of various classical biological control projects, which ascertained efficient restriction of the population, mainly by aphelinid parasitoids. However, although successful control was achieved on fruit and leaves, it was less effective on the stem and main branches (Walde et al. 1989). In contrast, the ecosystem's fragile balance may be disrupted by pesticides. Frequent application of insecticides in citron orchards makes the red scale a key pest of this crop in both Israel and Italy; in both areas, the challenge is to avoid infestation of the fruit by even a single scale (Fig. 6.4b).

6.7.2 **Coccus hesperidum** ***Linnaeus***

The brown soft scale *C. hesperidum* (Coccidae) (Fig. 6.4c) is one of 10 soft scales found in Israeli citrus orchards. It develops on a wide variety of hosts with cosmopolitan distribution. Outdoors, it is found on subtropical fruit trees, citrus in particular, but it is best known as a common pest of interior ornamental plants. The brown soft scale produces a large amount of honeydew, which leads to soiling of the leaves and fruit with sooty mold. The scale is attacked by several effective encyrtid parasitoids (Kfir and Rosen 1980; Kapranas et al. 2007). Small outbreaks of the scale in citrus orchards are always related to disruption of the biological balance, due to misuse or excessive application of insecticides. The frequent limited "hot spots" of brown soft scale outbreaks in citron orchards are the outcome of the latter event.

6.7.3 **Icerya purchasi** ***Maskell***

The cottony cushion scale (Fig. 6.4d), also known as Australian fluted scale, *I. purchasi* (Margarodidae) develops on a large variety of woody plant species (193 genera in 80 families (García Morales et al. 2016). Its indigenous area includes southeastern mainland Australia and Tasmania, and it is known to occur there in

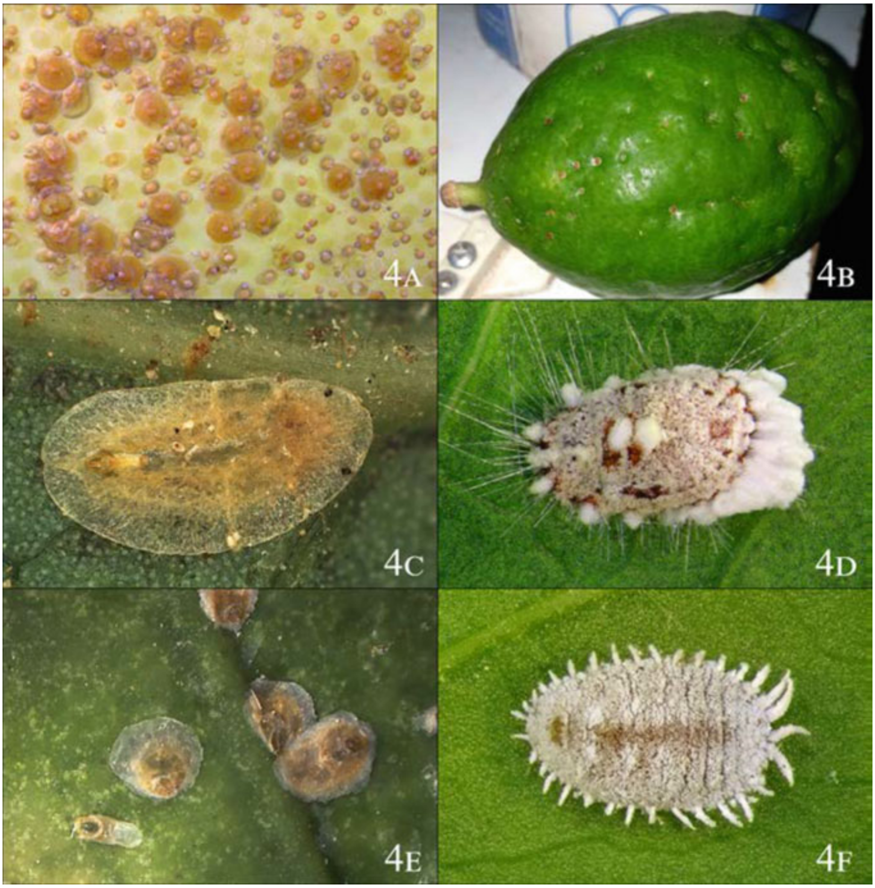

Fig. 6.4 Scales. **a** Different stages of *Aonidiella aurantii* [AP]; **b** *Aonidiella aurantii* on citron fruit [AA]; **c** Adult *Coccus hesperidum* [ER]; **d** Adult *Icerya purchasi* [AP]; **e** Adult females of *Parlatoria pergandii* [ER]; **f** Adult *Planococcus citri* [AP] [*Photo credits* Photographer initials, details in the acknowledgement section]

the natural habitat of wattle trees (*Acacia* spp.). The scale was introduced into California in the late 1860s, and was described 10 years later as it emerged as a serious aggressive pest of citrus (Ebeling 1959). The rapid spread of the scale was noticed almost everywhere; it reached the Mediterranean basin in 1910, when it was discovered in Israel (then Palestine) (Bodenheimer 1951). *Citrus* spp. seem to be among the most susceptible host trees. For example, a few years after its invasion of the Israeli territory, citrus orchards were entirely stripped of their leaves and fruit, and soon declined as a result of the extensive poisoning of feeding tissue and heavy sooty-mold cover (Bodenheimer 1951). Cottony cushion scale is attacked by 53 species of natural enemies, mainly predatory insects of 35 genera and 17 families (García Morales et al. 2016). However, two species of specific natural enemies, the predatory lady beetle *Novius cardinalis* and the parasitoid fly *Cryptochetum iceryae*, introduced from Australia, successfully controlled the scale. These enemies were first introduced into California (Quezada and DeBach 1973) and later into other areas, including Israel (Bodenheimer 1951; Mendel and Blumberg 1991). Since the introduction of *N. cardinalis*, the scale rarely causes any damage in citrus groves in the Mediterranean region. Insect growth regulators (IGRs)—insecticide compounds that interfere with the molting process of insects, such as fenoxycarb—are often applied against the citrus red scale. Fenoxycarb was first tested in Israeli citrus groves in 1987 (Bar-Zakai 1988). However, integration of IGRs in Israeli citrus groves, particularly fenoxycarb, indirectly led to an outbreak of the cottony cushion populations. This compound disrupted the biological balance of the cottony cushion by affecting *N. cardinalis* populations. Acclimatization of *C. iceryae* eventually solved the problem in commercial citrus groves (Mendel and Blumberg 1991). However, continuous applications of IGRs and neonicotinoids (a class of neuroactive insecticides) are the main reason for persistent infestations of the cottony cushion scale in local citron orchards. Furthermore, being an insect that takes advantage of microclimatic conditions of humid heat, its development could be favored by the protective nets used for the cultivation of citron in some areas.

6.7.4 Parlatoria pergandii *Comstock*

Bodenheimer (1951) suggested that the chaff scale *P. pergandii* (Diaspididae) (Fig. 6.4e) probably originated in the Indomalayan realm. The scale spread in most regions where citrus is grown. It arrived in California in 1889 and in Florida even earlier (Bartlett 1978). In Israel, the chaff scale shares the citrus orchards with two other *Parlatoria* species. It is a well-known pest of *Citrus* in other Mediterranean countries (Garrido Vivas and Ventura Rios 1993; Danzig and Pellizzari 1998; Foldi 2001). Although it is considered polyphagous (García Morales et al. 2016), it may be a characteristic insect pest of citron. This scale is chiefly a pest of citrus trees and its excellent adaptation to citrus, as reflected by its prolific development on all aboveground parts of the trees, may indicate that citrus is its principal host. Its wide occurrence in Israel in the first decades of the twentieth century suggests that it was brought into the country with citrus plant stock. The economic impact of the chaff scale varies among citrus areas (Rose 1990). Talhouk (1975) indicated that the scale is a problem in the Eastern Mediterranean and in Spain. Fruit colonization by chaff scales results in green spots (Gerson 1967), similar to the purple spots on apple skin caused by its congener *Parlatoria oleae*, hindering its marketability as a fresh product. The scale may cause damage in mature shaded citrus trees. Despite the typical management practice of shaded tree canopies of the citron orchards in Israel, this habitat seems unfavorable for the chaff scale. However, it is reported to be a significant pest in China (Karp and Hu 2018).

6.7.5 Planococcus citri *(Risso)*

The citrus mealybug *P. citri* (Fig. 6.4f) is the most widespread and destructive pest in the family Pseudococcidae (Bodenheimer 1951; Bartlett 1978), and it is found in a seemingly endless number of host plants (García Morales et al. 2016). The citrus mealybug belongs to the 'citri' group in the *Planococcus* genus, most members of which are believed to be native to Africa (Cox 1989). However, *Planococcus minor*, which is genetically close to *P. citri*, is absent from the African mainland; and it is suggested that the speciation of *P. citri* and *P. minor* may have happened in Asia (Rung et al. 2008). These studies support Bartlett's (1978) suggestion that the origin of the citrus mealybug is probably China. It was probably introduced from China to the Mediterranean area, maybe on citron stock, and therefore may be considered one of the old introductions of citrus pests to this area. The main injury inflicted by the mealybug on citrus is related to the rapid growth of its colonies on the developing fruit, which results in fruit drop, contamination of the fruit with honeydew and sooty mold, and attraction of fruit moths to the soiled fruit (Bodenheimer 1951). Citron is not among the susceptible citrus crops, but disruption of the biological balance by frequent insecticide application often disrupts the activity of *Anagyrus vladimiri*, a key natural enemy of the mealybug (Franco et al. 2009). Whereas in Israeli citron orchards the citrus mealybug is considered a minor pest, in Calabria it is a major one, probably due to the low winter temperature that limits the activity of the parasitoids and the high humidity in spring, which encourages high survival of the mealybug population.

6.8 Fruit Flies

Fruit flies are among the most impactful pests in citrus worldwide, particularly members of the genera *Bactrocera* and *Anastrepha.* The Mediterranean fruit fly, or medfly, *Ceratitis capitata* (Diptera: Tephritidae) is the most destructive pest of fresh fruit, including citrus, in the Mediterranean region (Papadopoulos et al. 2001), and in particular, it is a major citrus pest in Israel (Bodenheimer 1951; Rossler and Chen 1994). During the last decade the peach fruit fly *Bactrocera zonata* was noticed in Israeli citrus groves, but not in citron settings.

6.8.1 Ceratitis capitata *(Wiedemann)*

Silversti (1914) and Bodenheimer (1951) indicated that the origin of the Mediterranean fruit fly *C. capitata* is Afrotropical, likely West Africa. The origin was later confirmed by evidence of high mitochondrial DNA diversity (De Meyer et al. 2004). Its presence in the Mediterranean basin was initially recorded in Algeria in

1859 (Bodenheimer 1951). Medfly injury to citron fruit is rare, as the fruits are harvested unripe, and preventive measures are rarely taken against it. Damage may occur, however, in citron orchards adjacent to neglected fruit plantations with high medfly populations. The typical harvested unripe citron fruit is not suited to medfly development, which often occurs on ripe and dropped fruit.

6.9 Fruit Moths

Eleven species of Lepidoptera are known from citrus in Israel (Valeriya Seplyarsky, unpublished information), several of them already mentioned by Bodenheimer (1951). Among them, four species are known from citron orchards. Most of the species are polyphagous; two species are specific to citrus (discussed below), whereas typical host plants for the butterfly *Papilio machaon sphyrus* are members of the Rutaceae (Bodenheimer 1951).

6.9.1 Apomyelois ceratoniae *(Zeller)*

The carob moth, also known as the blunt-winged knot-horn, *A. ceratoniae* (= *Ectomyelois ceratoniae*) (Pyralidae) (Fig. 6.5a) is present in the Mediterranean basin, the Near East, South Africa, Australia and the Americas (CABI 2021). This moth is highly polyphagous (Gothilf 1970) and recognized as a major pest of almond in the Mediterranean region and Australia (Madge 2005), and of dates in California (Warner 1988). The carob moth is considered to have originated in the Middle East/Mediterranean region (Heinrich 1956). Its natural occurrence is also reflected by 23 parasitoid species that develop on different immature stages of the moth (Madge 2005). It is certainly not a tropical or subtropical species, since under low temperature (<20 °C) and short-day length (<12 h light), the larvae enter diapause (Cox 1979). The carob moth inhabits and damages citrus fruit only when these are contaminated by honeydew and/or sooty mold as a result of mealybug activity, mostly the citrus mealybug. The caterpillars tunnel into the peel and turn the fruit prematurely yellow, exuding gum from the wounds. This gum often kills the larvae (Argov and Gerson 2012). The carob moth therefore seldom attacks citron; and the interaction between them probably started when citron was introduced into the Mediterranean area.

6.9.2 Cryptoblabes gnidiella *(Millière)*

The honeydew moth *C. gnidiella* (Pyralidae) (Fig. 6.5b) is an extremely polyphagous species, with worldwide distribution (Bodenheimer 1951; Avidov and Harpaz 1969; Ben Yehuda et al. 1991). The Mediterranean basin has been suggested as its native

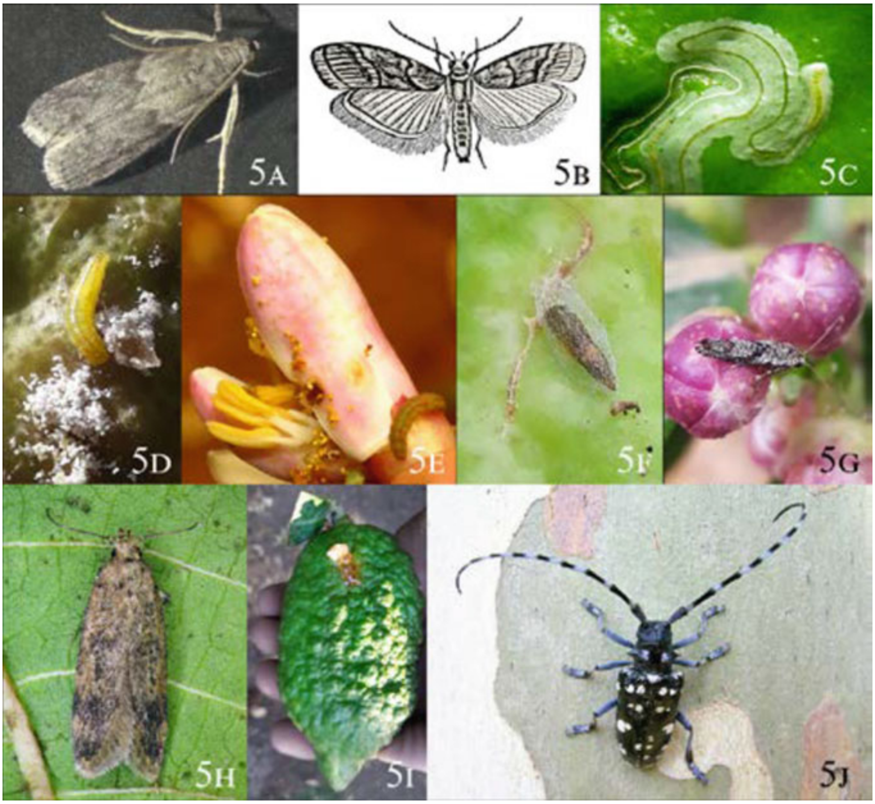

Fig. 6.5 Moth and longhorned beetle. **a** Adult female *Apomyelois ceratoniae* [IR]; **b** Adult drawing of *Cryptoblabes gnidiella* [BH]; **c** Leaf mining by *Phyllocnistis citrella* larvae [AL]; **d** Larva of *Prays citri* [ZG]; **e** Flower bud damaged by *Prays citri* [AL]; **f** Pupa of *Prays citri* [ZG]; **g** Adult of *Prays citri* [ZG]; **h** Adult of *Thaumatotibia leucotreta* [AP]; **i** Citron fruit damaged by *Thaumatotibia leucotreta* [AA]; **j** *Anoplophora chinensis* [MM] [*Photo credits* Photographer initials, details in the acknowledgement section]

area. However, 14 of the 18 known *Cryptoblabes* species are from Australasia and the Indian subcontinent (Wikipedia 2021). The latter information, coupled with the absence of reports about specific natural enemies of the moth (e.g. Molet 2013), and the fact that this moth does not undergo diapause, suggest that it was introduced into the Mediterranean region from the tropical or subtropical areas of the Far East. In fruit tree plantations, the females are attracted to and lay their eggs on fruit soiled with honeydew and/or sooty mold from mealybug colonization (Swirski et al. 1980; Silva and Mexia 1999). On citrus fruit, the first instar larvae initially feed on the honeydew and then on the fruit peel, inducing aesthetic damage, gum exudation, gallery formation, premature yellowing and drop (Silva and Mexia 1999; Moore 2003; Peri and Kapranas 2012). The honeydew moth is a minor pest of citron, because infestation of the fruit by mealybugs is uncommon. Judging from the interaction between the moth and citrus in general, it seems that it was not originally associated with this crop.

6.9.3 Phyllocnistis citrella *Stainton*

The citrus leafminer *P. citrella* (Gracillariidae) was originally described from Calcutta, India (Stainton 1856). The origin of this pest is Southeast Asia and in the first half of the twentieth century, it was known as a serious pest of citrus nurseries (Clausen 1931). It now occurs wherever citrus is grown (Heppner and Fasulo 1998) and has been known in the Middle East since 1994 (Argov and Rossler 1996). The moth is a pest of citrus and the related Rutaceae, as well as of some related ornamental plants (Kalshoven 1981; Beattie 1989). It attacks all citrus varieties, including citron. The adults are minute moths with a 4 mm wingspread. Emerging larvae burrow into leaves and form serpentine mines, which are filled with a central line of frass (Fig. 6.5c). They rarely occur on fruit (Argov and Rossler 1996). The citrus leafminer completes a generation within 2–3 weeks under long-day conditions at 25 °C. A typical tropical insect, it has no diapause. The citrus spring flush is rarely affected due to low winter temperatures, whereas the mid-summer and autumn flushes are more heavily attacked (Argov and Gerson 2012). Sudden flushes of new leaves largely escape leafminer damage by maturing before the pest population can respond to the increased resource (Wilson 1991). About 40 species of parasitoids, mostly Chalcidoidea, have been reported from its native range. In its areas of invasion, the moth is attacked and well controlled by both introduced and native parasitoid species (Argov and Rossler 1996; Vercher et al. 2004; Diez et al. 2006). The moth in Israel is under good biological balance and may cause limited damage to citron orchards, usually as a result of excessive usage of synthetic insecticides. The moth is considered a significant pest of citron in China. In Italy, the insect is of particular concern for nursery stock and newly established orchards, up to 4 years of age, as attacks on young shoots often depress and delay plant development.

6.9.4 Prays citri *(Millière)*

The citrus flower moth *P. citri* (Praydidae) (Fig. 6.5d, f, g) is widespread in the Mediterranean region, where it was probably introduced with some citrus varieties (Balachowsky 1966). The literature on the distribution of *P. citri* is unreliable due to misidentification, biology, and damage caused by congeners closely related to *P. citri* (CABI 2007), such as *Prays endocarpa* on the Indian subcontinent of Southeast Asia and *Prays endolemma* in the Philippines, both also known as citrus rind borer (EFSA 2008). *Prays citri* has been reported to attack other Rutaceae and species of Sapotaceae (*Manilkara zapota*, *Casimiroa edulis*) (EFSA 2008) and Oleaceae (*Ligustrum lucidum*) (Sinacori and Mineo 1997). The taxonomic status of the genus is confused, and in the literature on the family it is frequently referred to as Yponomeutidae, Hyponomeutidae or Plutellidae. However taxonomic revision of the genus (Sohn and Wu 2011) and a molecular phylogeny analysis of Yponomeutoidea (Sohn et al. 2013) suggest that it belongs to a newly formed family, Praydidae. Most known *Prays* species are associated with Rutaceae and Oleaceae. The citrus flower moth is one of the oldest citron pests in the Mediterranean, described in 1873. It is logical to assume that it was introduced together with citron stock.

In the Mediterranean region, all stages of the moth can be found throughout the year. The number of generations varies from 3 to 16 per year, depending on climatic conditions. For example, in Sicily, Italy, there are 11 generations, and in Israel between 8 and 10 generations (Argov and Gerson 2012). Flowers are the favored substrate for oviposition (Carimi et al. 2000). The larvae feed on the flowers (Fig. 6.5e), buds, and graft tissue (Bodenheimer 1951). Affected buds and flowers wilt and drop, and heavy attacks may result in almost total yield loss (Mineo 1993). In Sicily, the citrus flower moth is regarded as a key pest of nursery trees (Conti and Fisicaro 2015). In Israel, it is a major pest of lemon and citron (Avidov and Harpaz 1969). The susceptibility of both of these, as compared to other citrus crops, is probably related to their waves of flowering, which typically occur several times a year. In Egypt, the long florescence period in lime (*Citrus aurantifolia*) may explain the high population of the moth on this species, as compared to navel orange and mandarin trees (Abd El-Kareim et al. 2017). Furthermore, according to El-Sayed et al. (1994), specific flower volatiles of different citrus species may attract or repel the ovipositing females. The female sex pheromone of the citrus flower moth was identified in 1977 (Nesbitt et al. 1977) and has been successfully used in the monitoring of moth flights, to support pest-management decisions (Mineo et al. 1980; Mendonca et al. 1997), in mass trapping (Sternlicht et al. 1990) and in mating disruption (da Silva et al. 2006). None of these techniques are applied in citron orchards in Israel. Although the citrus flower moth has many natural enemies, none are specific and what is probably the most important parasitoid of the moth, *Ageniaspis fuscicollis* (Encyrtidae), was originally associated with the olive kernel borer *Prays oleae* (Mineo et al. 1974).

6.9.5 Thaumatotibia leucotreta *(Meyrick)*

Thaumatotibia leucotreta (Tortricidae) (Fig. 6.5h) was first reported in South Africa and assigned to the *Carpocapsa* genus, which includes the famous apple fruit moth and the codling moth; this is how it got its common name of “false codling moth” (Fuller 1901). Its indigenous area is most probably South Africa and other sub-Saharan areas. The moth is extremely polyphagous, attacking more than 70 host plants (CABI 2000), both wild and cultivated. The eggs are usually laid on the surface of the fruit, but may be oviposited on foliage, and occasionally on branches. The larvae bore into the fruit albedo and foliage, and occasionally into branches. The number of annual generations is related to ambient temperature and food quality

(Newton 1998). Most of the population studies on the false codling moth have been conducted on citrus in South Africa (Moore and Hattingh 2012).

The moth was discovered in Israel in 1984 on macadamia trees (Wysoki 1986). Since 2009, there has been a steep increase in its population density, including serious damage inflicted on several fruit crops. However, it has only been considered a serious pest of citrus since 2014 (Ben Yehuda and Sela 2020). To date, damage to citron orchards has usually been limited due to intensive treatment against other insect pests and typical strict sanitation. However, it seems that *T. leucotreta* may inflict serious damage on citron flowers and also on green fruits (Fig. 6.5i) (Assaf Avtabi, unpublished observations) and it has phytosanitary quarantine status for most international markets (Moore 2021), thereby threatening citron exports.

6.10 The Origin of Citron Pests

Table 6.1 displays a summary of the 28 reviewed arthropod pest species of citron. Only four of them are specific to citrus; all others are polyphagous, with 12 species being sympatric but probably related to citrus in its indigenous areas, whereas the other 12 species are allopatric. The reviewed citron pests are few among much larger entomofauna of citrus in general. Figure 6.6 displays the frequency occurrence of citrus arthropod pest species among different insect groups and mites in Israel, and the share of those found on citron.

6.11 Pest Management in Citron Orchards

Citron orchards in Israel and Italy (Calabria) are primarily cultivated for fruit serving the religious ritual of the Jewish Sukkot holiday. To qualify as kosher for this purpose, the citron fruit must be without any blemishes. What constitutes a proper citron fruit is defined in the third chapter of the Tractate Sukkah (the sixth Tractate in the "Seder Moed" in the second Order of the Mishnah). Since any arthropod infestation or injury to the fruit renders it non-kosher, it follows that the citrons must be arthropod-free, dictating that there is strict pest management in citron orchards.

Citron trees and their fruit seem to be more susceptible to arthropod pests than the main commercial citrus varieties. Citron is a fast-growing fruit; in particular, the fruit that develop from May flowers constitute the major crop in both Israel and Calabria; these fruit are more susceptible to mites and sucking insects (Hemiptera and thrips). The general susceptibility to pests coupled with the intended use as unadulterated kosher fruit make protection of this crop a serious challenge and often involves multiple chemical treatments. Table 6.2 compares pest management in citron orchards with that for other citrus fruit in Israel. Although the sample size is small, it reflects the management differences. The average number of insecticide treatments per year in citron is about 17.0, compared with 7.0 in lemon and 8.8 for other citrus

Table 6.1 Arthropod species as pests of *Citrus medica* mainly in Israel, and their affinity to citrus and natural citrus areas

Arthropod species	Citrus specific	Polyphagous	
		Related to citrus or the trees' natural area	Unrelated to citrus
Mites			
Aceria sheldoni	*		
Brevipalpus californicus			*
Eutetranychus orientalis		*	
Panonychus citri		*	
Phyllocoptruta oleivora	*		
Polyphagotarsonemus latus			*
Tetranychus urticae			*
Thrips			
Chaetanaphothrips orchidii		*	
Frankliniella occidentalis			*
Scirtothrips dorsalis		*	
Leafhoppers			
Asymmetrasca decedens			*
Whiteflies			
Aleurocanthus spiniferus		*	
Aphids			
Aphis craccivora			*
Aphis gossypii			*
Aphis spiraecola		*	
Myzus persicae			*
Toxoptera aurantii		*	
Scale insects			
Aonidiella aurantii		*	
Coccus hesperidum		*	
Icerya purchasi			*
Parlatoria pergandii[a]		*	
Planococcus citri		*	
Fruit flies			
Ceratitis capitata			*
Fruit moths			
Apomyelois ceratoniae			*
Cryptoblabes gnidiella		*	
Phyllocnistis citrella	*		

(continued)

Table 6.1 (continued)

Arthropod species	Citrus specific	Polyphagous	
		Related to citrus or the trees' natural area	Unrelated to citrus
Prays citri	*		
Thaumatotibia leucotreta			*
Totals	4	12	12

[a] In China

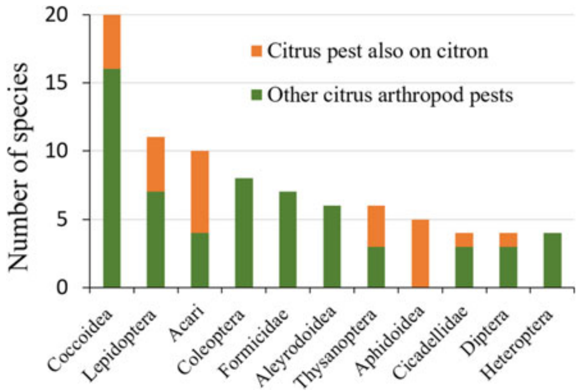

Fig. 6.6 Frequency of occurrence of citrus arthropod pest species among different insect groups and mites in Israel, and the share of those found on citron

(6.2 if the treatments against the medfly are excluded, where all have a minimal impact on the environment). Lemon is more interesting in this sense, because it is vulnerable to the same key pests as citron (as mentioned, both are highly susceptible to the citrus flower moth and to the citrus bud mite; conversely, the medfly is considered an insignificant pest for both crops). The intensive application of insecticides in citron is counterproductive and further increases the injury inflicted by arthropods. The insecticides may increase the fecundity or longevity of some pests directly by improving the feeding substrate, and indirectly by affecting their natural enemies. Further, a sublethal pesticide application and pesticide residues may lead to the rapid development of insecticide resistance. For example, Szczepaniec et al. (2013) demonstrated that applications of neonicotinoid insecticides suppress expression of important plant defense genes, alter levels of phytohormones involved in plant defense, and decrease plant resistance to spider mites.

Observations on different citron cultivars in Israel have suggested different levels of susceptibility to arthropod pests in general, or to specific species. Citron cv. Halperin is far more susceptible to spider mites than the closely genetically related cv. Chazon Ish, whereas cv. Yemenite is much more vulnerable to leafhoppers (Assaf Avtabi, unpublished observations).

Table 6.2 Examples of pest management (in the years 2018–2020) in adult orchards of citron vs. other citrus varieties as reported by the growers (N = number of treatments)

Location, citrus variety and category	Main arthropod pests (and number of treatments)	Management cycle and pesticides during the year
Israel coastal plain, citron cv. Hazanit, IPM	CFM, thrips and SM (N = 10–12)	Winter [Nov–Feb]: 2 treatments (tr.) with copper hydroxide or chalcanthite formulations [F] for Mal secco disease prevention. Spring [Mar–May]: 2–3 tr. of light mineral oil against CFM and thrips, 1 tr. with abamectin F against CFM and SM, 1 tr. of spinetoram F against SM. 1 tr. of spirotetramat or sulfoxaflor against CLM and aphids. Summer [May–Sep.]: 3 tr. of spinetoram against thrips and SM; occasionally, 1–2 tr. with mineral oil against red scale
Israel coastal plain, different citron cultivars, chemical management	CFM, LH, SM CRM, thrips, FCM (N = 16–26)	Spring: 1–2 tr. against red scale and citrus mealybug [CM]; Apr–July: 5–10 tr. against CFM and sometimes FCM; May–Sep: 5–8 tr. against SM and CRM; late Jun–Aug: 3 tr. against LH, 5–6 tr. against thrips
Israel, northern Negev, citron cv. Yemenite	Aphids, thrips, SM LH, CBM (N = 17–21)	Winter: 2 tr. of copper hydroxide and 2 tr. of abamectin against SM. Spring: 2 tr. of imidacloprid against aphids; 3 tr. abamectin + spinetoram and 1–2 tr. of methiocarb against thrips, 4 tr. of abamectin and/or spinetoram and/or lambda-cyhalothrin against CFM and SM. Summer: 2 tr. chlorpyrifos against mealybug, 2–3 tr. pyriproxyfen against red scale and 2 tr. abamectin against SP, 3–4 tr. of spirodiclofen and/or tau-fluvalinate against LH

(continued)

Table 6.2 (continued)

Location, citrus variety and category	Main arthropod pests (and number of treatments)	Management cycle and pesticides during the year
North of Israel, different citrus varieties, not citron	MFF, CRM, FCM (N = 9–11)	March–May: 4 tr. of spinetoram against MFF, 2 tr. of spinetoram against CRM. Jun–Sep: sulfur or summer oil + abamectin. Jul–August 1–2 tr. fenpyroximate or spirodiclofen or sulfur against SM, Jun–Jul, Oct: 1–2 tr. pyriproxyfen or spirotetramat against RS, 1 > tr. imidacloprid or sulfoxaflor or thiamethoxam against mealybugs. Autumn: 2 tr. of mating disruption
Israel, Yezrael valley, different citrus varieties, not citron	MFF, CRM, SM(SP?); CFM (lemon only) (N = 7–15)	March–September: 5–10 tr. of spinetoram against MFF and trapping devices, 1–4 tr. of abamectin and/or spinetoram against CRM. Spring–early summer: 1 > tr. imidacloprid against mealybugs, pyriproxyfen against red scale, 1 > tr. abamectin and/or spinetoram against thrips, 1 > tr. pyriproxyfen against whiteflies
Israel, western Negev, citrus var. Orr	CRM, SM, MFF (N = 5)	Spring and summer: 3 tr. spirodiclofen and/or sulfur F against CRM and SM, 2 tr. of pyriproxyfen against RS, trapping devices for MFF
Israel, western Negev, grapefruit	CLM, CRM (N = 10)	May–Jun: 1 tr. chlorpyrifos against mealybugs, 1tr. fenbutatin oxide against SM. Jun–Dec: 6 tr. abamectin against CLM. Jul–Aug: 2 tr. sulfur F against CRM
Israel, Judean foothills, lemon	CFM, CRM, SM, (N = 7)	Spring and summer: 2 tr. abamectin and/or spinetoram against CFM, 3 tr. spirodiclofen and or sulfur F against CRM and SM Israel, western Negev: 1 tr. of pyriproxyfen against citrus RS

(continued)

Table 6.2 (continued)

Location, citrus variety and category	Main arthropod pests (and number of treatments)	Management cycle and pesticides during the year
Israel, western Negev, lemon	CFM, CRM, SM, thrips (N = 9)	Spring and summer: 2 tr. abamectin and/or spinetoram against CFM, 3 tr. spirodiclofen and/or sulfur F against CRM and SM, 1 tr. chlorpyrifos against mealybugs, 3 tr. spinetoram and/or spinetoram + methoxyfenozide against thrips
Israel, western Negev, lemon	CLM, CRM (N = 5)	Apr: 1 tr. chlorpyrifos against mealybugs. Jun: 1 tr. fenbutatin oxide against SM, 1 tr. abamectin against CLM. Aug–Sep: 2 tr. sulfur F against CRM

CFM, citrus flower moth; SM, spider mites; LH, leafhoppers; CRM, citrus rust mite; FCM, false codling moth; CBM, citrus bud mite; MFF, Mediterranean fruit fly; CLM, citrus leaf miner; RS, red scale; tr., treatment

6.12 Serious Coming Threats

Four invasive species may seriously injure citron (and other citrus) cultivation in the Mediterranean: the pink citrus rust mite *Aculops pelekassi*, the citrus psyllids *Trioza erytreae* and *Diaphorina citri*, and the citrus long-horned beetle *Anoplophora chinensis*. Brief details of each of these threats are presented.

6.12.1 Aculops pelekassi *(Keifer)*

The pink citrus rust mite *A. pelekassi* (Eriophyidae) (Fig. 6.1m) displays a cosmopolitan distribution and develops only on citrus. In the 1960s and '70s, this mite inflicted considerable damage on Sicilian citrus groves. The outbreaks were probably a consequence of excessive insecticide application, mainly against scale insects and spider mites, in citrus groves in general and against *Prays citri* on lemon in particular, which likely interrupted the activity of the natural enemies of *A. pelekassi*. The mite thrives on the shoots, young leaves and fruit of lemon in particular. The typical color of heavily infested fruit gradually turns to bronze; the injury may be confused with that inflicted by *Polyphagotarsonemus latus*. However, in the latter case, the surface of the ripe fruit cracks and peels off (Vacante 2016). *Aculops pelekassi* is active year-round, developing 18–22 generations per year in mild climates. Under low temperature, *A. pelekassi* development slows dramatically. Climatic conditions significantly affect the development of mite populations and may cause steep fluctuations in the mite's population density (Vacante and Bonsignore 2010). The spread of *A. pelekassi* is mainly facilitated by human activities through the movement of infested plant materials or equipment. Since the late 1990s, infestations have become uncommon, limited to a few fruit, leaves or shoots. Judging from the susceptibility of lemon to this mite and the intensive applications of pesticides in citron orchards, citron might also be highly susceptible to injury inflicted by *A. pelekassi.*

6.12.2 **Trioza erytreae** ***(Del Guercio) and*** **Diaphorina citri** ***Kuwayama, Vectors of the Citrus Greening Disease***

The African citrus psyllid *Trioza erytreae* (Hemiptera: Triozidae) and the Asian citrus psyllid, *Diaphorina citri* (Hemiptera: Liviidae) transmit the causal agent of citrus huanglongbing (HLB, greening disease), *Candidatus liberibacter*. *Trioza erytreae* transmits the African form Ca. *liberibacter africanum* (Gottwald et al. 2007; Cocuzza et al. 2017), however, most cases of worldwide occurrence are currently related to Ca. *liberibacter asiaticus*, transmitted by *D. citri* (Hall and Gottwald 2011). Both psyllids pose a serious threat to citron cultivation. Infected citrus trees produce fewer fruit that are small, lopsided, bitter-tasting, and sometimes remain green in color (Bové 2006). Both psyllid species already occur in the Mediterranean basin.

Trioza erytrea (Fig. 6.2e) is probably native to southeast Africa. However, the psyllid is currently widespread in the subequatorial part of that continent, establishing itself in the Arabian and Iberian Peninsulas during the early decades of the twenty-first century (Cocuzza et al. 2017; Ruíz-Rivero et al. 2021). Both species are known to develop on various members of the genus *Citrus*, including *Citrus medica* (Aubert 1987; Hall et al. 2013). *Diaphorina citri* is native to Asia, all evidence points to India as its origin (Hall et al. 2013). *D. citri* has been known for several decades in Brazil (Hodkinson and White 1981); Burckhardt and Martinez (1989) reported on the interception of *D. citri* in an airport in France on plant material originating from Honduras. During the 1990s it was discovered in many new areas in the Western Hemisphere, including Argentina, Florida (USA) and the Bahamas (Halbert and Núñez 2004).

Both psyllids display high climatic tolerance, with no diapause, producing 6–8 annual generations, thriving on host plants with multiple flushes per year, such as lemon (Tamesse and Messi 2004; Hall and Hentz 2014). Seasonal population fluctuations of both psyllids are related to the occurrence of young flushes since eggs are laid exclusively on early leaves, and nymphs develop exclusively on young plant tissue (Hall et al. 2013; Cocuzza et al. 2017). Direct damage consists of the removal of sap and abundant secretion of honeydew on which heavy sooty mold develops. Furthermore, nymphs (Fig. 6.2f) feeding on the leaves, form open gall-like structures that later roll up and assume a chlorotic appearance until they drop (Hall et al. 2013; Cocuzza et al. 2017). Although the direct injury may seem alarming, real damage to adult trees is usually moderate. However, young plants may be seriously affected. *Tamarixia dryi* and *Tamarixia radiata* (Hymenoptera: Eulophidae) seem to be the most promising natural agents for biological control of *T. erytreae* and *D. citri*, respectively (Aubert and Quilici 1984; Urbaneja-Bernat et al. 2019).

6.12.3 Anoplophora chinensis *(Forster)*

The black and white citrus long-horned beetle *A. chinensis* (Coleoptera: Cerambycidae) is native to the Far East. It has become established in recent years in Italy and Turkey (EPPO 2021). Adults (Fig. 6.5j) are shiny black with scattered irregular white spots on the elytra, displaying a typical "cerambycid" shape and 21–37 mm body length. The antennas are very long with black and white joints. This polyphagous species has been reported from over 100 host species and is also known as a serious pest of members of the genus *Citrus*. In China, it has caused severe damage to citrus orchards; in Korea it was reported to be harmful on citron (Lee et al. 1992; Wang et al. 1996). In Italy and Turkey, it has caused damage to several ornamental tree species and to stonefruit. So far it has not been reported on citrus in the Mediterranean area. The damage is due to the alimentary activity of the larvae, which excavate deep tunnels in the lower parts of the trunk and in the roots, resulting in tree death (EFSA 2019).

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Chapter 7
Diseases of Etrog Citron and Other Citrus Trees

Moshe Bar-Joseph, David Ezra, Grazia Licciardello, and Antonino Catara

Abstract Citrus fruits, consumed both fresh and as juice concentrate, are responsible for the world's largest fruit tree industries. Among the cultivated *Citrus* species and hybrids, the etrog citron (*Citrus medica* L.) is one of the smallest crops, in both the size of its commercially cultivated areas and its limited geographic distribution. Furthermore, etrogs represent a specialty fruit crop, used mainly in traditional medicine and as a culinary interest for certain ethnocultures, and for the Jewish religious ritual of the week of Sukkot (tabernacle). Despite their uniqueness among edible citrus fruit, etrog trees share almost the entire range of susceptibilities to pests and disease agents that affect other citru*s* crops and may therefore host inoculum sources that will affect neighboring commercial citrus groves. This chapter provides a short historical account of some of the major epidemic diseases of the world's citrus industries and their impact on etrog citron cultivation.

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7.1 Introduction

Etrog citron (*Citrus medica* L.) trees and fruit, like all plants, are often afflicted by a variety of pathogenic diseases and/or damaged by abiotic events, such as hail and stormy winds. Infectious disease agents can cause severe damage by spoiling the quality and suitability of etrog fruit for use as a religious item, where demanding standards for its perfect appearance apply. Thus even a few bruises, scars or other blemishes caused by disease or physical damage render an etrog fruit with good size and shape unmarketable for religious use.

The outcome of infections of etrog trees differs depending on the pathogenicity of the invading organism and the prevailing environmental conditions. Some disease agents of citrus are detrimental to etrog groves, causing death of both young and mature groves, while the damaging effects of most other citrus pathogens are less dramatic, but can still compromise growth and impair flowering and fruiting.

This chapter describes:

(i) the major diseases affecting etrog and citrus trees production in general in the Mediterranean basin, with a consideration of diseases that are absent from the Mediterranean basin but exist in geographical areas to which etrog fruit are exported;
(ii) the characteristics of the major pathogens infecting etrog and other citrus trees;
(iii) the phenology of diseased etrog trees; and
(iv) the means of prevention and control of the major etrog tree diseases.

In the absence of sufficient research directly addressing etrog pests and disease agents, etrog cultivation and plant protection mainly relies on the availability of parallel information from the research developed for other intensively cultivated citrus species. Hence the chapter not only deals with pathogenic agents specifically endangering etrog trees, but with the wider range of diseases infecting global citrus production.

Special emphasis in this chapter is given to:

(i) two diseases of major importance—including the mal secco disease which is absent from most areas that import etrog fruit from the Mediterranean basin, and *Phytophthora*, a complex group of globally spread citrus pathogens; and
(ii) budwood transmitted pathogens including, viruses, viroids and the phloem restricted bacteria, which could impose considerable damage to citrus production in case of unregulated movement of etrog plants and vegetative tissues used for propagation.

7.2 A Brief History of Plant Pathology with an Emphasis on *Citrus*

The damaging effects of plant diseases on cultivated plant crops have been known since ancient times. Indeed the “Hoshana” Sukkot holiday prayer includes verses asking for the prevention of plant diseases endangering field and fruit crops. Phytopathology, the scientific study of diseases affecting plants, was only established as a specific discipline less than two centuries ago, following the outbreak of the devastating epidemic disease "potato blight" in northern Europe. This disease, which resulted in the disastrous Great Irish Famine (Erwin and Ribeiro 1996), still serves as a reminder of the vulnerability of global food supply and the importance of crop plant management to prevent the spread of detrimental plant diseases.

While the potato blight disaster became known around the world, in 1847, the citrus growers on Madeira Island had noticed more than a decade earlier that another *Phytophthora* sp. caused plaque, initially termed "gummosis" due to the rubber-like resin secreted from the severe lesions observable under the bark of the infected citrus trees. Later, gummosis disease spread across all of the Mediterranean ports, killing trees and destroying nearby cultivated citrus groves.

7.2.1 The Impact of Phytophthora Epidemics on World Citrus

Interest in global and Mediterranean citrus production intensified following James Lind's report of the curative effect of daily consumption of citrus fruit, as a remedy to prevent the disease in seamen termed scurvy, which was eventually found to be caused by vitamin C deficiency. As a result, a lucrative citrus industry developed to supply the citrus fruit needed to preserve the health of sailors cruising the routes of the East Atlantic toward Far East ports. Subsequently, the London surgeon and botanist N. B. Ward invented the "terrarium", essentially a miniature transportable glasshouse that allowed the long-distance transport, on ships, of rooted plants originating from remote exotic areas. It is worth noting that long before Ward's invention, a variety of *Citrus* spp. and other exotic plants were already present throughout the Mediterranean basin. These arrived into the area from seed sources, which were mostly free of many of the disease agents harbored by their mother plants. Ward's revolutionary invention protected plants from damaging salty winds and enabled the survival of rooted plants on long-distance cruises. Unfortunately, this blessing brought with it the disastrous *Phytophthora* sp. epidemic which caused, during the second half of the nineteenth century, havoc in etrog and other *Citrus* spp. throughout the Mediterranean basin. The remedy for the disease in most of the Mediterranean citrus production areas (see below) consisted of grafting citrus scion varieties onto *Phytophthora*-resistant rootstock. The practice originated in Spain, where growers noticed that, unlike orange and other citrus trees produced from seedlings on their own roots which were all lost to *Phytophthora*, the sour orange trees which served as ornamentals were apparently unaffected by the disease.

Interestingly, the practice of citrus grafting was already known to the ancient Chinese and Romans, and in the Talmudic tractates (Mudge et al. 2009; and see also Chap. 21 "The Grafted Etrog Citron Controversy" in this volume) more than two millennia earlier. However, it appears to have had only minimal uses for practical orange fruit production before the *Phytophthora* pandemic (Klotz 1978).

In the Jaffa area, unlike most other areas in the region that used the sour orange for rootstocks, the citrus trees were mostly grafted onto 'Palestinian' sweet lime, which offered both earlier and higher quality orange fruit, bearing marketable yields as early as 3 to 4 years after planting. The nursery propagation practice for 'Palestinian' sweet lime was by cuttings, which were often derived from trees infected with the *Citrus exocortis viroid* (CEVd), a citrus pathogen that was not recognized at the time but apparently contributed to the 'Palestinian' sweet lime's immunity to *Phytophthora* (see below).

Due to the *Phytophthora* sp. pandemic, grafting on *Phytophthora*-tolerant 'Palestinian' sweet lime and sour orange rootstocks became essential for continued citrus production. Grafting, however, from the Halachic standpoint (see also Chap. 21 "The Grafted Etrog Citron Controversy" in this volume) was absolutely prohibited for those etrog trees that were being cultivated to provide fruit for religious needs.

Nevertheless, since there were no objective means to differentiate between fruit harvested from grafted and non-grafted seedling trees, the observant customers, especially those living far from the etrog cultivation areas, were confronted with considerable difficulty finding reliable sources of religiously suitable etrog fruit. This confusion was often associated with insufficient horticultural and phytopathological information and naturally led, especially in the early phases of the *Phytophthora* epidemic, to serious religious (Halachic) and commercial conflicts, questioning, for example, why etrog fruit from cultivated areas with a long tradition of suitability for use during Sukkot holiday were suddenly forbidden. Such questions were often raised within Hassidic communities confronted with the dilemma of etrog sources, considered as reliable by their past generation community leaders, that suddenly became unacceptable for the coming Sukkot. Thus, gummosis disease not only had a major impact on the ways of growing the world's citrus trees, but also on trading etrog fruit, where close inspection was enforced to ensure that the fruit were derived from non-grafted etrog trees.

As a consequence, this chapter addresses issues that are not only for the small community of etrog tree producers but also for the far the wider communities of etrog fruit consumers.

It is also worth mentioning that, apart from China, Israel, Italy and just a few small groves in most of the world's citrus areas, the presence of etrog is limited to a few trees scattered throughout horticultural research institutes and botanical gardens. As a result, there has been far less research directly addressing etrog pests and disease agents compared with that on commercial citrus varieties. Nevertheless, the botanical relatedness of etrog to other commercially cultivated citrus species allows etrog growers to draw parallel information from the intensively researched commercial citrus production (Wallace 1978). The close relatedness also explains the great care etrog growers and users have to take in order to prevent the spread of citrus disease epidemics by transferring any citrus plants only with strict phytosanitary authorization. An unfortunate example of citrus disease damage is that of the recent citrus greening disease, or as it is often called, Huanglongbing (HLB). This disease has damaged orchards in Brazil and Florida over the past two decades and killed millions of citrus trees (Alvarez et al. 2016 and see HLB later in this chapter).

An understanding of past epidemiological events affecting etrog fruit production is also important for well-informed discussions on past authorization or Halachic restrictions pertaining to certain sources of etrog fruit (see also Chap. 20 “The Corfu Etrog Citron Polemic” in this volume).

The many diseases affecting etrog trees and fruit includes some very serious and detrimental ones, such as mal secco and gummosis, both fatal to etrog trees, and both needing special attention so that they will not decimate etrog groves or spread to nearby commercial plantations with susceptible varieties. As a rule, it should be strongly emphasized that the best and most economical means of disease control remains, wherever possible, the application of sanitation and disease-prevention measures (Hiltabrand 1959; Martin et al. 2016).

Readers interested in learning about the development of *Citrus* pathology would benefit from reading Chapot and Delucchi (1964), Scaramuzzi et al. (1986), Timmer et al. (1988), El-Otmani (2006), along with information on molecular technologies for pathogen diagnosis in Martin et al. (2016) and Visser et al. (2016).

7.3 Fungal and Fungal-Like Diseases

Fungi are spore-forming eukaryotic organisms with filamentous and branched bodies (mycelium) made of thread-like structures (hyphae); they lack chlorophyll. To reproduce, fungi use sexual or asexual spores, which develop on hyphae or as fruiting bodies. Some fungal pathogens survive on dead or decaying plant tissue, whereas others are obligate parasites of living plants. Infections by fungi start through natural openings, such as leaf stomata or tissue wounds, via mechanisms of active plant-tissue invasion.

This section includes diseases that are caused by “true” fungi (Eumycota) and those that are caused by “fungus-like” organisms (Oomycetes), which share some ecological and morphological features with the Eumycota. The distribution of these pathogens, as well as the severity of the diseases that they induce, are largely influenced by ecological conditions and by citrus host cultivation and management. Therefore, the same disease may assume different relevance in different areas of citrus cultivation. Recently published reviews have detailed most aspects of major or emerging fungal and fungus-like diseases in the Mediterranean area (Khanchouch et al. 2017) and worldwide (Batuman et al. 2020).

The diagnosis of fungal diseases is based on the specific morphologies of their hyphae, mycelia, fruiting bodies and spores, often following their isolation and culture on selected media. In recent years, major advances in qualitative and quantitative genetic testing technologies have considerably facilitated rapid and large-scale testing.

Management and control depend on the causal agent, the severity of the disease, the availability of genetically resistant varieties and registered chemicals, as well as the regional rules governing the use of those chemicals and the management adopted.

7.4 Major Fungal Diseases of Etrog

7.4.1 Mal Secco

Mal secco disease is caused by the mitosporic fungus *Plenodomus tracheiphilus* (formerly *Phoma tracheiphila* (Petri) Kanc. & Gik.). The disease is present throughout most of the Mediterranean basin (except Portugal and Morocco) and the Black Sea area (Russia and Turkey) (CABI/EPPO 2004). Mal secco is the most devastating fungal disease of lemons (*Citrus limon*) and etrog (*Citrus medica*) trees in these areas, causing considerable losses in both production and trees.

The main infection mechanism of orchard trees is spore dispersal by rain and wind. In Italy, infected plant parts left on the ground of the orchards provide an inoculum of spores in the soil, leading to root infection (Nigro et al. 2011). In Israel, infection mainly occurs in the tree canopy. The possibility of birds and insects serving as occasional vectors remains to be validated.

7.4.1.1 The Pathogen

The common name of the disease is citrus mal secco from the Italian words *male* (disease) and *secco* (dry). Mal secco was first noticed in 1894, affecting lemon trees on the Greek islands of Chios and Poros. In Italy, the disease was first reported in 1918 and Petri described the pathogen in 1929 as a new species, which he named *Deuterophoma tracheiphila*. In 1948, the name was changed to *Phoma tracheiphila* (Petri) L.A. Kantsch & Gikaschvili. It was renamed *Plenodomus tracheiphilus* (Petri) Gruyter, Aveskamp & Verkley in 2013 (De Gruyter et al. 2013).

Mal secco was first reported in Israel and neighboring countries in 1930, although the typical symptoms of the disease had been noted by growers in lemon and etrog trees many years earlier (Reichert and Chorin 1956). Species in the genus *Plenodomus* have teleomorphs, and in the *Leptosphaeria* and/or *Phialophora*, synanamorphs. Phylogenetic analyses supported placing *P. tracheiphilus* in the genus *Phoma*, as well as its relationship to *Leptosphaeria* species (Balmas et al. 2005; De Gruyter et al. 2013). No teleomorph of *P. tracheiphilus* is known.

When grown in the laboratory on potato dextrose agar (PDA) medium, the two pathogenic forms of *P. tracheiphilus* cultures show different phenotypes: (i) “chromatic”, which displays a red–orange pigment and (ii) “achromatic”, i.e., gray colored and lacking red pigmentation (Fig. 7.1a–c).

7.4.1.2 Symptoms

The symptoms of mal secco disease first appear in the spring as shoot and interveinal leaf chlorosis and dieback of twigs and branches (Fig. 7.1d). The first symptoms of canopy infection are leaf yellowing, followed by leaf shedding and twig dieback.

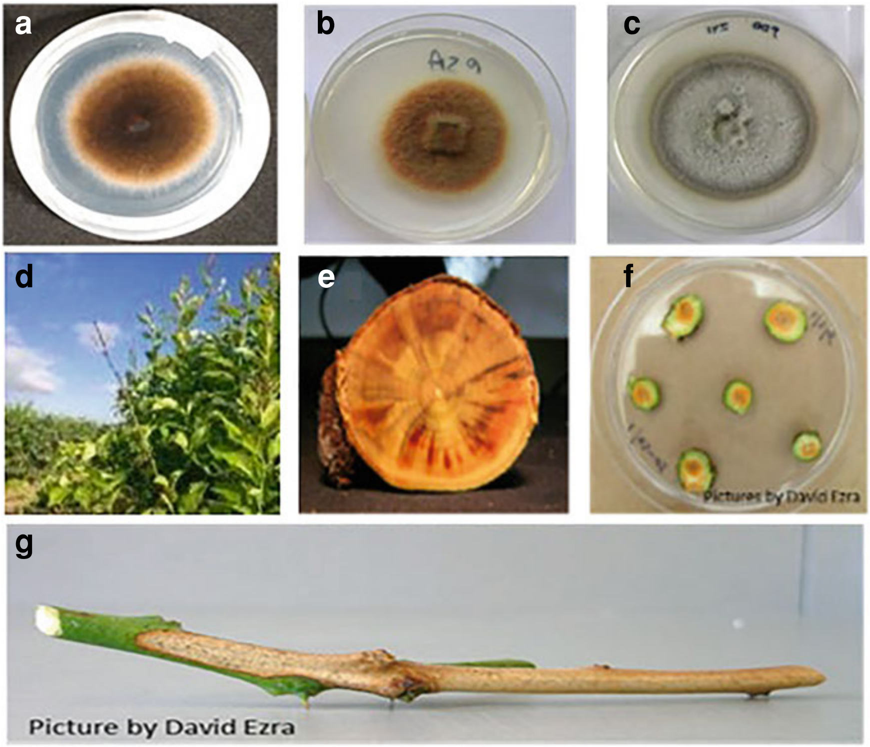

Fig. 7.1 Composite pictures of mal secco disease. The phenotypes of *P. tracheiphilus* cultures on PDA media, showing: the chromatic culture from the underside (**a**) and from above (**b**); the upper side of an achromatic culture (**c**); defoliation and dieback of shoots and branches, with mummified fruits on the dead branches, are the commonly observed symptoms of mal secco disease both on *C. limon* and etrog trees (**d**); cross section of a diseased *C. limon* branch (**e**) and cross sectioned diseased young cut shoots placed on PDA media for fungus culturing (**f**); sectorial death of a mal secco infected shoot of *C. limon* (**g**)

Raised black points within gray areas of withered twigs indicate the presence of underlying pycnidia (Fig. 7.1g). A common response of mal secco disease-infected lemon trees is sprouting from the base of the affected branches and rootstock suckers. Cutting into the wood part of infected twigs, branches or trunks, or stripping the bark, reveals a characteristic salmon-pink or orange-red discoloration, often associated with gum production in the xylem vessels (Fig. 7.1e, f).

Mal secco-infected etrog trees decline and wilt rapidly. Untreated trees will usually show symptoms after about three months. The first symptoms in the field on plant parts infected in the winter commonly appear in the spring (March to mid-June). In cases of chronic infection (a situation called "mal nero"), it might take years for the disease to kill the tree. Another variation of the disease is "mal fulminante", where the tree is infected through large roots or the trunk and dies very rapidly (sudden death). In both mal nero and mal fulminante, the salmon pink-orange discoloration is generally absent and, instead, a brown to black coloration can be observed. Infections through the roots or trunk are far less common in Israel. Infection of susceptible rootstocks by fungal penetration through offshoots (suckers) results in rapid invasion of the roots, resulting in mal fulminante and rapid death of the diseased trees (Nigro et al. 2011).

Mal secco disease is damaging to trees and groves of all ages, but its most dramatic expression appears on younger trees. The most intense signs and symptoms of the disease can be observed throughout the spring, and they recede during the summer and winter. Symptom intensity and disease progression depend on the initial infection sites, environmental conditions, and varietal susceptibility. Initially, the disease can be located on individual branches or tree sectors and from there, the pathogen progresses to the entire tree, leading to tree death (Solel and Salerno 2000). Etrog groves are among the most susceptible to mal secco infections, which cause the rapid wilting of branches with intense fruit drop and defoliation. The progress of fungal infection is often rapid and can precede the formation of abscission layers. In this case, the wilted fruit and leaves remain attached to the dying branches (Fig. 7.2c). The fruit of diseased trees are not harvested because they are wrinkled, misshapen, and consequently unsuitable for marketing. Similarly, etrog fruit from heavily diseased trees that fall to the ground are also unacceptable for religious practices, thus eliminating the danger of disease spread (Ezra et al. 2007).

One of the most characteristic symptoms of the disease is dieback of shoots and branches. The fungus penetrates the leaves and other plant parts through wounds, grows toward the xylem and penetrates the trachea (as indicated by the pathogen's name—*P. tracheiphilus*). It then grows through the trachea downward, toward the trunk and roots. Although the fungal tissue does not fill the trachea (Kroitor-Keren et al. 2013), the host plant reacts by secreting gum into the infected tracheas, thereby stopping the invader. This reaction causes blockage of the xylem, resulting in drying and death of the plant tissue above the blockage point. Penetration of the fungus into the water vessels is not uniform, and not all tracheas respond by secretion of resin and tissue death. Indeed, in many cases, drying of the shoots and branches is sectorial, with infected branches being partly dry and partly green (Fig. 7.1g), a unique and typical mal secco symptom.

7.4.1.3 Epidemiology and Etiology

The disease cycle begins with dispersal of the pycnidiospores by wind and rain during winter. As noted above, the suggestion of birds and insects as possible vectors has never been demonstrated. Conidial spores are produced in pycnidia emerging on dry diseased wood parts (Fig. 7.1g). Pycnidia appear as small black spots on the background of distinctly silver tissue. The spores are only dispersed short distances, usually landing on the leaves and branches of the same or a nearby tree. A spore landing on a leaf germinates, and the hypha grows towards wounded tissue. The fungus cannot penetrate into the plant tissue when there is no wound or other opening. Fungus-infected twigs and plant parts lying on the ground serve as a source of inoculum for root infection. De Cicco et al. (1988) demonstrated these spores'

Fig. 7.2 Cross section of a diseased stem showing the typical pigmentation of the fungal diseased zone (**a**); an etrog tree that has collapsed following infection of mal secco, next to an uninfected tree (**b**); defoliation of leaves, dieback of shoots and branches, and mummified fruits on the dead branches, the commonly observed symptoms mal secco disease both on *C. limon* and etrog trees (**c**)

survivability under controlled conditions in different soil types: the shortest survival period was about 30 days in sandy soil, and the longest, 120 days in clay. In the orchard, the spores may stay alive for up to one year depending on the soil type, with heavy soil providing the best conditions for survival (De Cicco et al. 1988). The optimum temperature for plant tissue invasion is 20–22 °C, whereas pathogen growth and progress in the xylem occur at 14–28 °C. Symptoms appear at 20–28 °C. Above 28 °C, progression of the pathogen and the disease is inhibited. In Israel, host infection occurs from November to the end of March. Disease invasion progresses and symptoms are apparent from April to mid-June. Kroitor-Keren et al. (2013)

demonstrated penetration and movement of the pathogen from spore germination near a wound on a leaf, to the death of a rough lemon model seedling, using a green fluorescent protein (GFP)-tagged transformant of the pathogen. The fungal hyphae growing into the leaf through the wound penetrate the mesophyll and grow toward the leaf veins. Once in the tracheids, they progress downward through the branches and eventually reach the main stem. From there, the fungus grows downward toward the roots (Timmer et al. 1988). Phialoconidia growing on the hyphae are released during the progress of the fungus in the trachea and follow the sap flow in the tree to other, upper parts of the plant, establishing new origins of fungal invasion within the plant (Kroitor-Keren et al. 2013).

Mal fulminante usually starts by fungal penetration through openings on the root or stem, which leads to systemic invasion of the functional xylem by the pathogen and the sudden wilting of branches or the whole tree (Migheli et al. 2009). Kroitor-Keren et al. (2013) showed that the germinating spores can reach the veins of the inoculated leaf within about two weeks. It takes them another week to reach the stem of the seedling where downward growth begins. Moreover, six weeks post inoculation, the fungus can be found in plant parts that are above the inoculation site. This latter appearance can be explained by the release of phialoconidia, or by the fungus reaching a junction between tracheids in the stem, where it changes direction and grows upward. At this point, the tree reacts to the fungal presence as described above, with leaf shedding and drying out of branches. Later, the symptoms become more evident, and the fungus starts to form the pycnidia that will serve as the inoculum for winter dispersal of the new spores.

7.4.1.4 Pathogenesis

Malseccin Toxins

As already noted, two phenotypes of the pathogen grown on artificial culture media are known. The chromatogenic one (red in color) produces at least five anthraquinone pigments: chrysophanol, helminthosporin, cynodontin, emodin, and islancidin. Culture filtrates grown at 23 °C and above contain substances that are toxic to lemon and tomato cuttings (Nachmias et al. 1977, 1980). An extracellular phytotoxic glycopeptidic complex of 90 kDa, termed malseccin, was found in the fungal culture filtrates. The compound was identified as a toxic 60-kDa protein fraction with no sequence homology to any known protein (Fogliano et al. 1998). Malseccin can induce mal secco-like disease symptoms in lemon shoots, including electrolyte leakage of tissues, reduced transpiration rates, and inhibition of lemon callus growth. It damages chloroplasts and inhibits photosynthetic activity of rough lemon leaves, and selectively damages protoplasts of different Rutaceae species (Nachmias et al. 1980). Barash et al. (1981) reported a 350–700-Da thermostable, hydrophilic phytotoxin, which acts by decoupling electron transport in chloroplasts and inducing chlorosis in lemon leaves. The activity of the toxin is affected by light: leaves injected with different concentrations of the toxin purified from culture filtrate showed reduced symptoms when covered with aluminum foil (Raudino et al. 2001; Reverberi et al. 2008). A similar effect was observed when plants inoculated with the pathogen were grown under very low light intensity. Under natural conditions, symptoms usually appear after 35 to 50 days, whereas under low light, it took more than 100 days for the symptoms to appear (Migheli et al. 2009).

Monitoring and Diagnosis

Most of the mal secco disease symptoms in the field, taken individually, may be caused by factors that are not related to mal secco. Leaf yellowing and shedding, dieback of the shoots and branches and eventually, death of the tree may be caused by lack of water and nutrients, extreme weather, or other pathogens or pests. However, a combination of a few of the described symptoms occurring simultaneously indicates the involvement of *P. tracheiphilus* and identification of the symptoms as mal secco disease.

The fungus can be isolated from soft or hard infected tissues such as leaves, shoots, branches or roots. A variety of solid media, suitable for fungal isolation, are used for *P. tracheiphilus* isolation in the laboratory, such as PDA. The fungus has distinct phenotypes (Fig. 7.1a–c) when grown on PDA. However, the frequent contamination of mal secco-infected tissues by other fast-growing fungi, such as *Colletotrichum* spp. and *Alternaria* spp., often interferes with the ability to easily identify the pathogen on the media. In culture, the red pigments secreted by *P. tracheiphilus* form clusters of crystals on the mycelium and on the agar. Exposing the culture to concentrated sodium hydroxide (NaOH) followed by near-ultraviolet light in the dark turns the reddish pigments blue.

Observation of cultured mycelium under the microscope shows a unique structure—a small, round, ball-like spore on the mycelium. These are the phialoconidia spores produced directly on the mycelium. When the slide is prepared using a destructive process, these phialoconidia detach from the mycelium and look like small lemon-shaped spores. This type of spore differs from the pycnidiospores formed in the pycnidia found on the surface of dry dead tissue.

Nachmias et al. (1979) developed a serological bioassay to identify the fungus, by using an antiserum against an acetone precipitate of *P. tracheiphilus* culture fluid in a double antibody sandwich (DAS)-enzyme-linked immunosorbent assay (ELISA). The bioassay displayed higher reaction values with infected lemon tissue extracts than with healthy ones. Rosciglione et al. (1989) developed an immunofluorescence-staining procedure for the specific detection of *P. tracheiphilus* propagules. However, serological methods were not further developed for the practical diagnosis of the disease.

Polymerase chain reaction (PCR) and real-time PCR based methods have been used for the identification of *P. tracheiphilus* (Rollo et al. 1990; De Gruyter et al. 2004; Balmas et al. 2005; Licciardello et al. 2006; Ezra et al. 2007; Demontis et al. 2008). These methods allow rapid, specific and sensitive identification of *P. tracheiphilus* in symptomatic and asymptomatic tissues.

Internal transcribed spacer (ITS)-based alignment of sequences present in GenBank (NCBI) has demonstrated close genetic similarities among Israeli and

Italian isolates of *P. tracheiphilus* (Ezra et al. 2007). The sequences of several regions of the nuclear DNA of *P. tracheiphilus*, including the ITS region are available for disgnosis (Balmas et al. 2005). For quarantine purposes, however, the more sensitive real-time or quantitative PCR is more suitable (Licciardello et al. 2006). *P. tracheiphilus* is of quarantine concern to most regional plant-protection organizations (APPPC, CPPC, COSAVE, IAPSC, NAPPO).

Control

Despite its considerable economic importance and intensive research, effective control of mal secco disease remains a challenge. Young plants in a robust growth state are most susceptible and need maximal care to avoid disease infection. Uncompromising sanitation remains the most efficient means of disease control. This involves repeated inspections during the spring when the symptoms are most easily discerned, through the summer and into the autumn when the fungal pycnidia surface on the dry wood parts, as well as during the winter. It is recommended that trees be examined every four to six weeks for new mal secco-like symptoms, and the suspected branches pruned immediately. The infected parts should then be immediately removed from the orchard and burned. Shredding and dispersal of the infected material in the orchard is prohibited, as it will serve as a source of inoculum. It is also not recommended to leave the infected plant parts on the ground of the orchard or near the orchard, as these can also serve as a source of inoculum. Trees with 30% or more of their volume infected or already removed are likely to be killed by the disease and their threat to the orchard is more pronounced than their usefulness for production. Therefore, it is advised to uproot any tree with > 30% infected parts rather than to try and recover it.

Copper spraying is used to kill germinating spores in the winter. However, the copper products are readily washed away by rain, necessitating repeat spraying after every rainfall event. Even so, the effectiveness of this treatment is limited. The best way to cope with this disease is by using resistant varieties, but there are no known resistant etrog varieties. Net covers provide protection against winter damage and despite their high cost, are feasible for use in the production of the luxury etrog fruit. Nets may also be helpful in decreasing the symptoms as they reduce the incoming light, which may suppress the disease's development, as noted above.

A new approach to controlling disease symptom appearance, developed in Israel, is to apply chemicals through the irrigation system. In experiments conducted in lemon orchards in the Negev, with the material "Hosen" (flutriafol 125 g L^{-1}) at a concentration of 5 L "Hosen" per hectare, twice in the autumn (September and October) and three times in the spring (March, April and May), reduced disease incidence significantly over the years of application. It should be emphasized that sanitation was performed alongside the compound's application. Under these conditions, orchards could be maintained disease-free (Ezra and Ovadia 2019 and unpublished).

Mineral fertilization affects the etrog tree's sensitivity to mal secco disease. Excess nitrogen, for instance, increases susceptibility by supporting foliage growth, which is favorable for the pathogen. Increasing the total nitrogen-to-nitrate ratio decreases disease severity, and a high phosphate concentration has a similar effect (Ezra 2020). Overhead irrigation should be avoided in infected groves as it may enhance spore spread in the orchard. Tree spacing is also important because the disease's impact is lower in widely spaced plantations.

Seeds for etrog seedling production should be soaked in water at 52 °C for 10 min (Klotz 1978) to eliminate any fungal spores.

7.4.1.5 Induced Resistance

CEVd (see later) has been shown to confer partial protection against mal secco disease in etrog citron and Rangpur lime plants. Invasion of the canopy branches of etrog plants by *P. tracheiphilus* was reduced by 90% in CEVd-infected plants, whereas the effect was less evident in Rangpur lime (Solel et al. 1995). Protection was only conferred to etrog plants that exhibited severe symptoms of CEVd infection, and this means of prevention is therefore unlikely to have immediate practical application in protecting etrog trees from mal secco disease.

7.4.2 Citrus Diseases Caused by Phytophthora

Although *Phytophthora* spp. share close morphological similarities with real fungi, they are different in many other characteristics. For example, fungal cell walls are made up mainly of chitin, whereas *Phytophthora* cell walls are mainly cellulose. Reproduction in *Phytophthora* also differs from that of fungi. *Phytophthora* produce motile zoospores that are disseminated and transported by rain and free water (e.g., in irrigation systems). In addition, there are phylogenetic characteristics separating *Phytophthora* from real fungi. These molecular analyses prompted the reclassification of *Phytophthora* species—globally spread destructive pathogens with broad host ranges—into the class Oomycetes. They are generally considered to be soilborne pathogens with the ability to spread by movement through soil, water and infected plant parts.

In many citrus-growing areas of the world, *Phytophthora* diseases, caused by different *Phytophthora* spp., are considered the most important and impactful diseases of citrus. Their most destructive influence is manifested in subtropical areas with high rainfall and high temperatures (Graham and Feichtenberger 2015). They were the cause of severe crop losses to citrus orchards in as early as 1836, much before Ireland's potato famine in 1845. Anton de Bary discovered *Phytophthora* (literally, "plant destroyer") as the causal agent of citrus plant decline in the Azores Islands, declared as the first appearance of *Phytophthora* in the citrus epidemic of 1832–1836. *Phytophthora* epidemics of citrus were then reported in 1841 from France, 1845 from Portugal, 1855–1889 from Italy, 1860–1879 from Australia, 1871 from Spain, 1875 from California, 1876 from Florida, 1869–1880 from Greece, 1906 from Cuba, 1911 from Paraguay, 1917 from Brazil, 1920 from Mexico, and 1935 from Trinidad (Savita and Nagpal 2012). *Phytophthora* spp. can damage citrus at any time during the production process, from seed germination to the orchard and in pre- and postharvest fruit.

7.4.2.1 Types of Phytophthora

Phytophthora spp. Damping-off of Seedlings

All citrus cultivars germinated from seeds are susceptible to damping-off, typically causing collapse of the seedlings just above the soil line. This collapse is due to penetration of the pathogen (soilborne or seedborne) into the stem just above the soil line, causing tissue lesions or rot followed by the seedling's death. *Phytophthora* spp. also cause seed rot or pre-emergence rot. Abundant moisture and temperatures favoring the pathogen's growth encourage rapid development of the disease and death of the seedlings. Plants usually become resistant to damping-off once the true leaves have emerged and the stem tissue at the soil line has matured (Graham and Timmer 1992).

Foot Rot and Gummosis

Of the different diseases that *Phytophthora* spp. cause in citrus, foot rot and gummosis are the most severe and impactful. *Phytophthora citrophthora* is the main causal agent of trunk gummosis in citrus. In low-grafted plants, the infection is near ground level. Lesions formed on the stem of young trees in the nursery or on the stalk of trees in the orchard extend down from the scion toward the bud union. If the rootstock is a resistant variety, the lesions may grow and result in girdling of the section. If the rootstock is susceptible, the root will develop crown rot, and even root rot as the pathogen proceeds toward the roots. Infected bark develops cracks that may secrete gum. The gum is water-soluble and during wet periods may dissolve and disappear from the trunk. However, during dry periods, secretion continues. Other symptoms appearing on diseased trees include pale green leaves with yellow veins, loss of leaves, and twig dieback in the canopy. If the pathogen is controlled or dies, an enclave is formed around the affected area. If left untreated, young trees in nurseries will be very rapidly girdled and die, and older trees in the orchard will be partially girdled, and display canopy defoliation, twig dieback, and short growth flushes (Graham and Timmer 1992; Cacciola and Magnano di San Lio 2008). Foot rot is among the major problematic diseases in etrog groves.

Fibrous Root Rot

Phytophthora spp. infection of the root cortex causes decay of the fibrous roots which become discolored (brown to black) and water soaked. Later, the cortex peels off, leaving the root core exposed. When root rot develops on susceptible rootstocks in the orchard, it causes tree decline and yield losses. When the disease is not severe, the tree produces new roots to replace the rotten ones, and the tree may survive and even overcome the disease. Under advanced stages of disease development and tree decline, or if the soil is saturated with water, the trees are unable to replace the damaged roots and cannot, therefore, maintain water and nutrient uptake (Cacciola and Magnano di San Lio 2008). This decline influences fruit size and production and causes leaf defoliation and dieback of the twigs and branches, as well as reduction of the canopy volume (Graham and Timmer 1992).

Brown Rot of Fruit

Fruit in the lower part of the tree, near ground level, are exposed to infection by *Phytophthora* spp. spores that are splashed by rain or move through irrigation water from infected soil. The infection produces decay, appearing as light brown with a leather-like texture in a ring around the sunken decay. Under humid conditions and favorable temperatures, a white mycelium forms on the rind surface. Under these conditions and long periods of humidity (more than 18 h), the pathogen spreads from the lower parts of the tree to the rest of the canopy, infecting other fruit on the tree. Diseased infected fruit in the orchard usually fall to the ground (Cacciola and Magnano di San Lio 2008). Infected fruit that are harvested and packed may not always show symptoms until they have been stored for a few days, during which time they might infect the other fruit in storage. Infected fruit have a characteristic pungent, rotten, sour odor. All citrus cultivars are affected, especially lemons (Graham and Timmer 1992). This disease causes severe damage when heavy or long periods of rainfall occur just before harvest, as immature fruit are not susceptible to the infection. Overhead sprinkler irrigation may contribute to severe attacks, especially if the water is contaminated with the pathogen's propagules (Cacciola and Magnano di San Lio 2008). *P. citrophthora* is the main causal agent of fruit brown rot in all citrus-growing areas, including the Mediterranean region, where brown rot is also caused by *Phytophthora hibernalis* (Graham and Menge 2000).

7.4.2.2 Causal Agents

There are about 150 known *Phytophthora* species (Cacciola and Gullino 2019) belonging to the family Pythiaceae, phylum Oomycota, kingdom Chromista or Stramenopila. Among them, ten *Phytophthora* spp. have been reported to infect citrus: *P. bohemeriae* Sawada, *P. cactorum* (Leb. & Cohn) Schröeter, *P. cinnamomi* Rands, *P. citricola* Sawada, *P. citrophthora* (R.E. Smith & E.H. Smith) Leonian, *P. hibernalis* Carne, *P. megasperma* Drechsler, *P. nicotianae* van Breda de Haan (= *P. parasitica* Dastur), *P. palmivora* (Butler) Butler, and *P. syringae* Klebahn (Cacciola and Magnano di San Lio 2008). Of these, the most common species of *Phytophthora* in citrus orchards are *P. citrophthora*, *P. nicotianae*, *P. syringae* and *P. hibernalis*. The last two are found in citrus orchards during the winter months due to their lower optimal temperature requirements. *P. citrophthora* and *P. nicotianae* have a wide host range (polyphagous) (Cacciola and Magnano di San Lio 2008). Another citrus pathogen of tropical origin, *P. palmivora*, is also highly polyphagous. *P. nicotianae*, *P. citrophthora*, and *P. palmivora* are the predominant species in citrus (Graham and Menge 1999; Graham and Timmer 2006).

Although *Phytophthora* is genetically distant from filamentous fungi and more closely related to brown algae, its growth is similar to that of fungi.

Phytophthora spp. have several dissemination and reproduction structures: infection of different tree parts is usually by biflagellate zoospores released from sporangia, and not by direct germination of sporangia on the tissue (Batuman et al. 2020). Chlamydospores are resistant structures that allow the pathogen to survive under unfavorable conditions (Cacciola and Magnano di San Lio 2008; Savita and Nagpal 2012). The sexual structures consist of the gametangia, termed antheridia (male gametangia) and oogonia (female gametangia), and oospores, which are formed after sexual reproduction and also act as organs of preservation (Cacciola and Magnano di San Lio 2008).

The pathogen survives in the roots as mycelium, chlamydospores or oospores that serve as primary sources of inoculum. Infected rootlets and fruit are the sources of secondary inoculum in the form of sporangia. Sporangia are produced upon contact with air and are therefore rarely formed on the gummy cankers at the foot of the trunk (Fig. 7.3b).

Sporangium germination is influenced mostly by temperature and soil water potential. A single sporangium releases 5 to 40 zoospores. These are motile and can swim short distances by flagellar movement or be carried much longer distances by free water in the soil. Zoospores are produced in response to and are attracted by root exudates. They swim toward the roots and encyst upon contact. Cysts germinate and penetrate the cortex either directly or through wounds. Once the fungus has entered the root, the infection may advance in the cortex, resulting in rot of the entire rootlet. The cycle can repeat itself as long as conditions are favorable and susceptible tissue is available (Cacciola and Magnano di San Lio 2008; Savita and Nagpal 2012). Zoospores can affect all plant parts as long as there is free water on them for at least 18 h. Zoospores infect the trunk, branches and roots through lesions, and can penetrate fruits, leaves, shoots and green twigs directly, even in the absence of lesions, via germ tubes (Cacciola and Magnano di San Lio 2008).

7.4.2.3 Disease Management

Pathogen Spread in the Orchard

Infested nursery stock is the primary means of *Phytophthora* spp. spread in a new orchard. Other known mechanisms of *Phytophthora* spp. dispersal are root-to-root contact, root growth into infested soil, and pathogen migration into the root-growing area. As already noted, water plays an important role in pathogen dispersal: inoculum movement by surface water and splashing of propagules from the soil or other plant parts to aerial parts of the plant are common. Irrigation water, especially where furrow or flood irrigation is used, or where runoff water carries the pathogen into canals or ponds where it is then used for orchard irrigation, may contaminate previously uninfested areas. When the soil is air-dried, propagule densities decline sharply.

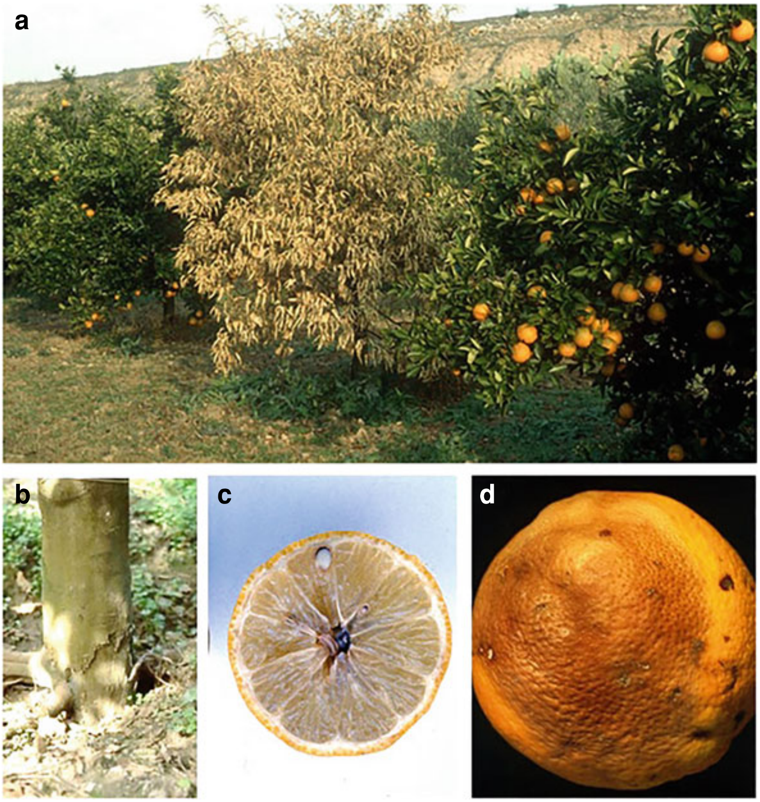

Fig. 7.3 Collapse of a sweet orange infected by *Phytophthora* root rot (**a**); bark collapse of sour orange after infection of basal root rot (**b**); brown rot of lemon fruit (**c**); leathery brown spot of lemon rind infected by *Phytophthora* (**d**)

Humans, also play a major role in disease spread, for example, by movement of soil, plants, or propagules on equipment when vehicles are moved from infested to noninfested groves or nurseries. Wind is not a major factor in *Phytophthora* spp. dispersal. However, windborne soil carries *Phytophthora* spp. and may contaminate non infested soils (Savita and Nagpal 2012; Batuman et al. 2020).

Diagnostics and Isolation

Methods for *Phytophthora* spp. identification from soil and plant material have been developed and established over the years. Among them are the use of specific selective growth media (BNPRAH [benomyl, nystatin, pentachloronitrobenzene, rifampicin, ampicillin, and hymexazol] or PARP [pimaricin, ampicillin, rifampicin, pentachloronitrobenzene]) (Erwin and Ribeiro 1996; Savita and Nagpal 2012). ELISA-based diagnostic kits are highly sensitive and easy to use (Timmer and Menge 1993). PCR-based methods using ITS (Martin et al. 2000) and real-time PCR methods have been developed for molecular diagnosis.

Simpler methods are used as well, such as baits. *Phytophthora* inoculum in soil can be determined empirically by placing ripe fruit on the ground for 3–7 days. Ripe fruit and leaves of lemon and sweet orange can be used as bait to capture *P. citrophthora* and other species in the soil.

Isolating *Phytophthora* can be complex, and benefits from the following considerations: *P. citrophthora* is abundant in citrus groves during spring and autumn, whereas *P. nicotianae* is more abundant in summer months. *P. citrophthora* is rarely isolated from the soil, and *P. nicotianae* is dormant during winter months (Cacciola and Magnano di San Lio 2008).

Disease Control

The first and most important method of *Phytophthora* spp. management is the use of resistant rootstocks. Since the epidemic outbreaks in the 1860s, this has been the best and most practical way to cope with the disease in the Mediterranean area. However, this approach is not free of problems. Although some rootstocks are resistant to root rot, they are not necessarily resistant to foot rot. Moreover, even if they are resistant to *Phytophthora*, they may be susceptible to other diseases and be unsatisfactory from a horticultural standpoint. Most grafted species are susceptible to the pathogen, and therefore splashing must be reduced to restrict infection. One way to achieve this is by grafting the scions high (at least 40 cm) above the ground.

All etrog types are highly sensitive to the disease. However, grafting onto tolerant or resistant rootstocks is not applicable for the cultivation of etrog fruits for religious purposes.

To avoid *Phytophthora* in citrus nurseries, seeds are heat-treated (50 °C for 10 min) and coated with pesticides. Treated seeds should be planted in sterilized, soilless media and irrigated with uncontaminated water. Sanitation, removal of diseased plants and avoidance of tool contamination help prevent disease outbreaks in the nursery and allow the supply of healthy plants to newly established orchards (Graham and Timmer 2006; Cacciola and Magnano di San Lio 2008).

Soil drainage in the orchards and elimination of standing water on the ground is essential because waterlogging induces buildup of *Phytophthora* populations in the soil and increases the risk of infection (Graham and Menge 1999). Tree planting on elevated rows and ground leveling to allow rainwater runoff may help with water drainage and distancing of the trunks and canopy from the ground. Avoiding “collar burial” is important to avoid direct contact between the scion and the soil (El-Otmani 2006; Schillaci and Caruso 2006).

Copper-based fungicides, such as Bordeaux mixture, copper oxychloride or mixtures of systemic copper-based fungicides, are highly effective against foot rot in citrus.

Epidemics of fruit brown rot, caused by *P. citrophthora*, are a bigger risk in orchards where foot and root rot incidence is high. Pruning and spraying of the lower part of the canopy around the tree (about 1 m above the ground) with copper-based or systemic fungicides is efficient at reducing fruit infection from water splashing off the ground. Treatment should be applied before the winter rains, generally by the first week of November, and if the winter is especially wet, a second application in January–February is recommended. Systemic fungicides such as fosetyl-Al and metalaxyl/mefenoxam are used for foot root and root rot control in mature orchards. Dimethomorph, painted on the trunk at high concentrations, proved to be as effective as fosetyl-Al and mefenoxam in suppressing canker development on citrus bark inoculated with *P. citrophthora* and *P. nicotianae* (Matheron and Porchas 2002). Metalaxyl/mefenoxam are used in nurseries to prevent damping-off (Graham and Timmer 2006). In the orchard, fungicide recommendations should be based on the results of propagule counts in the soil obtained by annual sampling. It is recommended that fungicide applications be continued for at least one year after initiation. Application methods include soil applications (soil drenching) and foliar applications (canopy spraying). The most suitable period for treatment against root rot caused by *P. nicotianae* is immediately before the roots begin to develop, when the first spring growth flush is at three-quarters of maximum. The treatment should be repeated in summer. If root infections are caused by *P. citrophthora* and are associated with foot rot, applications should also be repeated in autumn before winter rains and plant dormancy, or at the end of winter, a few weeks before the spring foliage flush, and a second application may be necessary in the summer (Cacciola and Magnano di San Lio 2008).

In some situations, the following treatments can halt disease spread: (i) removal of diseased bark along with a buffer strip of healthy, light brown to greenish bark around the margins of the infection; (ii) allowing the exposed area to dry out and repeating the procedure for several months until the wounded parts dry; (iii) supplementing the treatment with copper sprays.

Chemical control cannot fully eradicate *Phytophthora* from citrus orchards. Furthermore, to prevent the development of resistance to available fungicides, it is essential to incorporate other preventive measures to control the disease (Graham et al. 2015). These include avoiding the use of irrigation systems that cause excessive wetting of tree trunks and/or hanging fruit (e.g., by replacing sprinklers with drip irrigation). Alternatively, the orchard should be irrigated during the daytime and at the longest possible intervals to allow for water evaporation and to minimize the time during which the tree trunk is wet. Other horticultural measures include monitoring water status using tensiometers and weed control. Herbicide control of weeds around the tree collar enhances evaporation of excess water, thereby preventing exposure of the tree trunk to *Phytophthora* spp. infection.

7.5 Fungal Diseases of Leaves and Fruit

7.5.1 Alternaria Brown Spot

Alternaria spp. are saprophytic colonizers of citrus trees which, under conditions of warm temperature and prolonged wetness, can turn into pathogens. The disease is manifested through a host-specific toxin that is produced during spore germination.

Etrogs are susceptible to infection, but the most sensitive citrus plants are the ‘Dancy’ mandarin and its hybrids (Bella et al. 2011), sweet orange and lemon (Aiello et al. 2020).

7.5.1.1 Causal Agent

Alternaria alternata (Fr.) Keissel pv. *citri* Solel, the causal agent of brown spot, may be a serious problem under humid conditions and on rainy days. The spores are dispersed by wind, inducing massive infection of young leaves and small green fruit. A different pathotype causes leaf spot on rough lemon and Rangpur lime.

7.5.1.2 Symptoms

A. alternata pv. *citri* affects the tender green tissues (leaves, fruit, twigs) of susceptible *Citrus* species, resulting in typical brown spots surrounded by yellow halos, which expand into large necrotic areas; these result in leaf and fruitlet drop, and wilted twigs (Fig. 7.4a-c). Severely affected leaves and fruit drop quickly. Lesions on immature fruit can continue to occur for several months, resulting in dark spots with yellow halos. These symptoms may be confused with anthracnose. At maturity, *Alternaria* produces spores on wilted twigs and leaves, and these are dispersed through the air.

7.5.1.3 Management and Control

Control starts from the nursery stage and is aimed at preventing inoculum dissemination and the infection of young shoots. Management of groves planted with susceptible varieties involves frequent visual observation for symptoms and foliar sprays of copper fungicides, up to 10 sprayings per season. Other cultural measures for disease prevention include avoidance of excessive fertilization and irrigation, and the use of vigorous rootstocks. Other means to reduce disease intensity include grove ventilation by increased tree spacing and pruning to reduce disease development. Visual symptoms on fruit, leaves and twigs have diagnostic value, but need to be complemented by observation under the microscope.

7.5.2 Anthracnose

Anthracnose disease is caused by opportunist *Colletotrichum* spp. associated with citrus as saprophytes on dead tissue; the disease stage develops during fruit maturation or degreening. Bruised etrog fruit for religious use are regularly discarded, a practice that mostly prevents their predisposition to anthracnose infection.

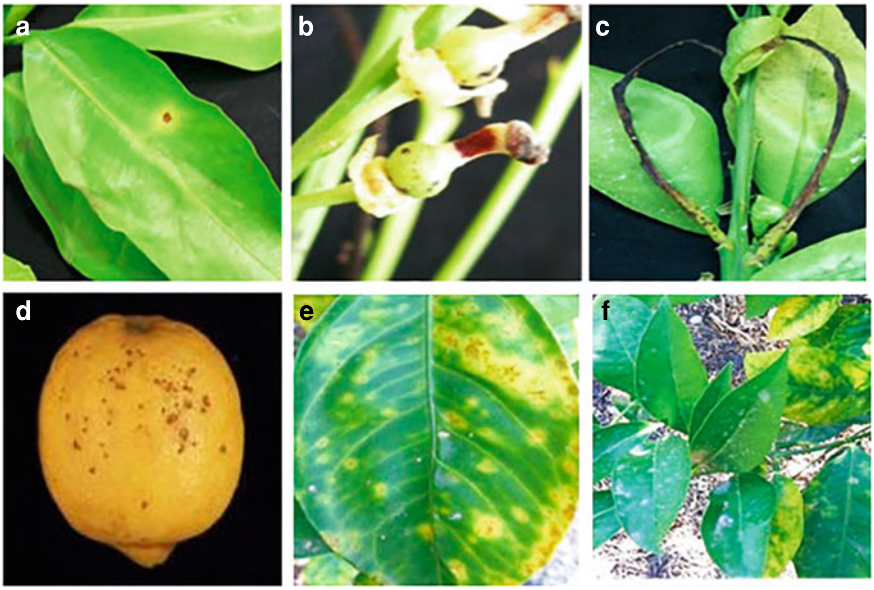

Fig. 7.4 Symptoms caused by *Alternaria alternata* pv. *citri* infection of green tender tissues: leaf spot with yellow halo (**a**); necrotic spots on fruitlets (**b**) and wilting of shoots (**c**); tan depressed lesions of the flavedo of a lemon affected by Septoria spot (**d**); typical leaf yellowing and underside pustules with yellow halos on leaves of previous spring flush associated to *Mycosphaerella* sp. (**e**); leaves of summer cycle appear healthy (**f**)

7.5.2.1 Causal Agents

Colletotrichum gloeosporioides (Penz.) Sacc., *Colletotrichum acutatum* J.H. Simmons, and *Colletotrichum karstii* [sexual stage: *Glomerella cingulata* (Stoneman) Spauld & Schrenk] are often associated with citrus as endophytes and as preharvest and postharvest pathogens. Under mild and wet conditions, such as rain, heavy dew, or irrigation, they first colonize the dead tissue and then spread short distances onto immature leaves and young small fruits. Infections may remain quiescent until the host tissue senesces, and the airborne sexual spores can spread long distances. *C. acutatum* causes post-bloom fruit drop in humid areas. On nutritive media, *Colletotrichum* spp. produce gray colonies showing fruiting bodies (acervuli) characterized by tiny dispersed black flecks, carrying large conidia.

7.5.2.2 Symptoms

Infections on leaves and fruit occur through microwounds resulting from biotic and abiotic stresses. They appear as chlorotic areas localized close to the leaf tip and turn into brown (called weather tip) or gray circular spots with a purple margin. When infected tissues become necrotic, the fungus develops the typical acervuli. Severe leaf infection may lead to leaf drop, whereas infection during bloom may cause fruit drop. Fruit may show “tearstains” as result of *Colletotrichum* spore germination and attachment of microscopic dark-colored appressoria on the rind. During long storage, the appressoria may germinate and penetrate the rind, rendering the fruit unsuitable for the fresh market. Infected twigs may show dieback.

7.5.2.3 Management and Control

Disease management is based on inoculum reduction by removing the dead twigs, eventually complemented by chemical sprays applied prior to the rainy season.

7.5.3 Septoria Spot

Septoria are widespread fungi affecting the leaves and fruit of many cultivated plants. The disease has been reported in almost all citrus-producing countries, including those in the Mediterranean area. All commercial citrus species and cultivars are susceptible. Lemon and grapefruit are the most frequently damaged, but late sweet oranges are also damaged in specific areas of cultivation (Khanchouch et al. 2017). The major impact is related to rind blemishes which affect the aesthetic of the fruit, an unacceptable condition for etrog grown for religious use.

7.5.3.1 Causal Agent

Septoria spot is caused by *Septoria citri* Pass. The causal agent survives in infected orchards as a saprobe, forming pycnidia on dead twigs and leaves. The infective propagules (conidia) are dispersed by splashing water and infect the fruit when they are still green. The infection may remain latent for months and appear in late winter as the fruit ripens (Menge 2000). In some countries, the fungus is categorized as a quarantine organism.

7.5.3.2 Symptoms

Septoria spots are initially small, round, light and tan depressed lesions of the flavedo (Fig. 7.4d), with narrow greenish margins. Later, they turn reddish-brown, with small black pycnidia inside the lesions. During fruit storage, the lesions may expand and coalesce into buried black blotches, eventually extending to the albedo and into the fruit segments. Severe infections may induce fruit drop and post-storage off-flavors. Symptoms may be confused with infections caused by *Colletotrichum* spp., *Alternaria* spp., or abiotic disorders. Leaf symptoms are initially seen on the adaxial surface of the leaf as small blister-like brown to black spots, a few millimeters in diameter, which turn brown after leaf drop. At this stage, pycnidia may develop when the lesion becomes necrotic.

7.5.3.3 Management and Control

The disease is effectively controlled by copper or other fungicides registered for preharvest foliar treatment (Timmer et al. 2004).

7.5.4 Melanose

Melanose disease, which affects mainly lemon and grapefruit, is a serious problem in areas with high humidity and substantial rainfall during early fruit development, whereas locations with high temperatures are less conducive to disease development.

7.5.4.1 Causal Agent

The causal agent *Diaporthe citri* Wolf (anamorph *Phomopsis citri* H.S. Fawc.) lives predominantly on recently dead wood; under wet conditions, the pycnidiospores are squeezed out and dispersed by water. Ascospores are disseminated relatively long distances by wind. Pectic enzymes secreted by the germ tubes generated by the spores enable their penetration into epidermal cells, which become filled with a reddish-brown, gummy substance. Later, the gum is released and hardens, imparting the characteristic raised and rough pustules, which do not produce spores. Freeze injury, storm damage, insect feeding, etc., often lead to greater inoculum.

7.5.4.2 Symptoms

The disease usually forms small reddish-brown to black pustules on the fruit rind, randomly distributed over its surface ("flyspeck" melanose), or in patterns that follow the movement of free water on the fruit surface ("tearstain" melanose). Infection of the fruit soon after petal fall leads to large patches that crack as the fruit expands. Lesions on leaves are small, black, raised pustules, surrounded by a temporary early yellow halo. Severe leaf infections may cause general chlorosis and leaf abscission. After initial infection and pustule formation, melanose symptoms do not progress any further. Infections on twigs, which resemble the leaf symptoms, may result in shoot dieback.

7.5.4.3 Management and Control

Despite some similarity with rust mite damage, which induces relatively smooth blemishes, raised and rough pustules are distinctive signs of the disease. Under certain conditions, copper spraying causes melanose-like blemishes (known as “star” or “stellate” melanose). Leaves are resistant after they become fully expanded, and fruit become resistant about three months after petal drop, according to the region. Regular pruning or topping of large trees is suggested to minimize the disease. Continuous application of a low dosage of copper fungicides is effective, provided the timing and frequency of application are correct. Applications can be stopped when the fruit are no longer susceptible.

7.5.5 Greasy Spot

Greasy spot and greasy spot-like symptoms on leaves and fruit have been described in most commercial citrus species and their relatives, especially in humid growing regions (Batuman et al. 2020). Similar greasy spot-like symptoms associated with different *Mycosphaerella* spp. have been reported on different citrus species in Italy (Grasso et al. 2005). Grapefruit is highly susceptible, followed by ‘Valencia’ and ‘Pineapple’ sweet oranges, lemon and tangelos (Timmer et al. 2004).

7.5.5.1 Causal Agent

The causal agent of greasy spot is *Mycosphaerella citri* Whiteside (anamorph *Zasmidium citri-griseum*), belonging to the family *Mycosphaerellaceae* (Ascomycetes) (Whiteside 1970). The infective ascospores develop on decomposing infected leaf litter on the soil inside the fruiting bodies (pseudothecia) that are immersed in decaying leaves and are aerially dispersed. They germinate on the leaf surface, forming epiphytic mycelia that penetrate through the stomata. Epiphytic growth on the leaf surface is supported by host secretion of honeydew.

7.5.5.2 Symptoms

Leaves infected by greasy spot show yellow–brown pustules on their abaxial surface and chlorosis on the corresponding upper side (Fig. 7.4e-f), while fruit show minute black blemishes on the rind that lower their quality. Disease symptoms are observed 4–6 months after pathogen incubation. Black rind blemishes, when they occur, are different from black spot caused by *Phyllosticta* or *Xanthomonas.* In the Mediterranean area, leaf yellowing and black pustules on leaves of the previous spring flush, leading to an earlier leaf drop have been attributed to *Mycosphaerella* spp. (Grasso et al. 2005).

7.5.5.3 Management and Control

Leaf chlorosis and yellow–brown pustules on the underside of leaves, associated with defoliation, suggest *Mycosphaerella* spp. infections. Copper effectively kills ascospores on leaves prior to their penetration of the leaf surface; however, copper treatments should not be applied when the outside temperature is above 35 °C or in dry weather. Strobilurin fungicides are used to control the fungus on more susceptible citrus species and under hot weather conditions.

7.5.6 Citrus Gray Mold

Gray mold diseases damage mainly lemon cultivated under prolonged wet and cool conditions.

7.5.6.1 Causal Agent

Citrus gray mold is caused by *Botrytis cinerea* Pers., which develops at moderate temperatures and the higher humidity conditions that often exist during postharvest storage.

7.5.6.2 Symptoms

Infection of blossoms, fruits, or shoots, through bruises or wounds, causes dieback of shoots and prompts postharvest fruit decay. Infected flowers wilt and die, causing yield loss, and damage to immature fruits, which may develop gray bumps and irregular scars (Fig. 7.5a). Injury to more mature fruit can result in ridges on the fruit surface. Later, the infected tissues show gray spores that serve as inoculum to infect other plant tissues. During storage, *B. cinerea*-related diseases are easily recognizable for the velvety gray spores that develop on infected areas.

7.5.6.3 Management and Control

Avoidance of mechanical injury or protection from frost damage can reduce the number of infections. The velvety gray spores associated with soft rot of the affected tissues enable easy identification of the disease. Infected fruit and shoots should be removed from the field to reduce the amount of inoculum and prevent infection on other trees. If necessary, protective fungicides should be applied (such as copper) to prevent infection on blossoms and fruit. Optimized storage conditions and fungicide sprays enable effective disease control.

Fig. 7.5 Gray bumps and scars on lemon fruits caused by gray mold infected petals on the rind (**a**); fruiting bodies of *Armillaria mellea* developed around an infected tree (**b**); symptoms of dry root rot on 'Troyer' citrange rootstock: decay of the bark without gumming (**c**); dry brown wood (**d**); dry root rot causing the failure of regrafting (**e**). (*Sources* (**a**) photo from www.patagrumipstsicilia.it)

7.6 Root Diseases

7.6.1 Armillaria Root Rot

Armillaria root rot is a fungal disease that affects many woody plants, and occasionally may damage and ultimately kill infected citrus trees. It occurs more frequently in soils with high moisture or that previously hosted infected susceptible species such as *Prunus*, almond, grape and oak.

7.6.1.1 Causal Agent

Armillaria mellea (Vahl) P. Kumm is a complex of several species that differ in virulence, host specificity, and ecology. Only one of them, *Armillaria tabescens* (Scop.) Emel, has been reported to be pathogenic to citrus in some citrus-growing areas. The fungus spreads by root contact or via black strings of fungal mycelia (rhizomorphs), which can grow short distances through the soil and penetrate citrus roots. The pathogen invades the roots and crown, eventually girdling the crown region and destroying the entire root system; this is accompanied by a strong mushroom odor.

7.6.1.2 Symptoms

The first symptoms of Armillaria root rot, which are mostly observable only after the disease has become well-established, are poor growth or dieback of shoots, small yellowing leaves, and premature leaf drop. The fungus spreads from the infection site and invades lateral roots and the crown region, where it spreads as a white mycelial plaque between the bark and wood. In the orchard, infected trees are found in circles, reflecting the "root-to-root contact" of fungal rhizomorphs in the soil. Once symptomatic trees are seen, the disease has already spread into the roots of the surrounding trees. Eventually, mushroom fruiting bodies may develop around the base of the infected tree (Fig. 7.5b).

7.6.1.3 Management and Control

Preventing infection of new trees by maintaining health and vigor is a priority. Therefore, it is important to avoid planting in an area that is already infested with *Armillaria.* Once the infection is apparent, it is difficult to save the tree. A temporary delay in disease progression may be obtained by removing the soil around the crown to allow the bark to dry out. Infected trees and neighboring trees, and all roots greater than 12 mm diam. must be removed, dried, and disposed of by burning. White mycelial plaques in the cambium region between the bark and wood, and clusters of mushrooms occurring shortly after rains at the base of infected trees, are of diagnostic value in distinguishing *Armillaria* from most other wood-rotting fungi.

7.6.2 Dry Root Rot

This disease occurs worldwide and is prominent in plants grafted on citranges weakened by root girdling or injury. All citrus rootstocks are susceptible to root diseases caused by *Phytophthora* spp., nematodes, root–scion incompatibility, tristeza, and injuries from cultivation and a range of physiological stress factors, including overproduction which causes carbohydrate starvation in the root system, overwatering, and poor drainage, predispose the trees to root rots (Adesemoye et al. 2011).

7.6.2.1 Causal Agent

Dry root rot is caused by *Fusarium solani* (Mart.) Sacc. and other *Fusarium* spp. (Hypocreales, Nectriaceae), and is prevalent under conditions of poor soil drainage and aeration, excess fertilizer, or alterations in soil pH, all of which are favorable to disease development and a sudden decline in plants.

7.6.2.2 Symptoms

Diseased citrus plants show a range of symptoms, such as decay on the bark of major roots and the root crown, but without oozing gum. The inner wood is hard and dry, and brown in color (Fig. 7.5c–e). This contrasts with *Phytophthora* root rot which occurs mostly on the feeder roots. Citrus trees infected with dry root rot show yellowing of the midveins, pale and chlorotic color, and leaf abscission. The canopy is reduced and shows lack of vigor, and the fruit are smaller.

7.6.2.3 Management and Control

Yellowing of midveins associated with necrotic symptoms of the inner wood, generally restricted to the rootstock, and lack of gum oozing are indicative of the disease. There are no effective control measures, except for preventing the stress factors that predispose the plant to the disease.

7.7 Bacterial Diseases

Bacteria are microscopic single-celled microorganisms (1–2 μm in size), living on plant surfaces or inside the plants. They can be rod-shaped (bacilli), spherical (cocci), spiral-shaped or filamentous (thread-like).

Most plant-pathogenic bacteria have long thread-like flagella for movement through liquid media, whereas those that have no flagella cannot move. Their reproduction is established by splitting into two with surprising rapidity, producing a huge number of cells in a short time. Under favorable conditions, one bacterium can produce one million progeny per day, but reproduction is limited by lack of nutrients. Certain species produce spores, called conidia, at the end of a filament, whereas others transform themselves into spores. Yet other species do not produce spores at all.

Bacterial diseases of plants occur under warm and moist conditions, as in tropical regions, and can affect any type of plant. However, bacterial infections can be highly destructive to plants and fruit under all conditions.

Large populations of microscopic bacterial cells can be directly visible as oozing on heavily infected tissue, or as colonies on cultured laboratory samples. Specific staining of magnified bacteria allows their separation into Gram-positive (purple) and Gram-negative (red) types.

Most of the plant-pathogenic bacteria are Gram-negative and survive on plant debris, seeds or soil, or in perennial hosts. Others survive on plants epiphytically, in buds, on wounds, or inside the infected tissues and organs. Soil-inhabiting populations of bacterial pathogens grow on the host and decline when they are released into the soil but may build up again if susceptible hosts are grown in successive years. Bacteria penetrate their plant host through wounds and natural plant openings such as stomata, hydathodes or lenticels. They attach to the cells via pili.

Other fastidious bacteria infecting citrus trees are endophytic and spread initially with introduced propagation material, often followed by natural spread via insects (vectors) feeding on phloem or xylem tissues of infected trees. Diagnosis of bacterial diseases is based on pathogen-specific symptoms, culturing and biochemical typing, and immune and molecular genetic tests, such as PCR.

A class of bacteria without cell walls, the *Mollicutes*, includes spiroplasma and phytoplasma species which affect citrus. While spiroplasmas are culturable, phytoplasmas are obligate bacterial parasites of plant phloem tissue and of the insect vectors that are involved in their plant-to-plant transmission. The *Mollicutes* have a pleiomorphic or filamentous shape, a diameter of normally less than 1 μm, and a small genome.

7.7.1 Citrus Blast and Black Pit

Citrus blast and black pit occur in several citrus areas with low temperature, high relative humidity, and windy conditions. Blast affects leaves and twigs; black pits appear on fruit. Lemons are most susceptible to black pit, whereas etrog, sweet orange and grapefruit are susceptible to blast.

7.7.1.1 Causal Agent

Pseudomonas syringae pv. *syringae* van Hall lives as an epiphyte on various hosts, including spontaneous weeds, and citrus twigs and leaves. During wet periods, the population increases and may infect young succulent tissues of citrus, penetrating through injuries caused by wind, frost or heavy rains. The bacterium can be easily isolated from young lesions on nutrient agar media and identified by serological and chemical tests. Biological activity can be tested by inoculation of actively growing hosts.

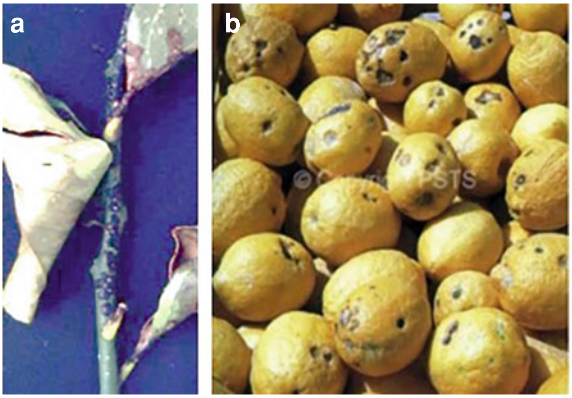

Fig. 7.6 Citrus blast of lemon leaves and twig (**a**) and black pit on fruit (**b**) caused by *P. syringae pv. syringae*

7.7.1.2 Symptoms

Blast develops first as dark spots on sweet orange and grapefruit petioles and moves to the midvein and the twig tissues, which become brown. The leaves start to curl, dry up and drop, whereas the infection on twigs enlarges to some extent and then stops, forming a kind of scar. In severe infection, the entire twig is killed, and the canopy may appear as if damaged by frost (Fig. 7.6). Black pits develop in the rind of young fruit as small brown spots, or as sunken spots in mature fruit.

7.7.1.3 Management and Control

In areas where the disease is recurrent, timely application of protective copper sprays before the first rain, repeated in the case of extended rainy periods, helps to protect leaves and shoots from the infection. Planting a windbreak, as well as cultural practices that reduce excessive shoot growth during the fall are recommended.

7.7.2 Citrus Stubborn Disease/Little-Leaf (Alelet)

Stubborn disease was thought to be caused by a virus until the late 1960s, when mycoplasma-like organisms were found associated with several plant yellowing diseases. Infected groves have been reported in many countries of the Mediterranean (Turkey, Syria, Lebanon, Cyprus, Israel, and Egypt, as well as Morocco). The disease is rare in etrog groves, but nearby young grapefruit and orange groves are sporadically seriously damaged by it. Most mandarins and lemons are rarely infected but will show symptoms when top-grafted on diseased rootstocks. Periwinkle (*Catharanthus roseus*) and some wild and cultivated crucifers may be naturally infected.

7.7.2.1 Causal Agent

Spiroplasma citri Saglio et al., a phloem-limited, wall-less culturable bacterium (mollicute), shows a spiral-like morphology. Transmission is rather rare by grafting since *S. citri* is unevenly distributed among infected trees. The disease is naturally spread in the Mediterranean areas by the phloem leafhopper *Circulifer haematoceps* (syn. *Neoaliturus haematoceps*), whereas in California and Arizona (USA), *Circulifer tenellus* and *Scaphytopius nitridus* are the prevalent vectors. The pathogen propagates and circulates in these vectors, which normally inhabit wild native Mediterranean-like bush vegetation, from which they take off and migrate to cultivated citrus plants. Infections are erratic and mostly limited to widely spaced young orchards, normally about 1–2 years after planting. The disease is not seed-transmitted.

7.7.2.2 Symptoms

Stubborn is rarely a lethal disease, but it has a marked economic effect on productivity, especially when infection occurs soon after planting. Diseased trees show dwarfing and compact shape, with short twigs and small mottled leaves. Symptoms are mainly pronounced in late summer, when the bunch-type tree growth shows mottling, often resembling zinc deficiency. Fruit yield can be significantly reduced, and its quality affected by a smaller and asymmetrical size, thinner rind and brownish aborted seeds.

7.7.2.3 Management and Control

Infection of susceptible varieties is easily recognized by external symptoms. For confirmation and to test the health status of citrus species such as etrog trees, molecular tests based on PCR are recommended. Testing must be performed on many samples from each candidate tree, because the pathogen distribution within infected trees is often erratic, despite the systemic nature of the disease. When cultured on solid nutrient media, the bacterium forms characteristic fried-egg-shaped colonies. Management of the disease is based on preventive measures (quarantine and eradication). Use of healthy budwood is mandatory. Nursery trees should be maintained in insect-proof enclosures or in pathogen-free areas. Protective measures, including whitewashing with kaolin and the practice of netting, such as used in etrog groves, are expected to reduce disease infection in other, more susceptible citrus groves.

7.8 Virus Diseases

Viruses are ultramicroscopic noncellular pathogens that depend on host cells to reproduce. The citrus virus genomes are mostly composed of RNA molecules encapsidated in a virus-encoded protein coat. Structurally, plant virus particles are either elongated or spherical. In the past, citrus viruses were mostly disseminated via diseased propagation material and grafting of the diseased budwood, often followed by natural spread of the disease agents by local insect vectors.

Plant viruses are categorized, based on their interaction with the transmitting insects, into three modes: nonpersistent, semi-persistent and persistent, depending on the nature of the viral association with the vector parts. Interestingly, many citrus viruses infecting citrus groves in the past were mainly spread by grafting, since they either had lost the ability to be recognized and transmitted by an insect or had been introduced into commercial citrus planting without their associated vectoring insect. In recent years, advances in molecular techniques have enabled their molecular characterization, along with the continuous emergence of several novel citrus viruses.

Previously, detection of virus and virus-like diseases was based mainly on the use of "indicator" plants—susceptible hosts that expressed a specific phenotype in a relatively short time. These lengthy and expensive biological indexing procedures for citrus virus disease detection (Wallace 1978; Roistacher 1991) were eventually replaced by the highly sensitive ELISA, recently supplemented by advanced molecular amplification techniques such as PCR, a method that allows rapid multiplication of specific segments of a genome to detect even very few particles, and by sequencing the full genome of the virus using next-generation procedures (Visser et al. 2016).

As for other systemic diseases (such as stubborn or HLB), there is no suitable treatment for controlling citrus virus and viroid diseases. The common strategy for all of these is based on prevention (quarantine, eradication, and certification of propagation material), use of tolerant varieties, sanitation, and minimization of losses through physical, chemical and biological approaches, consistent with integrated pest management.

7.8.1 Tristeza

Since the 1930s, quick decline (QD) and stem pitting, two manifestations of tristeza disease, have caused the deaths of millions of citrus trees (Bar-Joseph et al. 1989; Dawson et al. 2013; Lee 2015). The disease probably started spreading from symptomless trees on tolerant rootstocks introduced from South Africa to South America. Other sources of tristeza-infected propagation material led to its spread to other geographical areas, including the Mediterranean. Since sweet orange and mandarin trees grafted on sour orange rootstock are highly susceptible to QD, this rootstock, which was highly adapted to a wide range of edaphic conditions, had to be replaced with tolerant selections, such as 'Troyer' and 'Carrizo' citrange, among others. Some CTV isolates that overcome trifoliate resistance have been detected in some countries (Yokomi et al. 2017).

The etrog trees that were grown on their own roots due to religious requirements, escaped the typical tristeza symptoms. However, infected etrog can suffer from decline and serve as a source for the disease's spread into commercial citrus areas.

Several Rutaceae species, such as *Aegle, Aeglopsis, Citropsis* and others, and non-citrus species (*Passiflora gracilis* and *Passiflora coerulea*) have been reported as experimental hosts (Moreno et al. 2008, citing others).

7.8.1.1 Causal Agent

Citrus tristeza virus (CTV) (genus *Closterovirus*, family *Closteroviridae*) is a phloem associated virus (Karasev et al. 1995; Mawassi et al. 1996). Virions are 2000 nm in length and 12 nm in diameter, with the largest known single-strand (+)-sense RNA (19.3 kb) found in plant genomes (Fig. 7.7e). The disease is widely spread throughout the world's citrus areas. It is efficiently vectored by the brown citrus aphid *Toxoptera citricidus* Kirkaldy (Fig. 7.7a) and to a lesser extent by the cotton/melon aphid *Aphis gossypii* Glov. Aphids transmit the virus in a semi-persistent mode, requiring about half an hour for acquisition and sustaining continued transmission for up to 1 or 2 days.

7.8.1.2 Symptoms

Field manifestation of CTV depends on the specific viral strains and isolates and includes the dramatic tristeza or QD of sweet orange grafted on sour orange rootstock, which leads to tree death (Fig. 7.7b, f), and stem pitting associated with sparse foliage, dwarfing, and a drop in performance, regardless of the rootstock (Fig. 7.7c). A third symptom, termed seedling yellows, is seen on sour orange, lemon, and grapefruit seedlings in the greenhouse. Infected etrog trees are either asymptomatic or show leaf flecking, reduced tree growth, and slight wood stem pitting (Fig. 7.7d).

7.8.1.3 Management and Control

To respond to this disease, major changes had to be introduced in the cultivation practices of commercial citrus groves, as the use of CTV tolerant rootstocks and clean propagation material is strongly recommended. Chemical or biological control of the aphid in nurseries and mother trees plots could reduce infection rates while they are not effective in commercial groves. Although CTV is present in many citrus groves throughout the Mediterranean countries, stem pitting and trifoliate resistance-breaking isolates of the virus have not been reported, and are included in the EPPO A2 list of pests recommended for regulation as quarantine pests. Therefore, every effort has to be made to prevent the transfer of etrog propagation material (budwood) infected by these CTV isolates.

Furthermore since the most efficient CTV vector, the brown citrus aphid, is also still absent from the Mediterranean basin, the dual effort of preventing the entrance of both the vector and new strains should be highly prioritized.

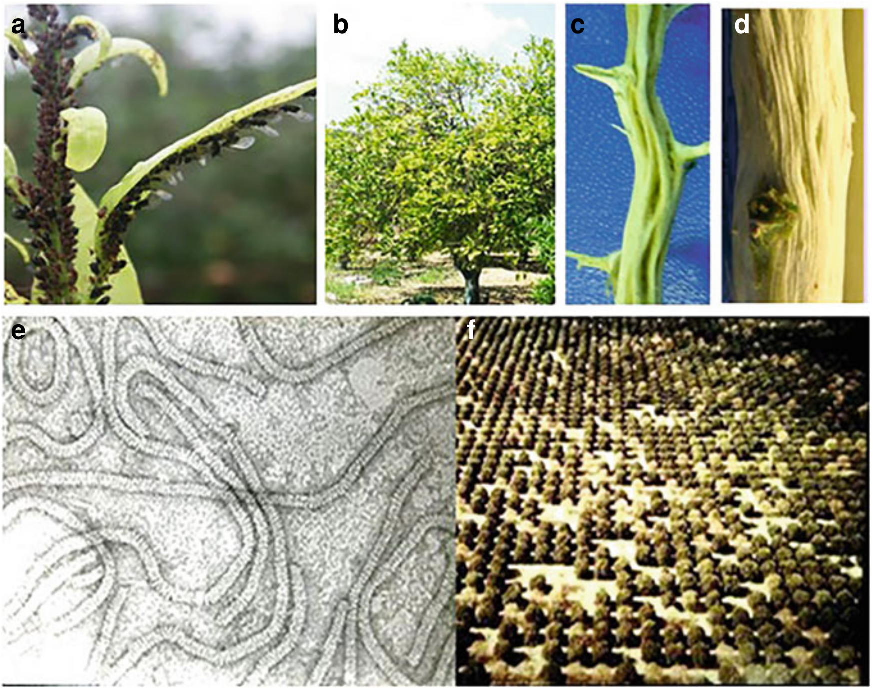

Fig. 7.7 Effects of *Citrus tristeza virus* on citrus. Brown aphids feeding on a tender shoot of citrus (**a**); sparse foliage of a citrus tree affected by tristeza decline (**b**); stem pitting on infected 'Mexican' lime twig (**c**) and etrog citron stem (**d**); electron microscopy of CTV particles (12 nm in width) counterstained with an aqueous solution of silver uranium (**e**); a CTV infected Florida grove on sour orange rootstock photographed in the 1970s showing clearings of uprooted dead trees and others in various degenerated conditions (**f**) (Credit of photo (**f**): the late Dr. S. M. Garnsey)

For most practical purposes, the biological assay on 'Mexican' lime (*Citrus aurantifolia*) seedlings, which results in typical vein clearing and stem pitting symptoms, has been replaced by serological assays such as DAS-ELISA, tissue-print ELISA, a wide range of RT-PCR-based assays and genotyping (Scuderi et al. 2016). However, at present, biological tests on a battery of indicator plants remain the only reliable technique to identify the aggressiveness of new CTV isolates. Countries where the stem pitting isolates are prevalent use the practice of inoculating trees with mild CTV strains to prevent the effects of subsequent severe strains infection (cross protection). Effective results have been obtained on grapefruit in South Africa and Australia and on sweet orange in Brazil.

7.8.2 Citrus Variegation/Citrus Crinkly Leaf/Citrus Leaf Rugose

These three diseases, which have been reported to infect citrus trees propagated with old clone budwood sources from different geographical areas in the pre-molecular citrus virology era, were considered to belong to the "psorosis virus complex" (Garnsey 2000).

7.8.2.1 Causal Agents

The three syndromes are caused by two different subtype citrus virus species of the *Ilarvirus* genus, family *Bromoviridae*, which are serologically related. Citrus variegation virus (CVV) is closely related to ilarviruses, other than Citrus leaf rugose virus (CLRV). Crinkly leaf virus is a CVV strain (Ge and Scott 1994; Scott and Ge 1995). The virus is present in old-line apple trees and grapevines, which could serve as sources of repeated citrus infections. However, strict regulation for disease-free fruit trees has considerably eliminated these risks.

7.8.2.2 Symptoms

CVV and CLRV induce almost the same symptoms of leaf distortion and wrinkling, sometimes associated with chlorosis. Symptoms of CVV are more obvious on lemon, sour orange, grapefruit, and citron, whereas CLRV infections of lemon result in milder symptoms associated with noticeable leaf flecking. Fruits are smaller and wrinkled (Fig. 7.8a, b).

7.8.2.3 Management and Control

Detection is based on symptoms on different herbaceous hosts and ELISAs. These viruses are mainly transmitted by infected budwood and mechanically with contaminated propagation tools, and they are conveniently avoided by using virus-free material for nursery propagation.

7.8.3 Concave Gum

Concave gum disease was once widely spread in old sweet orange, mandarin, and grapefruit groves worldwide. Etrog is a tolerant carrier. Today, however, the disease has nearly disappeared due to the practice of visually selecting disease-free mother trees.

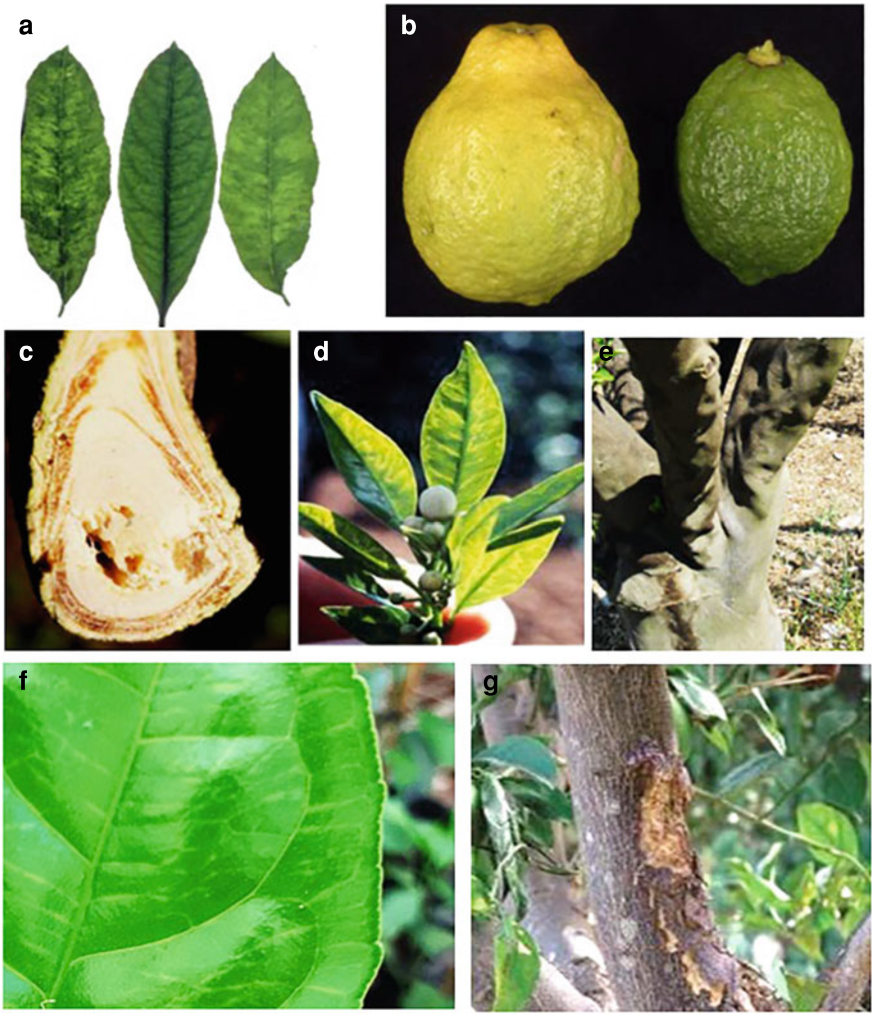

Fig. 7.8 The **a**–**b** Induced symptoms of infectious variegation on etrog leaves (**a**) and lemon fruits (**b**); concentric gum rings (**c**), oak leaf (**d**) and trunk concavities (**e**) caused by concave gum virus on mandarin; leaf vein banding (**f**) and scaly bark (**g**) caused by psorosis on sweet orange

7.8.3.1 Causal Agent

The causal agent of concave gum was long considered a mystery, but recent molecular genomic studies have associated the disease with a bipartite, negative-strand RNA tentatively named *Coguvirus* in the order *Bunyavirales*. The associated virus is evolutionarily linked to, but distinct from the phlebo-like viruses that infect primarily arthropods (Navarro et al. 2018a, b; Velázquez et al. 2019). Confirmation of such viruses as causal agents of concave gum disease is pending.

7.8.3.2 Symptoms

Affected trees have broad concavities on the limb or trunk, with gum oozing out of cracks. Affected limbs and branches do not develop normally, the foliage appears pale, and the internodes are shorter than normal (Fig. 7.8c–e). Young leaves develop psorosis-like oak-leaf pattern symptoms, which have diagnostic value when visual inspections of the disease are carried out during the spring and fall vegetative flushes. Serological ELISA and molecular PCR tests are available.

7.8.3.3 Management and Control

The principal management activity is prevention of new infections using disease-free propagation material authorized by a certified budwood-propagation program.

7.8.4 Psorosis

Psorosis was the first citrus disease recognized as being caused by a viral infection, based on its ready graft transmissibility and the absence of a culturable disease agent (Wallace 1978). Although these lines of evidence were not sufficiently indicative to associate virus etiology with a particular plant disease, they greatly enhanced the development of effective strategies for psorosis control, through the development of methods for biological indexing and the propagation of disease-free budwood (Roistacher 1991). The absence of vector transmission of psorosis, except in Texas, USA (Timmer and Garnsey 1980; Palle et al. 2005) and Argentina, has also contributed to the disease's extinction in most of the advanced citrus-producing areas.

7.8.4.1 Causal Agent

Citrus psorosis virus (CPsV) belongs to the genus *Ophiovirus*, with filamentous particles that contain three single-stranded RNA molecules (Moreno et al. 2015; Velasquez et al. 2019).

7.8.4.2 Symptoms

Psorosis symptoms vary with tree age: young trees, up to about 7 years after planting, only show some leaf symptoms during the springtime for about 2–3 weeks, whereas infected adult trees show severe bark scaling of trunks and limbs which gradually increases in size (Fig. 7.8a), associated with typical wood staining, absent in leprosis bark scaling. The trunk invasion induces yellowing of the canopy, leaf fall, and ultimately, poor production performance.

7.8.4.3 Management and Control

Because there is no natural spread of psorosis in the Mediterranean area, the disease has been almost eliminated from commercial citrus produced in the region. This historical success in dealing with the psorosis disease problem serves as an outstanding example of the significance of certification programs (Hiltabrand 1959) to control and culturally manage diseases of etrog and other citrus.

7.8.5 Citrus Leaf Blotch

Citrus leaf blotch virus (CLBV) was found to be associated with the bud-union incompatibility problem of ‘Nagami’ kumquat grafted on ‘Troyer’ citrange rootstock in Spain (Galipienso et al. 2001). Later studies established the relatedness of CLBV and Dweet mottle disease reported earlier from California, USA. In addition to *Citrus*, CLBV infects sweet cherry, kiwifruit, and peony. Experimental hosts include *Nicotiana glauca, Nicotiana occidentalis*, and *Nicotiana benthamiana.*

7.8.5.1 Causal Agent

The virus causes vein clearing of certain citrus species, stem pitting of etrog citron, and bud-union abnormalities on citrange or citrumelo rootstocks. The disease is transmitted mechanically from citrus to citrus, and it is also seed-transmitted at low rates from infected ‘Troyer’ citrange, ‘Nagami’ kumquat and sour orange (Galipienso et al. 2001; Guerri et al. 2004). However, the main route of CLBV spread is through infected propagation material.

7.8.5.2 Symptoms

The main reservoir of this virus, the ‘Nagami’ kumquat, is symptomless, while ‘Dweet’ tangor (Roistacher and Blue 1968; Hajeri et al. 2010) and etrog plants show chlorotic blotching or mottling and stem pitting, respectively, and trifoliate, citrange and citrumelo rootstocks show bud-union crease. However, these symptoms do not constitute conclusive evidence of CLBV infection in plants and must be confirmed by PCR methods.

7.8.5.3 Management and Control

Since the disease is seed-transmitted and mechanically transmitted, all types of propagation material must be regularly tested to prevent CLBV spread. Both thermal therapy and shoot-tip grafting are effective in eliminating the disease from sources of budwood.

7.8.6 Citrus Vein Enation

Citrus vein enation disease was first studied by Wallace and Drake in 1953, who described symptoms as small papillae that grew from veins on the undersides of leaves of sour orange (Wallace 1978). The disease is spread in many countries of the world, including some in the Mediterranean area. Many citrus species can be infected, included etrog citron, but most are symptomless.

7.8.6.1 Causal Agent

Citrus vein enation virus (CVEV), a member of the genus *Enamovirus* in the family *Luteoviridae*, was identified in Spain by deep sequencing the small RNA (sRNA) fraction from infected and healthy etrog citron plants (Vives et al. 2013). CVEV is transmitted in a persistent manner by its aphid vector, *Toxoptera citricidus*, and by other aphids (*Myzus persicae* and *Aphis gossypii*).

7.8.6.2 Symptoms

On woody indicators, 'Mexican' lime, rough lemon, and sour orange, the disease is characterized by enations (up to 1 mm) on the leaf veins, galls (cauliflower-like) on the bark of stems and is especially associated with thorns or wounds (Garnsey 1988). Trees grafted on rough lemon or 'Volkamer' lemon may show galling at the graft union.

7.8.6.3 Management and Control

Since the disease causes no direct economic losses, the causal agent is considered as a "quality" pest, to be excluded from citrus planting material by normal certification (EPPO 1995). Available dot-blot hybridization and RT-PCR tests are available to select healthy planting material.

7.9 Citrus Viroid Diseases—The Etrog Connection

Viroids are a unique group of subviral plant pathogens. They are small (246 and 400 nucleotides), with naked, single-stranded circular RNA genomes. The viroid genomes are tenfold smaller than the smallest RNA viruses and they do not function as messenger RNA for protein synthesis. They were first reported by Diener (1971) and are the smallest infectious agents that multiply autonomously, albeit only in plant cells.

The etrog-infecting viroids belong to the family *Pospiviroidae*, whose members replicate in the nucleus of plant cells (Di Serio et al. 2017). In the absence of genomic information that can be translated into functional proteins, the viroids replicate by using a host plant cellular enzyme that normally serves for messenger RNA synthesis from the host's template DNA. Although viroid genomes are composed of single-stranded RNA molecules, pairing between bases on opposite halves of the circular molecules occurs, resulting in a rod-like structure. These structures are organized in the *Pospiviroidae* into five distinct functional "domains" (Keese and Symons 1985) (see Fig. 7.9): a conserved central domain associated with viroid replication (CCR), a pathogenicity domain with structural elements that could modulate symptom expression, a variable domain that exhibits the greatest sequence variability between otherwise closely related viroids (V), and left and right terminal domains with roles in viroid replication and evolution (TL and TR).

The history of citrus viroids started with observations that budding old-clone citrus propagation material on trifoliate orange (Benton et al. 1950) and Rangpur lime (Moreira 1959) rootstocks was associated with an anomaly termed exocortis (bark scaling). The realization that etrog citron showed distinct symptoms when inoculated with diseased budwood (Salibe and Moreira 1965), and the later finding of disease-susceptible and fast-reacting citron selections (Roistacher et al. 1977), led to the adoption of etrog plants as indicators of exocortis infections in citrus trees. Interestingly, graft-inoculated etrog indicators often varied in the intensity of the epinasty symptoms, considered indicative of exocortis infection. Thus, while some were showing strong symptoms others were showing much milder symptoms. These

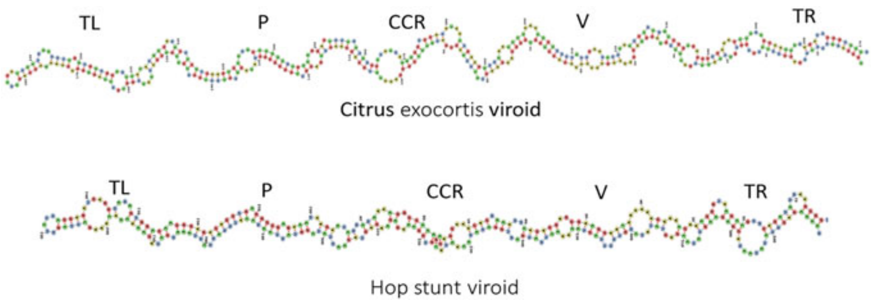

Fig. 7.9 Predicted minimum free energy secondary structure for the plus strand of Citrus exocortis viroid (CEVd) isolate 1 (EU512994) (372 nucleotides) and Hop stunt viroid (HSVd) CC-H isolate 3 (FJ716214) (299 nucleotides) isolated from citrus, using RNAfold web server (Gruber et al. 2008). The relative positions of the domains: terminal left (TL), pathogenic (P), central conserved region (CCR), variable (V) and terminal right (TR), on the predicted structures of CEVd and HSVd, respectively, are indicated

inconsistent reactions of the susceptible etrog indicator plants to exocortis infections were initially thought to indicate variable responses to infections by different exocortis-causing strains, which differed in their pathogenicity. Furthermore, only certain commercial etrog selections showed severe epinasty, dwarfing, and decline when infected with CEVd or combinations of citrus viroids.

Later realization of the viroid nature of exocortis disease agents and developments in viroid separation technologies led to the understanding that the old-clone citrus budwood was often infected not only by CEVd isolates, but also by variable complexes consisting of different citrus viroids ranging from 284, 300, and 330 to 375 nucleotides, only the largest consisting of CEVd.

Molecular characterization showed similarities between citrus viroids causing cachexia and xyloporosis diseases of mandarins and 'Palestinian' sweet lime rootstocks, respectively, and Hop stunt viroid (HSVd), a member of the genus *Hostuviroid* (Sano et al. 1986).

Later, due to the development of new technologies, different viroids have been identified. The most numerous belong to the genus *Apscaviroid*—citrus bent leaf viroid (CBLVd), citrus dwarf viroid (CDVd), citrus viroid V (CVd-V), and citrus viroid VI (CVd-VI) (Tessitori 2017). Citrus bark cracking viroid (CBCVd) belongs to the genus *Cocaviroid.* More often they are mixed with different viroids, with citrus exocortis viroid (CEVd), hop stunt viroid (HSVd), and citrus dwarfing viroid (CDVd) being the most widespread. Old-clone citrus often are infected by two or more different viroid species (Hadas and Bar Joseph 1991; Kyriakou et al. 2005).

Ancient mosaics from the early 5-sixth centuries C.E. in Israel depict etrog citron fruit, showing deformations, resembling symptoms of CVd (Bar-Joseph 2003). It should be noted, however, that the CVd induced fruit deformations differ from the typical "gartel" phenomenon. The later could be a fruit developmental problem and is often observed on CVd-free etrog fruits Because CVds are not seed-borne, it was postulated that the early introductions of CVd-free etrog plants were eventually infected mechanically by the endemic CVds infecting grapevines. The CVd infections of citron and other citrus species, were perpetuated by cuttings and graft propagation and became a problem when certain sensitive rootstocks were used with CVd-infected "old line" budwood (Bar-Joseph 2015).

Citrus viroids have been explored as potential dwarfing molecules in commercial citrus production of citrus grafted on trifoliate orange and its hybrids (Hutton et al. 2000; Tessitori et al. 2002; Hardy et al. 2007; Vidalakis et al. 2010). Graft transmission of such complex populations to certain citrus hosts often results in inconsistent dwarfing symptoms, due to the loss of one or more citrus viroids from the initial complex.

Biological indexing on "Arizona 861-S1" etrog citron selection detects, almost indistinctly, any viroid infection, whereas sequential polyacrylamide gel electrophoresis, hybridization, RT-PCR, and real-time RT-PCR allow the detection of single or multiple infections.

Viroids in etrog citron groves spread from infected to healthy plants via propagation from cuttings and to a lesser extent mechanically, either by goats rubbing their horns on tree trunks, or by pruning and fruit-picking tools (Bar-Joseph

2003). Management strategies for controlling viroid diseases rely mainly on the use of viroid-tested propagation material and on the prevention of mechanical contamination by disinfecting tools with bleaching solution.

Present-day diagnostic tests of citrus viroids are based mainly on PCR assays. Readers interested in the subject of viroid pathogenesis are recommended to read Flores et al. (2017).

7.9.1 Citrus Exocortis Viroid

In the past, exocortis (bark-shelling or "scalybutt" disease) was widely spread throughout the world's citrus industries. The natural host range of CEVd includes both Rosaceae plants and other non-citrus hosts, such as grapevine, tomato, eggplant, turnip, carrot, and broad bean.

7.9.1.1 Causal Agent

CEVd, within the family *Pospiviroidae* (Semancik and Weathers 1972), consists of two main sequence and pathogenicity variants (Visvader and Symons 1985). Unlike some other citrus diseases which lack designated vectors, and hence propagation of disease-free planting material ensures long-lasting elimination of disease spread, viroid transmission is not restricted to vegetative propagation. It also occurs mechanically via pruning knives and fruit-picking tools and even naturally, on the horns of grazing animals, which may rub their contaminated horns on distant tree stems. Mechanical spread of CEVd is of particular concern for cutting or budwood source trees that serve for the propagation of large numbers of plants. Under normal grove conditions, the rates of mechanical spread are of far less concern.

7.9.1.2 Symptoms

Depending on CEVd isolates and the associated citrus viroids, infected etrog plants show a variety of symptoms, ranging from severe stunting, leaf epinasty and rugosity, petiole wrinkling and necrosis, to midvein necrosis, and browning of the tip of the leaf blade. In the case of own-rooted plants, a reduction in root growth is associated with the leaf symptoms and is reflected in reduced yields. *Poncirus trifoliata* and Rangpur lime rootstocks may show severe bark shelling (Fig. 7.10a–c). Synergistic effects of CEVd with other citrus viroids result in enhanced bark shelling or reduced tree growth and yield in commercial groves grafted on different rootstocks, whereas other combinations of citrus viroids show antagonistic effects and less pronounced symptoms.

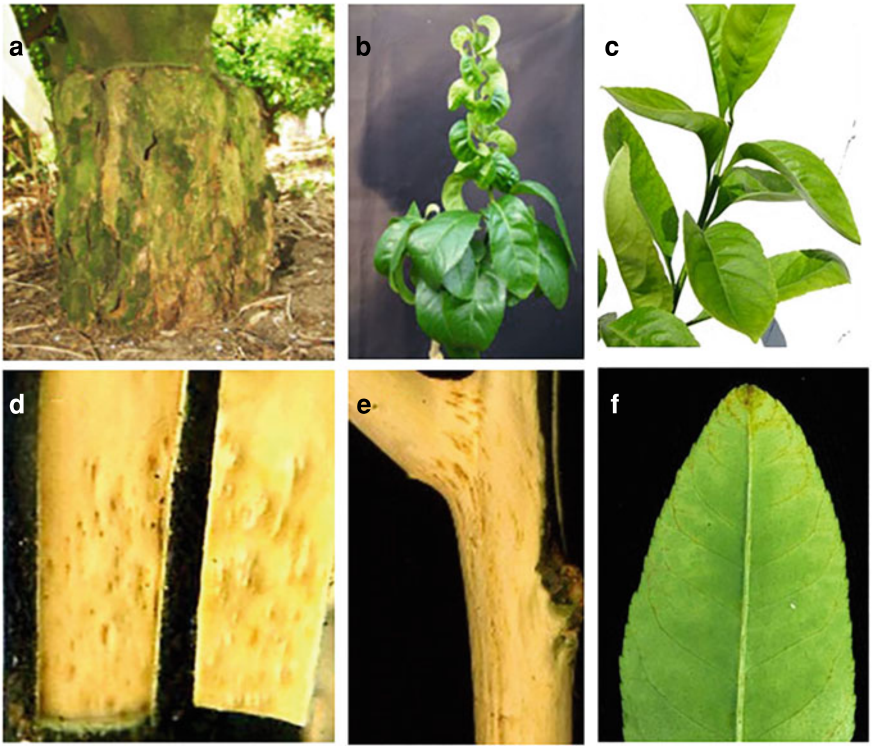

Fig. 7.10 Exocortis viroid induces severe bark scaling on trifoliate orange rootstock (**a**) and severe leaf curling on etrog citron (**b**); while citrus dwarfing viroid effects are very mild on etrog citron (**c**). Cachexia infection causes minute pin-holing in the wood associated with pegs from the bark on alemow (**d**) and mandarin 'Parson's Special' (**e**), and mild tip browning of citron leaves (**f**)

7.9.1.3 Management and Control

Use of viroid-free budwoods and cuttings from certified mother trees is mandatory to start with healthy trees and to avoid the spread of infection through pruning tools. Tools suspected of carrying CEVd should be disinfected by dipping in a corrosive solution of 2% sodium hydroxide and 2% formaldehyde. To obtain rapid (1–2 months) appearance of symptoms, the graft-inoculated etrog plants should be maintained at a temperature regime of 32–40/27–30 °C (day/night) to force rapid growth. Molecular genetic tests based on PCR are available and are replacing biological indexing.

7.9.2 Cachexia

Cachexia decline of easy peeling mandarins (Semancik et al. 1988) and xyloporosis of trees grafted on 'Palestinian' sweet lime rootstock (Palacio-Bielsa et al. 2004) are serious diseases in susceptible host plants. The causal agent of citrus cachexia is a viroid that is genetically similar to HSVd, which is widely present in the Mediterranean region on cultivated stone fruit trees, pomegranate and grapevine.

7.9.2.1 Causal Agent

HSVd (genus *Hostuviroid,* family *Pospiviroidae*) has the largest host range among the citrus viroids and is associated with different sequence variants, which include the causal agent of cachexia disease (CVd-IIb, 299 nucleotides and CVd-IIc, 296 nucleotides) with a 6-nucleotide cachexia-expression motif in the variable domain. Other isolates, such as CVd-IIa (302 nucleotides), lack these determinants and do not show cachexia symptoms (Semancik et al. 1988). The main means of HSVd spread through most world citrus-growing areas is contaminated propagation material, followed by secondary mechanical spread.

7.9.2.2 Symptoms

In etrog citron, HSVd induces very mild necrotic spots on the stem just below the insertion of the leaf petioles, and sometimes petiole wrinkling and leaf-tip necrosis (Fig. 7.10d–f). The most common symptoms observed in susceptible citrus trees such as lime, tangelo, mandarin, clementine, 'Satsuma' mandarin, and kumquat are discoloration and gum impregnation of the bark, which can be easily seen by scraping or removing the outer bark layers: this reveals pegs on the cambial side of the bark, with corresponding depressions or pits in the wood. Most susceptible trees are stunted and chlorotic, with reduced fruit production. Diseased trees may eventually decline and die. Some cachexia disease variants induce bark-cracking symptoms on trifoliate orange and its hybrids.

7.9.2.3 Management and Control

Use of viroid-free budwood and cuttings from certified mother trees is mandatory to start with healthy trees and to avoid the spread of infection through pruning tools. Tools are decontaminated by dipping in a 2% sodium hydroxide and 2% formaldehyde solution. The preferred indicator for cachexia indexing is 'Parson's Special' mandarin; however, it is slow to show symptoms and in recent years it has been replaced by PCR tests for disease detection.

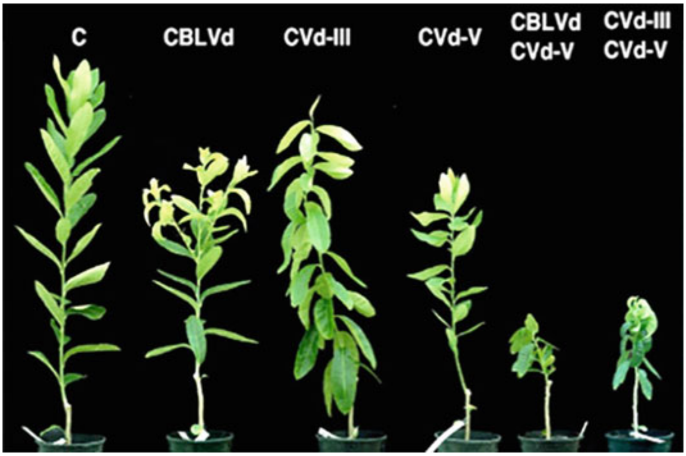

Fig. 7.11 Symptoms of viroid infection in etrog citron plants, 4 months post inoculation. General appearance of non-inoculated plants (c), infected with a single viroid (CBLVd, CVd-III, or CVd-V), or co-infected with two viroids (CBLVd and CVd-V or CVd-III and CVd-V). (Courtesy of P. Serra; from Serra et al. 2008a)

7.9.3 Citrus Bent Leaf

Citrus bent leaf viroid (CBLVd, formerly CVd IB) (genus *Apscaviroid,* family *Pospiviroidae*) was characterized after transmission from citrus trees infected with a complex of CDVd to avocado (Ashulin et al. 1991). In etrog citron, CBLVd induces localized midvein necrosis that results in abrupt downward bending of the leaves alternating with flushes of symptomless leaves. In trifoliate orange, CBLVd has been associated with bark pitting, mild stunting, and canopy volume reduction, while it has synergistic interactions in mixed infection with CVd-V (Fig. 7.11).

7.9.4 Citrus Dwarfing

Dwarfing of citrus caused by citrus dwarfing viroid (CDVd, formerly CVd-III) (genus *Apscaviroid,* family *Pospiviroidae*) has been reported in most world citrus-growing areas on trees grafted on trifoliate orange and its hybrids. The viroid, formerly named CVd-III, is graft-transmitted and mechanically transmitted, with some sequence variability that appears to be conserved within geographical areas. The host range is restricted to rutaceous plants. In greenhouse studies, CDVd was associated with a decrease in root growth of 'Carrizo' citrange and Rangpur lime seedlings, and interaction with CTV increased the viroid titer, but with no expression of symptoms, in 'Mexican' lime. In etrog citron, CDVd induces leaf epinasty characterized by petiole ringing and necrosis, and general leaf drooping caused by petiole bending and median vein necrosis (Fig. 7.10c). It has been reported to have synergistic interactions in mixed infection with CVd-V (Fig. 7.11).

7.10 Citrus Diseases Exotic to the Mediterranean Area

7.10.1 Citrus Black Spot

Citrus black spot (CBS), first reported in Australia (1895), has been present for a long time in many countries of Central and South America, and in South Africa, China and Japan. Recently, suspected infections have been intercepted on fruits coming from Portugal, Malta, and Tunisia. CBS affects many *Citrus* species and hybrids, but losses are greatest in lemon, 'Valencia' orange and grapefruit. It is also recorded in a nonpathogenic form on many other hosts in different families. The pathogen is included in the EPPO A1 list of pests recommended for regulation as quarantine pests within the CBS-free citrus-growing areas of EU-Med.

7.10.1.1 Causal Agent

Phyllosticta citricarpa (McAlpine) Van der Aa (syn. *Phoma citricarpa* McAlpine) (teleomorph *Guignardia citricarpa* Kiely) and other *Phyllosticta* spp. have been described associated with fruit and leaf spot in citrus, but in most cases pathogenicity tests are lacking (Guarnaccia et al. 2017). Both the ascospores and conidia of *G. citricarpa* are primarily produced in leaf litter and released after wetting by heavy dew, rainfall, or irrigation. Conidia are formed inside dark brown or black pycnidia, on fruit and fruit pedicels. In climates with frequent summer rains, conidia reach susceptible fruit by rain splash. Infections are latent until the fruit becomes fully grown or mature, producing black spot symptoms months after infection, often near or after harvest. The fungus can readily be carried on citrus fruit, but the risk of spread is relatively low.

7.10.1.2 Symptoms

Infected fruit and leaves show initially small, round (3–10 mm), reddish and slightly raised lesions which later change to sunken necrotic spots with gray centers, surrounded by dark brown rings (Fig. 7.12a–c). Fruit are susceptible from fruit set until they reach a resistant age. In commercial citrus, the disease causes premature fruit drop and postharvest losses. Symptom development is increased on the light-exposed side of the fruit, and intensified by high temperatures, drought, and low tree vigor. Latent infections also occur on leaves, twigs and flowers of citrus and other

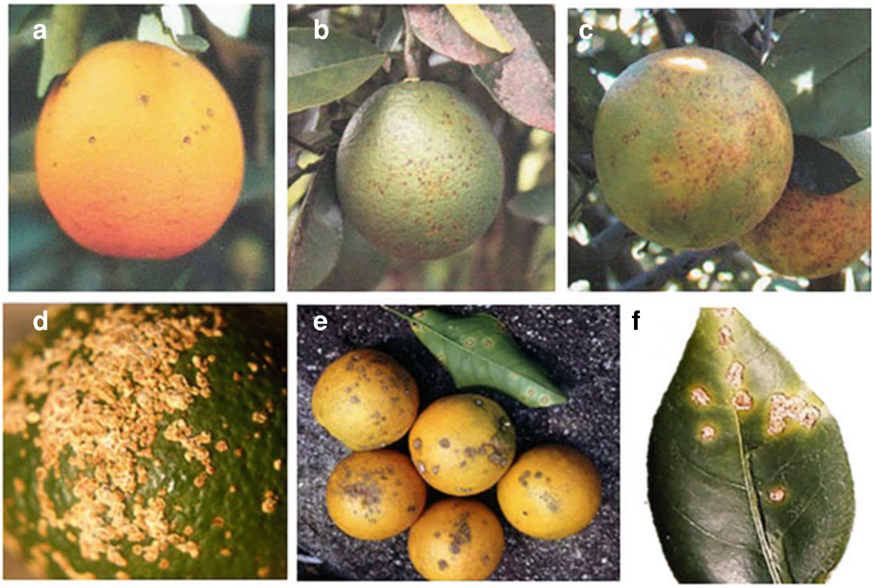

Fig. 7.12 Range of symptoms associated to citrus black spot (**a**–**c**); brown raised pustules of citrus scab on a green fruit of lemon (**d**); crater like lesions on fruits and leaves of grapefruit infected by bacterial canker (**e**, **f**). (*Source* Fundecitrus, https://www.fundecitrus.com.br/doencas/pinta-preta#sobre)

hosts. False melanose associated with speckled blotch symptoms may be associated, with similar fruit symptoms.

7.10.1.3 Management and Control

Proper irrigation and several combinations of fungicide sprays during the growing season, after the petals have fallen, enable disease management along with the control of other pathogens. The required intensity and number of sprays vary depending on the prevailing climatic conditions, inoculum availability, period of cultivar and fruit susceptibility, and fruit destination (Batuman et al. 2020). Symptoms on leaves and fruit have diagnostic value, eventually confirmed by microscope observation of conidia or real-time PCR. Export of fruit from infested countries must be restricted to those originating only from orchards found free of the causal agent and intensively treated against the pest, with thoroughly inspected and sanitized transport vehicles. Once the disease reaches epidemic status, attempts to eradicate it are unsuccessful.

7.10.2 Citrus Scab

Citrus scab is distributed in many humid zones of citrus-growing countries, except Mediterranean regions. The disease affects lemon, grapefruit, tangerine, clementine and mandarin, and rootstocks such as sour orange, rough lemon, 'Cleopatra' mandarin and ornamentals. The disease is far less common in 'Persian' lime, kumquat, pummelo, citron or lime.

7.10.2.1 Causal Agent

The main causal agent of citrus scab is *Elsinoë fawcettii* (= *Sphaceloma fawcettii*), affecting most citrus species. A second agent, *Elsinoë australis* (= *Sphaceloma australis*), affects only sweet orange (sweet orange scab) (Chung 2011).

7.10.2.2 Symptoms

The typical symptoms of this disease are observed on the leaves and fruit as a yellowish area with a small spot in the center, which later develops into a slightly raised pustule, turning from pink to light brown, to warty and brown or dark gray (Fig. 7.12d). In severe cases, these symptoms are associated with malformation and fruit drop. However, as the fruit become larger, the pustules turn into flat lesions, which can be visually confused with gray mold or black spot.

7.10.2.3 Management and Control

It is recommended that the pathogen inoculum be reduced by thinning, pruning and vigorously removing infected tissue to allow exposure to sunlight and enhanced air movement. Reducing humidity minimizes disease development (Timmer et al. 2004). In the case of severe infection, fungicides should be applied to protect the spring flush (before it is one-fourth expanded) and soon after petal fall (to protect fruitlets), and again later, until the fruit becomes resistant to infection. However, sweet orange scab does not require control measures during the spring flush. Strobilurin compounds are more effective than copper fungicides (Timmer et al. 2004).

7.10.3 Citrus Bacterial Canker

Citrus canker is a difficult to control bacterial disease, severely damaging citrus, considered as a quarantine pest and subject to strict phytosanitary measures. Unlike most *Citrus* species which are highly susceptible to canker, the etrog citron shows only limited necrosis, indicating complete and active resistance to citrus canker bacteria.

7.10.3.1 Causal Agent

The disease is caused by two species of bacteria belonging to the genus *Xanthomonas*: *X. axonopodis* pv. *citri* (Hasse) Vauterin et al. (synonym: *Xanthomonas campestris* pv. *citri*), the agent of the most severe Asiatic citrus canker or canker A, and *X. fuscans* ssp. *aurantifolii,* the disease agent of canker B. *X. axonopodis* pv. *citri* is recommended for regulation as a quarantine pest in most of the Regional Plant Protection Organization lists (EPPO 2019). This pathogen spreads naturally with stormy rainfall. Infection occurs through stomata and other natural openings, and wounds, including those caused by the citrus leaf miner (*Phyllocnistis citrella* Stainton). Long-distance movement occurs via plants, tools, harvesting boxes, and non-sanitized nursery production.

7.10.3.2 Symptoms

Susceptible citrus species show raised circles that are 2–10 mm diam., with canker lesions on the underside of the leaf, often surrounded by a water-soaked margin and a yellow halo, which later changes to dark brown or black when the middle part of the lesion turns corky or spongy with a crater-like center (Fig. 7.12e, f). Infection of young leaves ends up as holes at the lesion sites. Infection on fruit starts with small lesions that grow in size and coalesce to form concentric circles. Severe infection may evolve into premature fruit drop. Canker leaf and fruit symptoms resemble citrus bacterial spot, greasy spot, scab, leprosis, Alternaria rot and citrus scab.

7.10.3.3 Management and Control

Restrictive phytosanitary measures forbid the movement of propagating material and fruit from areas infected by canker. In the case of disease introduction into a new area, eradication by rogueing infected trees is highly recommended. Where the disease is already established, copper sprays applied during fruit growth and development reduce infection. Reliable diagnosis depends on PCR.

7.10.4 Citrus Variegated Chlorosis

Citrus variegated chlorosis (CVC) has been observed since 1987 in Sao Paulo and Minas Gerais States in Brazil (Lee et al. 1993). Almost all sweet orange varieties are susceptible to the disease regardless of the rootstock. To a lesser extent, lemon, mandarin and its hybrids, kumquat, trifoliate orange, and grapefruit can also be infected. Rangpur lime, citron and pummelo are tolerant (Chung and Brlansky 2005).

7.10.4.1 Causal Agent

CVC is caused by *Xylella fastidiosa* (Wells et al.) ssp. *pauca,* a xylem-limited bacterium similar (same genus) to strains causing Pierce's disease of grape, phony peach, and leaf scorch diseases of almond, coffee, oak, olive, plum and sycamore. The pathogen is included in the EPPO A2 list of pests recommended for regulation as quarantine pests. The disease is spread by xylem-feeding sharpshooter leafhoppers (Cicadellidae). Recently, transmission of CVC through citrus seeds from infected trees has been reported.

7.10.4.2 Symptoms

Diseased trees show severe leaf chlorosis and yellowing, resembling nutritional deficiencies (zinc, boron, potassium), and brown gummy lesions on the corresponding lower side of the leaf (Fig. 7.13a–d). Symptoms are more severe in autumn and winter and on young trees. Trees more than 8–10-years-old may exhibit symptoms only on a single limb or branch, showing reduced vigor and growth, and abnormal flowering and fruit set. Fruits are small, highly acidic and not suitable for juice processing or the fresh market. Severely affected trees may show leaf drop. Some foliar symptoms appear similar to anthracnose and greasy spot diseases.

7.10.4.3 Management and Control

Field diagnosis of CVC is difficult because the symptoms can be confused with those of other diseases or nutritional deficiencies. However, the causal bacterium can be cultured on suitable media and visualized under a light microscope. Serological tests and molecular assays based on DNA hybridization or PCR are available. Their application to screen budwood source trees and nursery material should be encouraged to reduce the risk of introduction of the disease. PCR assays are useful to distinguish subspecies and strains of the bacterium. Once infection is confirmed, single affected limbs must be pruned whereas fully infected trees should be removed; in the case of large infections, trees in the entire grove need to be removed. Weed control of sharpshooter hosts is recommended. Several non-citrus hosts of the agents are known, and their vectors have also been described.

Fig. 7.13 Symptoms of citrus variegated chlorosis (CVC) on fruits (**a**, **b**) and leaves (**c**, **d**) (*Source* Fundecitrus, https://www.fundecitrus.com.br/doencas/cvc)

7.10.5 Citrus Greening—Huánglóngbìng

The disease HLB, literally "yellow dragon disease", was formerly known as greening disease. In East Asian countries, it is also known as mottle leaf, likubin, phloem necrosis, and dieback. Almost all commercial citrus species, cultivars and hybrids, and some related plants (*Severinia buxifolia*, *Limonia acidissima*, *Vepris lanceolata*, and the ornamental orange jasmine *Murraya paniculata*) are susceptible. The disease is rather restricted to *Citrus* spp. and is considered a major threat to citrus production worldwide; therefore, every effort must be made to prevent its further spread to disease-free areas (Bové 2006; Gottwald et al. 2007). The presence of diseased trees and vectors close to Mediterranean citrus-growing areas is considered a serious threat to the region's citrus industry. Information on HLB is also presented in other chapters of this book.

7.10.5.1 Causal Agents

Three species of *Candidatus* Liberibacter—a Gram-negative bacteria of the *Gracilicutes* clade—are the causal agents of HLB. *Ca.* L. asiaticus (Asian form, Las) and *Ca.* L. americanus (Lam) are both transmitted by the Asian citrus psyllid *Diaphorina* *citri* (Kuwayana). African greening, caused by *Ca.* L. africanus (African form, Laf), is transmitted by *Trioza erytreae* (Del Guercio). Both the Laf agent and its vector are sensitive to heat, and have been reported from the highlands of Africa, Madeira, Saudi Arabia, parts of Portugal, and Yemen.

Transmission of HLB in propagation material, although erratic, was probably the source of the recent serious disease outbreaks that spread through the Brazilian and Florida (USA) citrus industries. Psyllids acquire the bacteria as both nymphs and adults, and they can spread the disease large distances as they are carried by winds throughout their lifespan. Seed transmission remains insignificant and highly questionable. The three species of *Ca.* Liberibacter are included in the EPPO A1 list of pests recommended for regulation as quarantine pests.

7.10.5.2 Symptoms

Symptoms of the disease are variable and can be confused with nutritional disorders of citrus. Infected trees show yellow shoots, vein yellowing and mottling of leaves (Fig. 7.14a, b and Fig. 7.15), defoliation, and dieback. The fruit are small, asymmetrically shaped (lopsided), poorly colored, with the stylar end remaining green (hence the name "greening" coined in South Africa) (Fig. 7.14c). Damage from HLB infections often starts with decay of rootlets and lateral roots, decline of vigor, sparse foliage, and tree death. Trees show stunted growth, off-season flowering, yellowing, and poor performance. In most cases of severe spread of the disease the groves are abandoned (Fig. 7.14d). The albedo thickens and the vascular bundles of the columella turn brown (Fig. 7.15). None of these symptoms are disease-specific (see citrus stubborn disease), and diagnosis must be confirmed using molecular techniques. Seed abortion is also common, and the juice has an off-taste and off-odors.

7.10.5.3 Management and Control

The most important aspect of HLB is prevention, with strict implementation of quarantine, especially in geographical regions producing citrus for the fresh fruit market. These are expected to become seriously affected by the disease, due to restrictions in the use of insecticides and antibiotics for vector and bacterial control, respectively. Therefore, suspected symptoms of the disease should be referred to the official plant pathology services. Considerable research effort is being invested in controlling HLB and will hopefully provide a remedy before HLB reaches the Mediterranean region. However, in the meantime, growers and customers must make every possible effort to keep the region free of the HLB agent and vector. Integrated disease management, based on early detection, biological and chemical control of the vectors, and rogueing of HLB-infected trees may reduce disease spread and yield losses. Isolation and protection of mother trees and nursery propagation material are highly recommended. In certain varieties, an expert eye can easily recognize the disease. However, for confirmation, real-time PCR is the main identification method.

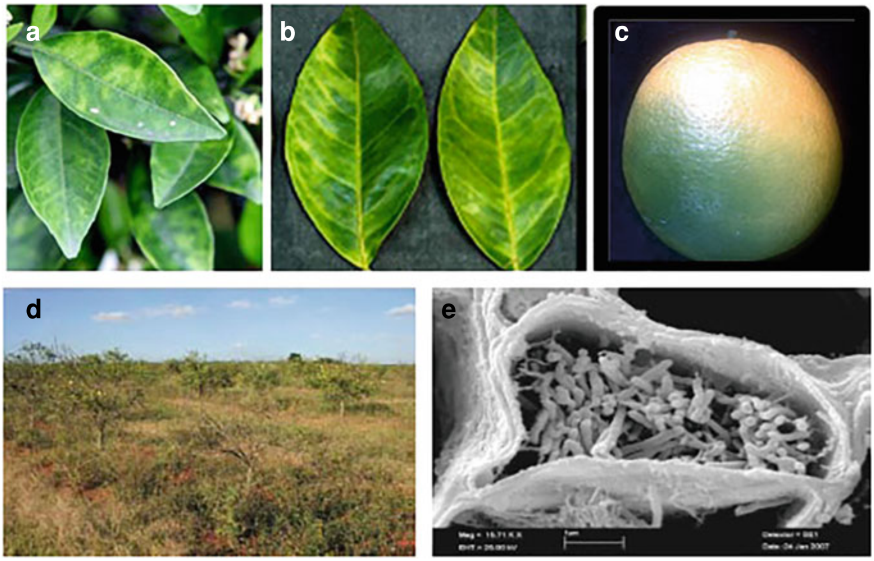

Fig. 7.14 Leaf mottling and vein yellowing (**a**, **b**) and fruit stylar end greening (**c**) induced by huanglongbing disease. Young citrus grove (photographed in Cuba, December 2007), abandoned after the HLB spread through the island (**d**); scanning electron microscope image of a citrus phloem cell densely populated by *Candidatus* Liberibacter asiaticus, the causal agent of huanglongbing disease (**e**). (*Source* EW Kitajima)

7.10.6 Witches' Broom

A serious disease affecting acid lime (*Citrus aurantifolia* Swingle), sweet lime and citron trees, initially observed in the Northern coastal plain of the Sultanate of Oman, probably in the 1970s, is now spreading through the United Arab Emirates, Iran, and India. The disease was graft-transmitted to 'Meyer' lemon and several rootstocks, including rough lemon, Rangpur lime, *Poncirus trifoliata*, 'Troyer' citrange, *Citrus macrophylla, Citrus ichangensis, Citrus hystrix* and *Citrus karna.* Most commercial sweet orange, grapefruit, mandarin and pummelo cultivars are unaffected. Citron is among the naturally infected species (Chung et al. 2006; EPPO 2019).

7.10.6.1 Causal Agent

Electron microscopy observations have associated the disease with phloem-invading phytoplasmas, which are wall-free bacteria (*Mollicutes*) affecting annual and woody plants. The causal agent of lime witches' broom, molecularly identified as *Candidatus* Phytoplasma aurantifolia, is categorized as a quarantine pest in most countries and NPPO lists (EPPO 2019). The disease is naturally transmitted by the leafhopper

Fig. 7.15 Further symptoms of huanglongbing in Cuba: albedo thickness and leaf mottling are typical of this disease in all countries where the disease occurs. (*Source* Juliana de Freitas Astua)

Hishimonus phycitis (Distant) in the family *Cicadellidae*, and is commonly present on citrus in Oman, United Arab Emirates, and Iran.

7.10.6.2 Symptoms

Symptoms include witches' brooms—proliferating twigs with small, pale leaves—followed by dieback and tree death in about 3–5 years. In graft-transmission tests, the symptoms of the disease are manifested intensely at high temperatures.

7.10.6.3 Management and Control

Once the tree is diseased, there are no means of control. The only meaningful management is to avoid the introduction and spread of diseased propagation material. Diagnosis consists of witches' broom symptoms on susceptible varieties. However, the location of suspected cases must be confirmed using molecular genetic analyses.

7.10.7 Citrus Chlorotic Dwarf

The debilitating disease affecting all citrus cultivars, citrus chlorotic dwarf disease, was first observed in the mid-1980s and recognized in Turkey (Çinar et al. 1994). The disease is particularly detrimental to many citrus species: lemon, grapefruit, sour orange, alemow, rough lemon, common mandarin, 'Satsuma' mandarin, 'Clementine' mandarin and tangelo. At present, it remains restricted to Turkey and some Asian citrus countries.

7.10.7.1 Causal Agent

Citrus chlorotic dwarf-associated virus (CCDaV) belongs to the *Geminiviridae* family (Loconsole et al. 2012a). The virus has a single-stranded DNA genome and is naturally transmitted by the bayberry whitefly (*Parabemisia myricae* Kuana) and probably also by cowpea aphid (*Aphis craccivora* Koch).

7.10.7.2 Symptoms

Infected grapefruit, lemon, mandarin, and sour orange varieties show chlorotic flecking on young leaves, and leaf deformations that include crinkling, inverted cupping, spoon-shaping, variegation, severe chlorosis, and leaf distortion. Trees are severely stunted, and the fruit are smaller in size. Disease symptoms resemble those of other diseases affecting leaves: citrus variegation, Satsuma dwarf, citrus leaf rugose, and citrus yellow vein clearing. Indexing on sour orange, rough lemon and *Citrus macrophylla* under warm conditions, and PCR are used to identify the disease.

7.10.7.3 Management and Control

Use of disease-free budwood is basic to preventing the spread of citrus chlorotic dwarf disease. Control of the bayberry whitefly helps slow its spread. Reservoirs of the pathogen in infected groves, once the disease is established in a new area, should be eliminated.

7.10.8 Citrus Yellow Vein Clearing

Citrus yellow vein clearing, initially reported from Pakistan in 1988 in lemon and sour orange (Catara et al. 1993), is spreading rapidly in the lemon- and lime-producing areas of China, Iran, India and Turkey (Önelge 2003; Loconsole et al. 2012b).

7.10.8.1 Causal Agent

Citrus yellow vein clearing virus (CYVCV), genus *Mandarivirus*, is a filamentous virus (Grimaldi and Catara 1996; Loconsole et al. 2012b) that is transmitted mechanically and vectored by cowpea aphid (*A. craccivora*) and spirea aphid (*Aphis spiraecola* Patch) to beans and lemons, and by citrus whitefly (*Dialeurodes citri* Ashmead) to lemons (Önelge et al. 2011).

7.10.8.2 Symptoms

Leaves of lemon and sour orange show yellow vein clearing of the lateral veins, best seen with transmitted light, and yellow flecks, more visible on young leaves, during the spring and autumn flushes (Fig. 7.16). Tissues along the adaxial veinlets may became water-soaked and then turn brown. Compared with tristeza vein clearing of acid lime leaves, symptoms of citrus yellow vein clearing are more pronounced and persistent. Sometimes the leaves are also crinkled and warped, with wavy edges that persist as the leaves mature. These symptoms are remarkably similar to those induced by infectious variegation and crinkly leaf virus. Small chlorotic rings, sometimes associated with yellow vein clearing, are reminiscent of ringspot disease, but do not persist as the leaves mature. Sweet orange shows only a slight vein clearing. Field-grown sour orange may show slight mottling.

7.10.8.3 Management and Control

Use of disease-free budwood is mandatory. Shoot-tip grafting can help recover infected mother trees. Preventive measures are essential to avoiding contamination and disease spread from germplasm collections. Indexing by graft inoculation of bark patches, or sour orange or lemon seedlings or budlings gives the best results on continuously flushing indicator plants. In the absence of controlled conditions, symptoms can be observed on the underside of the leaf parts and along the veinlets, mainly during spring and autumn flushes.

7.10.9 Citrus Tatter Leaf

This disease was first reported in Riverside, California, USA, in 'Meyer' lemon (*Citrus limon* x *C. sinensis*) introduced from China. The virus, named citrus tatter leaf virus (CTLV), was identified as a strain of *Apple stem grooving capillovirus*, which infects apples and pears in the EU territory. CTLV has been reported in Australia, Korea, Nigeria, Japan, South Africa, and China, and in Cyprus, where it has been recently found to be widespread in lemon orchards (Alas et al. 2019).

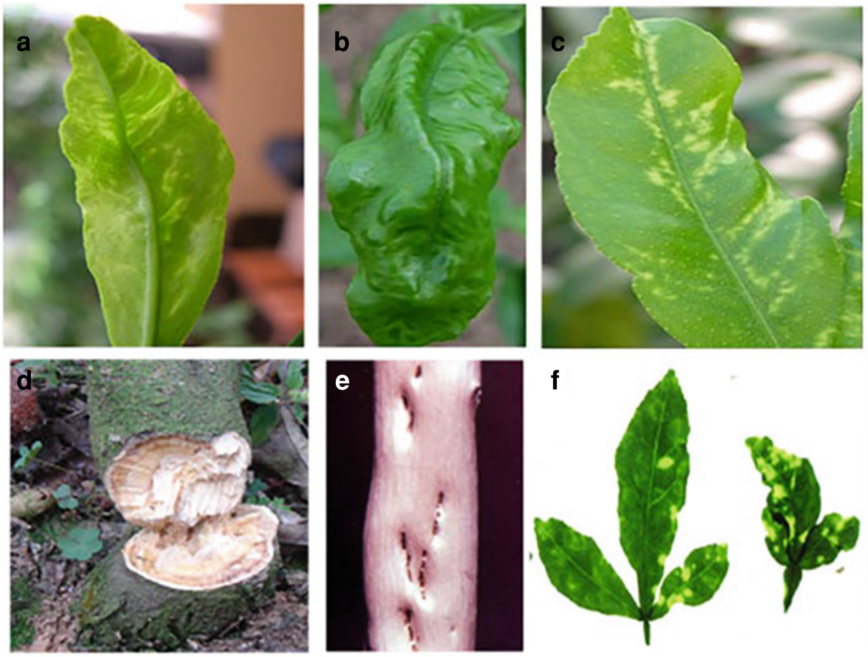

Fig. 7.16 Vein clearing, yellow flecks, and distortion of young leaves of lemon (**a**) and sour orange (**b**), and mature leaf of lemon (**c**) infected by citrus yellow vein clearing virus. Symptoms caused by citrus tatter leaf: graft incompatibility on sweet orange grafted on *P. trifoliata* (**d**), and stem pitting (**e**) and tattered leaves on citrange (**f**)

7.10.9.1 Causal Agent

Citrus tatter leaf capillovirus (syn.: Citrange stunt virus) is a strain of ASGV that affects apples and pears (Tatineni et al. 2009). The disease spreads mainly by graft propagation of infected budwood, and mechanically (Garnsey 1974). Knife slashes and leaf abrasion allow infection from *Nicotiana clevelandii* to citron and from citron to citron. Seed transmission has been observed in *Chenopodium quinoa*, cowpea, and soybean, and there is some evidence of it in lemons (Tanner et al. 2011). The virus is included in the list of quarantine pests of many citrus countries and in the EPPO A1 list (EPPO 2019).

7.10.9.2 Symptoms

The virus produces persistent clear spots which on leaves of 'Rusk' and 'Troyer' citranges (*Poncirus trifoliata* × *Citrus sinensis*), 'Swingle' citrumelo (*P. trifoliata* × *C. paradisi*) and other *P. trifoliata* hybrids, associated with tattering of the leaf blade (Fig. 7.16g). Stems of citrange may be deformed and have a zigzag growth pattern associated with chlorotic and pitted areas (Fig. 7.16f). *Citrus excelsa* is also sensitive to tattering and wood pitting. Almost all citrus plants are symptomless if grown on their own roots or on tolerant rootstocks. When latently infected, scions on *P. trifoliata* or its hybrid rootstocks may show a bud-union crease about a year after grafting (Miyakawa and Tsuji 1988), with a marked yellow to brown line, detectable after bark removal (Fig. 7.16e). Affected trees are stunted, some with excessive suckers, chlorotic, and over blooming, and they frequently die.

7.10.9.3 Management and Control

No natural CTLV vector is known, emphasizing the need for special care in ensuring the propagation of only tested and disease-free plant material. 'Rusk' citrange seedlings or budlings grafted on rough lemon rootstock are used as biological indicators of the disease. ELISA and reverse transcription—PCR allow rapid and accurate diagnosis (Hailstones et al. 2002; Hilf 2008; Cowell et al. 2017).

7.10.10 Leprosis

This serious disease is widely spread throughout South America and infects most commercial *Citrus* species, including etrogs, under a variety of names, such as nailhead rust, nailhead spot, scaly bark, and "lepra explosiva" (Cruz-Jaramillo et al. 2014; Ramos-González et al. 2017). This disease has not been recorded in the Mediterranean area or in the United States.

7.10.10.1 Causal Agents

Recent studies indicate a variety of bacilliform viruses (*Citrus leprosis virus*), belonging to the genus *Dichoravirus* (family *Rhabdoviridae*) and *Cilevirus,* are associated with citrus leprosis symptoms. Citrus leprosis viruses (CiLVs) do not move systemically in the host except for short distances along the mid-vein or secondary veinlets. They cause similar symptoms in a range of different citrus hosts and are transmitted by the same vector, mites of the genus *Brevipalpus* (Acari: *Tenuipalpidae*) in a persistent manner (Tassi et al. 2017)—the viruses multiply in the mites and a mite may spread the virus throughout its life. Citrus leprosis virus is categorized as quarantine pest in most countries and Regional Plant Protection Organization lists (EPPO 2019).

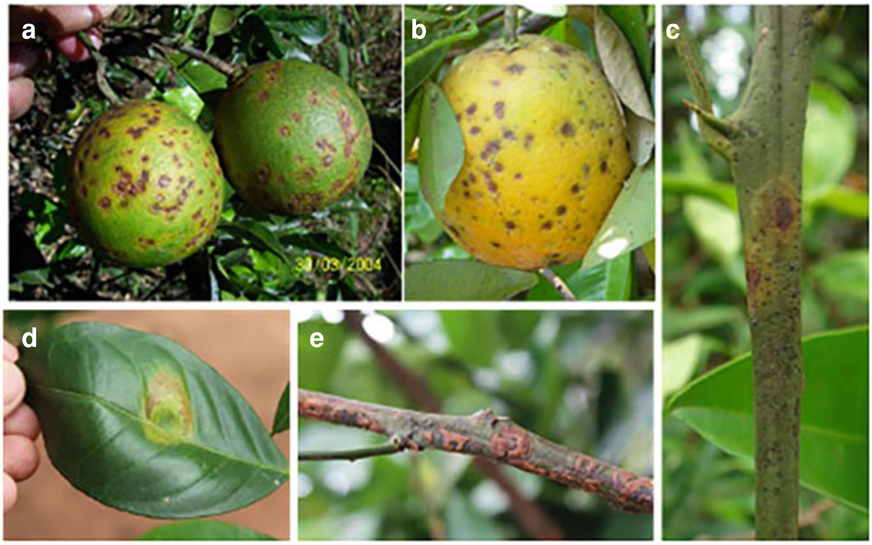

Fig. 7.17 Symptoms of citrus leprosis on fruits (**a**, **b**), stem (**c**, **e**) and leaves (**d**). (*Source* Fundecitrus, https://www.fundecitrus.com.br/doencas/leprose)

7.10.10.2 Symptoms

The leaves show circular lesions (10–30 mm diam.) centered at the mite vector's feeding site, dark brown at the center and surrounded by a chlorotic halo with 1–3 concentric rings that are visible on both sides of the leaves. In heavy infections, the lesions coalesce and at high temperature, show cracking. Green fruit initially show yellow spots, which later become brown and depressed, and they change color prematurely and drop, resulting in substantial yield losses (Fig. 7.17a, b, d). Young stems show small, chlorotic and shallow lesions that become darker and turn corky with age, and progress to bark scaling (Fig. 7.17c, e). Leaf and fruit symptoms of leprosis may be confused with measles and citrus canker. Therefore, molecular technologies must be applied for a precise diagnosis. While symptoms on the trunk with CiLV bark scaling are like those from citrus psorosis, there is no wood staining that is associated with psorosis disease.

7.10.10.3 Management and Control

Brevipalpus mites occur on citrus worldwide but rarely cause significant damage. The virus spreads only short distances along the midvein or secondary veins. Infected mites can spread the virus throughout their lifetime. Miticide sprays 2–4 times per year are regularly applied in leprosis-infested groves, along with pruning of the affected parts to reduce the inoculum sources.

7.10.11 Citrus Sudden Death

Citrus sudden death (CSD) is a problematic disease, reported from Brazil in 2004 (Maccheroni et al. 2005). Initially, the disease spread only sporadically, affecting mainly trees grafted on Rangpur lime and 'Volkamer' lemon rootstocks. Current estimates of number of orange trees killed in Brazil stands at approximately four million (Matsumura et al. 2017).

7.10.11.1 Causal Agent

Similarities in the symptoms and distribution of CSD-affected plants with the widely present CTV in Brazil led certain groups to consider that CSD was caused by a CTV variant. Later studies associated the disease with a *Marafivirus*, family *Tymoviridae* (Maccheroni et al. 2005).

7.10.11.2 Symptoms

Symptoms of the disease include pale green discoloration of the tree canopy, followed by decline and tree death (Fig. 7.18a–e). The most typical symptom is a yellow stain observed in Rangpur lime and 'Volkamer' lemon rootstocks. The symptoms of the disease are difficult to reproduce on indicator plants, but PCR diagnosis is possible.

7.10.11.3 Management and Control

The disease can be controlled by inarching trees prior to their natural infection or even in the early stages of infection with tolerant rootstocks such as 'Swingle' citrumelo or 'Cleopatra' mandarin. The recent wide use of 'Volkamer' lemon as well as *Citrus macrophylla* rootstocks in certain Mediterranean areas has made CSD a possible threat, although climatic factors and variation in vector populations in Brazilian vs. Mediterranean citrus areas could delay or prevent CSD movement to new citrus areas.

7.10.12 Satsuma Dwarf and Related Diseases

Satsuma dwarf, firstly reported in Japan, affects many citrus species and cultivars, and ornamental Rutaceae (Iwanami 2010). Citron is highly susceptible and is even considered an indicator plant for these virus agents. Today, several diseases previously considered different in some details are considered phenotypically and genetically affine.

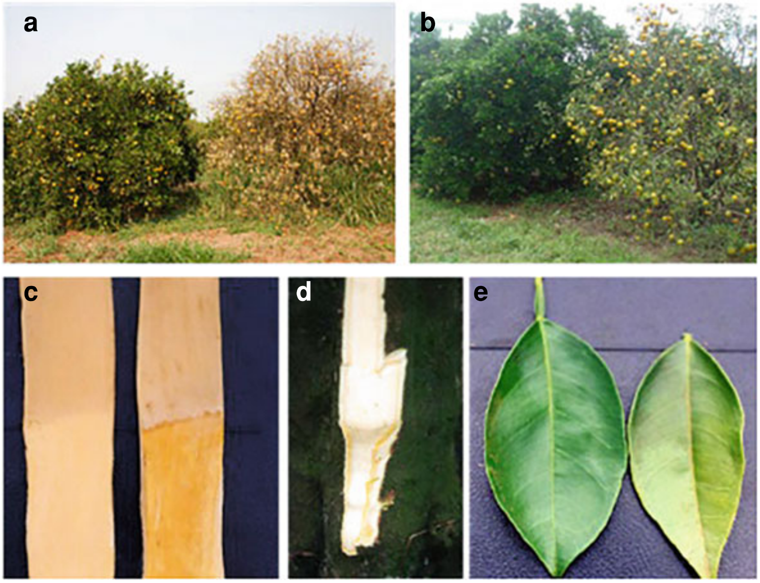

Fig. 7.18 Trees affected by sudden death disease in an open field (**a**, **b**). Symptoms on stems (**c**, **d**) and leaves (**e**). (*Source* Fundecitrus, https://www.fundecitrus.com.br/doencas/msc)

7.10.12.1 Causal Agents

Satsuma dwarf virus, the type species of the genus *Sadwavirus*, belongs to the genus *Sadwavirus*, family *Secoviridae*. SDV has not been reported in the EU-Mediterranean area and is included in the EPPO A2 list. Several additional viral disease agents, previously described as separate viruses, are now considered to belong to the SDV species, namely, Citrus mosaic virus (CiMV), Navel orange infectious mottling virus (NIMV), Natsudaidai dwarf virus (NDV), and Hyuganatsu virus (HV). CiMV, NIMV, NDV and HV can be differentiated serologically and by RNA analysis.

7.10.12.2 Symptoms

All the viruses of this group cause malformation of the spring flush in 'Satsuma' mandarin, as narrow, boat- or spoon-shaped leaves. Infected trees are stunted and produce poorly. In addition, NDV is associated with vein clearing, mottling, and curling of the 'Natsudaidai' orange, while NIMV mainly affects sweet orange trees.

7.10.12.3 Management and Control

SDV is readily transmitted through grafts and mechanically, and therefore sanitation and propagation of virus-free material allow establishing and maintaining healthy citrus groves. ELISA or PCR assays are available for the diagnosis of SDV. Shoot-tip grafting eliminates the pathogens.

7.10.13 Citrus Yellow Mosaic

Citrus yellow mosaic virus (CYMV) belongs to the genus *Badnavirus*, family *Caulimoviridae*, with bacilliform-shaped virions. The disease was first reported in India in 1975 as the cause of yellow flecks or dots on young leaves of sweet orange, lemon, mandarin, grapefruit, and pummelo. These symptoms eventually develop into leaf mottling and bright yellow flecking along the veins. Infected trees show poor performance and fruit quality (Ahlawat et al. 1996). CYMV is transmitted by bark and leaf-patch grafting as well as mechanically. It is vectored by the citrus mealybug *Planococcus citri* (Garnsey et al. 1998). Genetically, this citrus virus is closely related to cacao swollen shoot virus (Huang and Hartung 2001). As a preventive measure to control the disease, management is based on the use of virus-free propagation material and the removal of infected trees.

7.10.14 Citrus Bark Cracking

Citrus bark cracking viroid (Citrus viroid-IV), genus *Cocadviroid,* family *Pospiviroidae*), is the smallest of the citrus viroids, apparently a recombinant of HSVd and CEVd. The disease is graft-transmitted and mechanically transmitted in most citrus growing areas. Its presence in the EPPO region is restricted to Slovenia and Germany on hop, where it causes severe damage, and to a small restricted area of south Italy on citrus. It is included in the EPPO A2 list (EPPO 2019). Symptoms are like those of the citrus dwarfing viroid (CDVd). These include moderate stunting, random epinasty, and necrosis of midveins and petioles. Infected trees on trifoliate orange and ‘Carrizo’ citrange rootstocks show significant reductions in tree size and root systems, and severe bark cracking, with variable antagonistic and synergistic reactions depending on the other coinfecting citrus viroids that are present.

7.10.15 *Citrus Viroid V*

Citrus viroid V (CVd-V), an *Apscaviroid*, was detected in the citrus relative *Atalantia citroides*, considered immune to viroid infection. This viroid has been mostly overlooked in field sources containing HSVd or CDVd, which have electrophoretic mobility similar to that of CVd-V on sequential polyacrylamide gels (Serra et al. 2008a, b). CVd-V is present in a range of commercial citrus species from several citrus-producing areas around the world. In etrog citron, CVd-V shows synergistic interactions, such as enhanced leaf symptoms and pronounced dwarfing, when coinfected with some other citrus viroids.

7.10.16 *Citrus Viroid VI*

Citrus viroid VI (CVd-VI) (genus *Apscaviroid,* family *Pospiviroidae*) (Cao et al. 2017) was originally reported in Japan and termed CVd-OS. The natural host range of CVd-VI includes citrus and persimmon (*Diospyros kaki* L.). In etrog citron, CVd-VI induces mild petiole necrosis and mild leaf bending, differing from that induced by other citrus apscaviroids. Infection of trifoliate orange trees results in severe CEVd-like bark scaling and stunting.

7.10.17 *Citrus Viroid VII*

Citrus viroid VII (CVd-VII) is a tentative *Apscaviroid* (Chambers et al. 2017), waiting to be approved by the International Committee on Taxonomy of Viruses (ICTV). CVd-VII (368 nucleotides) was discovered in New South Wales, Australia. In etrog citron, CVd-VII induces epinasty, leaf bending, and midvein necrosis.

7.11 Conclusions

Fruit of the etrog citron must be blemish free to meet the high standards required for their use in religious celebrations. Furthermore, the trees used to produce the fruit for this purpose must be grown on their own roots. These requirements pose challenges in dealing with the wide range of fungal, bacterial, virus and virus-like diseases that attack citrus.

Etrog citron is particularly damaged by some diseases affecting primarily lemon, as mal secco disease, widely epidemic in the Mediterranean area, and root rot by *Phytophthora*, frequently occur in many soils or in case of incorrect management of irrigation. Other fungal diseases are much less significant but still need some attention in orchard management.

Almost all citrus viruses can be carried in citron plants which may provide a source for those vectored by insects. Among them, citrus tristeza virus is the most relevant inducing typical symptoms of stem pitting and being transmissible by aphids. Exocortis and cachexia viroids causing leaf blade malformation and vein necrosis and a reduction of functionality are relevant for their transmission mechanically by pruning in the field. All other viroids, less frequent to find in commercial orchards, multiply on citron and play synergistic effects when mixed with exocortis and other viroids.

In addition to those diseases that are prevalent in the Mediterranean region, several others pose significant constraints to citrus production in other countries around the world. Their presence introduces the need to adopt widespread and often demanding control regimes to sustain commercial production. Awareness of the seriousness of these diseases, and the imposition of strict quarantine protocols, are critical if they are to be excluded from the Mediterranean region in general, and from etrog citron production in particular.

Epilogue by Moshe Bar-Joseph

My first memory of an etrog fruit, when I was about 6 years old, was the precious *etrog* fruit purchased collectively for the Sukkot services at my birth town of Turda, a Romanian Jewish Community. After we immigrated to Israel a few years later, in 1950, my late father would purchase his own precious etrog fruit for the Sukkot holiday services.

My first encounter with etrog cultivation was a few days after Sukkot in 1966 when, as a newly assigned citrus pathologist at the Volcani Institute, I came to collect the leftover fruit from an etrog grower's packinghouse. To my surprise, most of his discarded fruit seemed to be very similar in size, color and shape to those that I would have considered valuable. Upon closer inspection, however, each of these etrogs showed some minor blemishes that were sufficient for refusal by its demanding religious customers. Back in the laboratory, the blemishes were of no consequence, and we extracted the seeds and produced hundreds of etrog seedlings which we used as indicator plants for the citrus disease exocortis. In later years, we obtained our own seed sources, yet I continued to purchase, every year, an expensive etrog fruit from a reliable dealer, holding to my promise that the discarded etrog fruit would only serve for the exocortis indexing work. Through my etrog fruit-purchasing tours, often accompanied by our boys, and my professional interest, I became acquainted with the complexities of the religious etrog fruit markets and was often surprised by the unusual gap between the interests of supermarket citrus fruit buyers and the thorough examination of an etrog fruit selected for religious purposes.

The devoted attachment of religious buyers to etrog is best illustrated in comparison to the use of etrog seedlings as indicator plants of citrus viroid diseases. The latter have been mostly replaced by the far more sensitive molecular technologies, such as PCR, yet each year I continue to purchase a perfectly shaped etrog fruit, honoring the millennia-long persistence of the traditional religious interest in etrogs, in stark contrast to the rather short-term interest in etrog for diagnostic needs.

My heartfelt thanks to each one of my colleagues who joined me in the task of expanding the English version of this chapter.

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Chapter 8
The Citron (*Citrus medica* L.) in China

David Karp and Xulan Hu

Abstract Citron (*Citrus medica* L.) is the type species of the genus *Citrus*, one of the primary species of cultivated citrus, and a parent or ancestor of the commercially important acid citrus fruits. Southwestern China is a crucial center of origin and diversity for citron. The diversity of this species in China is extensive, but poorly documented until recently. Prized for its fragrance, citron played an important role in Chinese art and culture. Today, citron is grown in most of the warmer citrus-producing areas of China, and is used in Chinese traditional medicine, ornamental pot culture, and for human consumption as both fresh and processed products. In Chinese traditional medicine, dried citron is used as a tonic, to regulate *Qi*, the life force. Citrons are classified by fruit shape as either common (nonfingered) or fingered. In most of China, fingered citrons predominate because they are more suited to cultivation for medicinal and ornamental uses. Typically, common citrons grown in China have locules in which juice vesicles are absent, or are very scanty and rudimentary. 'Ning'er Giant', typically weighing 3–5 kg, sometimes reaching 8–10 kg, may be the world's largest citrus cultivar. Fingered citron trees vary in stature, cold hardiness, flower color, and other significant horticultural characteristics; the fruits vary in size, shape, number and thickness of fingers, proportion of fruits that are open or closed, and the point on the fruit at which the carpels become distinct. The distinctive forms of many named cultivars reflect different genotypes. There also exist in China genotypes that are intermediate in morphology between common and fingered citron. Putatively "wild" citron trees producing small fruits grow in forests, in semi-wild margins between natural and cultivated areas, and in private gardens

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in the subtropical forests of western and southern Yunnan. Scientists in China and elsewhere have paid increasing attention to citron germplasm resources during recent years.

8.1 Introduction

The diversity of citron (*Citrus medica* L.) in China is extensive. Citron trees grow wild in the forests, and dozens of cultivars, varying greatly in size and including round, oblong, oblate, fingered, and intermediate shapes, exist either in the wild or in cultivation.

China recently surpassed Brazil to become the world's largest producer of citrus fruits (FAO 2016). China is a primary center of origin and diversity for many species and types of citrus, including mandarin (*Citrus reticulata*), kumquat (*Fortunella* spp.), and trifoliate orange (*Poncirus trifoliata*) (Swingle and Reece 1967; Gmitter and Hu 1990). Although its citron cultivation and resources are little known in the rest of the world, China is a crucial center of diversity for this fruit, and very likely the world's largest producer. Citron cultivation and studies are paltry compared to those of more commercial citrus such as oranges, mandarins and pummelos, but more scientific publications on citron appear in China than in the rest of the world combined.

Books on citron cultivation have been published in China, but these are chiefly practical horticultural treatises (Xu and Deng 2002; Shi and Shao 2008). In order to better understand Chinese citron germplasm resources and their uses, the authors began a project in 2008 to visit the country's major citron-growing areas, with a particular focus on the southwestern province of Yunnan. The resulting observations, integrated with a survey of the published literature, are presented in this chapter.

8.2 History and Culture

The earliest references to citron appear in the Vajasaneyi, a collection of sacred Hindu texts written in India around the eighth century B.C., more than a millennium before the first description in China (Simoons 1991). De Candolle (1886) and Hodgson (1967) both believed that citron originated in northeastern India and adjacent regions, because there it grows wild and natural hybrids showing citron characteristics are abundant. Bonavia (1888) was not sure whether citron originated in India and spread to China, or vice versa. Since the first Chinese reference to citrons appeared in the fourth century A.D., long after references to other forms of citrus such as pummelo and mandarin, Tolkowsky (1938) thought that citron was not native to China, but a foreign importation. Gmitter and Hu (1990) described some of the diversity of citrus, and particularly citron, in Yunnan; they maintained that this region played a more important role than previously supposed in the origin and distribution of *Citrus* species. Guo (1993) proposed, on the basis of geographical distribution, that western and southwestern Yunnan might be considered to be the center of origin in China, with wild citron from Cangyuan Va Autonomous County in western Yunnan being the progenitor species from which cultivated citron and lemon evolved.

The earliest mention of citron in China is in the flora of Chi Han (304 A.D.), who called it "*kou-yuan*," the name by which it was known until the Song Dynasty. Chi Han describes how the fruit, which had a non-fingered shape familiar from most citrus fruits, was highly fragrant, and prized by foreigners. In the previous century, he wrote, western countries sent 10 jars of citron to the emperor as a tribute (Simoons 1991).

In the early tenth century Liu Xun, a T'ang official, elaborated in his "Register of Strange Things Beyond the Ranges" on how citrons were prized in southern China:

> Its skin resembles that of an orange, but is the color of gold, so that men make much of it, and they love its fragrant aroma. The elite and nobility close to the royal seat in the capital display them in their households on platters and mats, attracted to them as rare fruits from a distant quarter. The flesh is thick and white, like that of a radish. Female artisans in the south vie at taking its flesh to carve and chase into flowers and birds, which they steep in bee's honey and touch up with rouge. These hold a unique place for their wonderful artistry… (Schafer 1967).

In the fingered citron the carpels grow separately, starting at the end opposite the stem (i.e., the distal end), so that the fruit looks like a fist or a hand. This type is often assumed to have been brought to China from India by Buddhist monks, and has long been called "*foshou*," meaning "Buddha's Hand", but there is no clear evidence that this happened, or when. It was already important in the tenth century in the Min Empire, in modern-day Fujian Province. Chinese artists depicted fingered citrons in jade (Fig. 8.1) and ivory carvings, bronze teapots, and lacquered wood panels (Tolkowsky 1938; Simoons 1991).

Paintings and drawings from the Ming and Qing eras often depict household scenes featuring bowls holding one to a dozen citrons, common or fingered, sitting on a table, by themselves or with different citrus or other fruit. In various images, lovers disport themselves, scholars and bureaucrats read, and wealthy homeowners repose, next to a bowl of citrons.

For Chinese artists of erotic images, the fingered citron was emblematic of female sexuality. In the Qing era, fingered citron was the fruit most frequently carved in bamboo by Chinese artists (Rawson et al. 2015).

In China, the citron was grown from the Yangtze Valley southward, and the fingered form was the most common. In northern regions citrons had to be brought at considerable expense from the south, and thus were affordable only to the wealthy. The Chinese considered the citron to be a symbol of happiness, wealth, and longevity. They prized it for New Year's gifts, and placed it as an offering at the shrines of household gods in their homes, or on altars at their temples, and as an alternative to incense, to perfume the air (Tolkowsky 1938; Simoons 1991; Xu and Deng 2002).

Fig. 8.1 Sculpture of fingered citron carved in carnelian in eighteenth century China (*Photo credit* Metropolitan Museum of Art, New York)

8.3 Nomenclature

Non-fingered citrons, with an oblong to spherical shape familiar from many other citrus types, are called “common citrons” in this review. The use of this term to distinguish non-fingered from fingered citrons dates back at least to Firminger (1874) and was endorsed by Bailey (1919). The name for the non-fingered citron in Chinese is “*xiāng yuán*” (香櫞 in Chinese ideograms).

The Chinese name for fingered citron is “*fó shǒu*” (佛手 in Chinese characters), meaning “Buddha’s Hand.” This is the name by which it is known, in closely related or cognate versions, in many languages around the world. The botanical name is *Citrus medica* var. *sarcodactylis* (Hoola van Nooten) Swingle (This name came from the Greek words “*sarkos*” meaning “fleshy” and “*dactylos*” meaning “finger”).

Curiously, Buddha’s Hand or fingered citrons are frequently called “bergamot” in Chinese scientific literature in English (Zhou et al. 2005b; Lu and Wu 2006; Mei et al. 2006; Zhang and Xu 2007). The true bergamot (*C. bergamia* Risso) is a very different acid citrus fruit, originating in Italy, that most closely resembles sour orange. It is unclear when, how, or why this erroneous terminology came to be employed; a similar misnaming occurs in Korea, where yuzu (*C. junos*) is often erroneously called "citron" in English translation. Fortunately, this misuse of "bergamot" appears to be diminishing and in many recent Chinese publications on citron the proper term, "fingered citron," is used (Guo et al. 2009a, b, c, d; Chen et al. 2010; Cao et al. 2011; Liao et al. 2013).

Several Chinese citron cultivars, notably those commonly cultivated in Zhejiang Province, have been described in the scientific literature, but no comprehensive description or taxonomy of Chinese citron cultivars has yet been published. As a result, in order to refer to particular types, it has been found necessary in this chapter (as in a previous paper; Ramadugu et al. 2015) to identify putatively distinctive genotypes of citron by choosing names, usually based on morphological and/or geographical characteristics, for example, 'Ning'er Giant,' 'Yunmao Oval,' 'Octopus,' and 'Weishan Bullet.'

8.4 Current Citron Cultivation in China

Citron is grown in most of the warmer citrus-producing areas of China, from Yunnan and Sichuan provinces in the west to Zhejiang and Jiangsu provinces in the east and to Guangdong Province and Guangxi Zhuang Autonomous Region in the south. Citron is also grown in Chongqing Municipality, Hunan, Hubei, and Henan provinces (Deng 2008); in southwest Guizhou Province, the lower elevations of eastern Tibet Autonomous Region (Xizang), and Hainan Province (Lim 2012); and in Anhui Province (Anon 2017) (Fig. 8.2a, b).

The main uses of citron are for processing for Chinese traditional medicine, for ornamental pot culture, and for human consumption of fresh or processed fruits. The fruits are also sold for ornamental and decorative purposes. In some areas, citron is used as a rootstock for other citrus, such as mandarin, sweet orange, and citron itself, or as a hedgerow (personal observations, 2008–2017). Other uses include extraction of essential oils, and additives for the flavoring of cigarettes (Li et al. 2000; Liang et al. 2006a; Guo et al. 2009a; Lü et al. 2011).

Citron is grown mostly on a small scale, often just a few trees in a rural yard. There are some larger plantings, such as a 133 ha planting of common citron in Yunnan, and substantial facilities for producing potted fingered citron plants in Jinhua, a prefecture-level city in central Zhejiang. Because citron is a relatively minor crop in China, reliable statistics regarding cultivation and production are not available. It has been estimated that 2000 ha of citron were cultivated in China in 2008 (Xiuxin Deng, personal communication, 2008).

Fig. 8.2 **a** Map of Citron cultivation in China (*Credit* Seth Karp). **b** Map of Citron cultivation in Yunnan and Southern Sichuan (*Credit* Seth Karp)

8.4.1 Propagation

Citron trees are propagated in China using four different methods.

8.4.1.1 Cuttings

Both hardwood and softwood cuttings are widely used for both common and fingered citrons. This method is easy and quick, but has the disadvantage that cold hardiness and drought resistance are not as good as for grafted trees. Citron cuttings, which are easy to root, are usually made in spring, and sometimes in summer or fall. Usually, each cutting is 20–30 cm long, with a few buds. The rooting media used are sand, peat moss, or even common soil. Sometimes rooting hormones such as indole acetic acid (IAA), indole-3-butyric acid (IBA), or 1-naphthaleneacetic acid (NAA) are applied, while in other cases no root induction agent is used.

8.4.1.2 Grafting

In some areas grafting is used for both common and fingered citrons. The major rootstocks are trifoliate (*Poncirus trifoliata* (L.) Raf.) and local citron seedlings. Citron seedlings are preferred because they result in a uniform graft union and vigorous growth. Trifoliate rootstock is also used, although the graft union is typically uneven, with the rootstock larger than the scion. In Jinhua, Huyou (*C.* × *changshan-huyou* Y. B. Chang, a natural hybrid of *C. sinensis*, *C. grandis* and possibly other species of *Citrus*) is used as an interstock for bonsai fingered citron (Shi and Shao 2008). Grafted trees live longer and perform better than trees grown from cuttings.

8.4.1.3 Seed

Citron is sometimes grown directly from seed (Liu et al. 2014).

8.4.1.4 Tissue Culture

Researchers have developed methods to use tissue culture to propagate citron trees. Tissue culture has the potential to multiply citron plants by 1–3 million a year (Zhou et al. 2005a; Zhang et al. 2009a).

8.4.2 Diseases, Pests, and Freeze Damage

Huanglongbing (HLB, citrus greening), a highly destructive bacterial disease associated with the fastidious Gram-negative, phloem-limited, *α-Proteobacteria*, *Candidatus* Liberibacter sp., does not spare citron (He et al. 2005; Deng et al. 2008). In some parts of China where citron is grown, HLB has not yet arrived, but when it does spread it often becomes a serious problem. A survey in Guangdong, where HLB is endemic, found that fingered citron was the most infected of 16 citrus cultivars, with all samples diseased (Deng et al. 2012). In contrast, Ramadugu et al. (2016) found that citron, along with its progeny, lemons and limes, performed better than other *Citrus* types in withstanding decline from HLB infection.

In contrast, researchers have observed that citron has never demonstrated canker disease (*Xanthomonas axonopodis* pv. *citri* Hasse) in the field, and inoculated plants of 'Chinese' citron did not develop lesions (Deng et al. 2010).

Other significant diseases of citron in China include anthracnose (*Colletotrichum gloeosporioides*), citrus scab (*Elsinoë fawcettii* Bitanc. & Jenkins), and green mold (*Penicillium digitatum* [Pers.:Fr.] Sacc.) (Li et al. 2011).

Major insect pests include citrus red mite (*Panonchus citri* McGregor), citrus leafminer (*Phyllocnistis citrella* Stainton), chaff scale (*Parlatoria pergandii* Comstock), spirea aphid (*Aphis citricola* van der Goot), and orange spiny whitefly (*Aleurocanthus spiniferus* Quaintance).

Premature leaf abscission and sunburn are other common problems.

Since citron is among the most cold-tender of citrus crops, damage from freezing weather is a significant problem in districts with cool winters. In Jinhua (Zhejiang Province), where temperatures in winter can fall as low as −3 to −5 °C, many producers of bonsai fingered citron trees use protected greenhouses and plastic tunnels, and spray water on the trees during freezes. Researchers there have evaluated the available fingered citron germplasm for cold hardiness (Guo et al. 2009d; Jiang et al. 2012a, b), and elucidated the molecular mechanisms underlying cold regulation of plant defense and stress responses (Guo et al. 2009c; Chen et al. 2010; Cao et al. 2011; Yang et al. 2012).

8.4.3 Medicinal Uses and Properties

The primary use for which citron is grown in China is as a medicinal plant. In Chinese traditional medicine, dried slices (Fig. 8.3) and strips of both common and fingered citron are used as a tonic, to regulate *Qi*, the life force or energy flow (Zhang 2015). The fruit are often sliced thin and dried in the sun or on trays in ovens (Fig. 8.4). As is the case for other citrus grown for medicinal use, citrons are typically harvested somewhat immature, when the rind is still greenish, because the medicinal properties are said to be more potent at this stage. Liang et al. (2006a) found that the essential oil content of individual fruits reaches a maximum when they are a light yellow

Fig. 8.3 Dried 'Chuan' fingered citrons, for use in Chinese traditional medicine, in Xiaogu, Sichuan (*Photo credit* David Karp; 7 Nov. 2008)

or golden color, but Wu et al. (2013) determined that the antioxidant activity of fingered citron essential oils does indeed decrease with maturity at harvest, declining by approximately 20% from the immature to the fully mature stage.

According to Jiao (2001), common citron (*xiang yuan*) is

> acrid, sour, and bitter in flavor and warm in nature. [It] regulates *Qi*, loosens the chest, and transforms phlegm. *Xiang yuan* is suitable for liver *Qi* depression that causes rib-side pain, stomach duct pain, fullness and oppression in the stomach duct and abdomen, belching, and vomiting. … [It also] enhances the appetite during the initial stage of pregnancy.

Similarly, Jiao (2001) characterises the fingered citron (*foshou*) as follows:

> …rectifies *Qi* and harmonizes the center, and soothes the liver and resolves depression. [It] is suitable for liver-stomach disharmony, *Qi* stagnation stomach pain, oppression in the chest, rib-side distention, poor appetite, and vomiting.

Common citron is said to have a stronger phlegm-transforming effect than fingered citron, but the latter to be more effective in checking retching. Some practitioners consider common citron to be an inexpensive substitute for fingered citron (Jiao 2001).

In addition to fruit products, the leaves of citron trees are used to treat cough and respiratory ailments (personal observation, 2008).

Modern medical researchers are finding evidence that citron does offer beneficial health properties. Fingered citron has been reported to contain various bioactive

Fig. 8.4 Drying fingered citron slices for Chinese traditional medicine near Huaning, Yunnan (*Photo credit* David Karp; 22 Oct. 2011)

coumarins, flavonoids, tetranortriterpenoids, monoterpenoids, and acridone alkaloids (Chan et al. 2010; Li et al. 2013). A review of medical literature by Panara et al. (2012) found that citron possesses analgesic, hypoglycemic, anticholinesterase, anticancer, antidiabetic, hypocholesterolemic, hypolipidemic, insulin secretagogue, anthelmintic, antimicrobial antiulcer, and estrogenic properties.

Among dozens of studies on the medical effects of citron, Guo et al. (2009a) observed that the essential oil extracted from fingered citron fruits has a strong antibacterial effect, with good thermal stability and longlasting effectiveness. Peng et al. (2009) confirmed that fingered citron had an insulin secretagogue effect in rats, and stated that it would be very beneficial to patients with type 2 diabetes. Both Lü et al. (2011) and Shao et al. (2011) found that fingered citron essential oil had an antiproliferative effect on melanoma cells in vitro. Kim et al. (2013) confirmed that fingered citron essential oil possesses anti-inflammatory properties while Al-Kalifawi (2015) found that essential oils of fingered citron could be used as a therapeutic agent for human microbial infections.

8.4.4 Ornamental Cultivation

The second most important use of citron in China is as an ornamental dwarf, or bonsai, tree, to be sold in a pot or basket (Fig. 8.5). The center of ornamental citron

Fig. 8.5 Bonsai fingered citron plants in pots for sale at a street market along a road in Jinhua, Zhejiang (*Photo credit* David Karp; 17 Oct. 2008)

production is the city of Jinhua, in Zhejiang Province, which annually produces about 500,000 fingered citron trees in pots, with a value of approximately $US 5 million.

There, citron trees are cultivated both in greenhouses with removable plastic covers, to protect them against rain and winter cold, and in open-air plantings. Fingered citron plants are raised in black plastic pots initially before transplanting into more decorative pots. The growing medium comprises perlite + peat + mushroom bran (1:1:1) with incorporated slow-release fertilizers (Lu and Wu 2006). Near-infrared reflectance spectroscopy can be used to diagnose nutritional deficiencies (Liao et al. 2012). Producers use trellises, stakes and ties to ensure that the limbs and fruit maintain an attractive upright growing habit (Fig. 8.6).

Local growers and researchers have selected and developed several dwarfed varieties, such as 'Aihua' and 'Qingpi,' which are naturally suited to bonsai production. Fruits are often grafted onto small plants, giving them the look of an ornamental flowering plant. Jinhua growers also harvest about 500 tonnes of fingered citrons annually for fresh sales and for processing for use in Chinese traditional medicine.

8.4.5 *Culinary Uses and Processing*

The authors have observed in citron-growing areas of China that culinary uses and processing are the third most important use of citron in China overall, but quite

Fig. 8.6 In Jinhua, fingered citron growers use trellises, stakes, and ties to ensure that the limbs and fruit maintain an attractive upright growing habit (*Photo credit* David Karp; 17 Oct. 2008)

important for common citron. The albedo from select common citron cultivars is sweet and juicy, and the Chinese often enjoy eating it fresh (Fig. 8.7). The rind and albedo are also used in savory dishes, but recipes in Chinese cookbooks are not particularly common. Karp (1998) mentions three recipes using fingered citron: chicken rolls steamed in lotus leaf; stewed fruit and white fungus; and crispy mock Buddha's Hand (with pork, cornstarch, and eggs).

One common use is candied rind, which is similar to products made in Brazil, the Mediterranean area (primarily Italy, Greece, and Corsica), and Puerto Rico (Klein 2014). Those areas produce candied citron mostly for export, but virtually all of the Chinese production is consumed domestically. It seems possible that China might export this product in the future; equally, producers in other countries might well consider using elite Chinese common citron cultivars such as 'Ning'er Giant' for their large size and naturally sweet albedo.

Citron-processing factories visited by the authors are small and family owned, making from a few hundred kilograms to 20 or 30 tonnes of candied citron annually. Manufacturers are often very secretive about the particulars of their processing methods. Both common and fingered citron are used, but mostly common citron is processed. The harvest season for culinary citron is August to October. Fruit are harvested at full size, although the rind may be light green or yellow. The basic technique, similar to the traditional method used in the Mediterranean, is to scoop out the central portion (locules and seeds, and juice vesicles, if any), then to cut the

Fig. 8.7 Mr. Pei-Yong Zhang eats a slice of common citron at his home in Dehong Prefecture, Yunnan (*Photo credit* David Karp; 4 Nov. 2008)

rind and albedo into thin strips which are soaked in water to remove the bitterness and then boiled in sugar syrup.

Tonghai, in Yunnan (elevation 1800 m), has a long history of making candied citron peel, which is a famous local product. Local factories use some 80–100 tonnes of citrons annually from nearby growing areas, particularly Huaning County.

Other products made from citron in China include soft drinks, wine, preserves, juice concentrate, tea, and essential oils. For extracting juice from fingered citron, Jie (2007) found that steam distillation and supercritical carbon dioxide extraction were the best methods.

In Jingjiang, in Jiangsu Province, citron trees have been planted on a large scale as street trees, because of their attractive shape, appearance, and aroma. Since 2007 these trees have produced roughly 2000 tonnes of fruit each year, most of which have been discarded. To make use of this fruit, local authorities have encouraged processors to make citron soft drinks.

8.5 Major Cultivars of Chinese Citron and Select Citron Hybrids

Citrons are classified by fruit shape as either common (non-fingered) or fingered; there are a few rare types that are intermediate in character between these two groups.

It is also useful to distinguish pure *C. medica* specimens from citron hybrids, using both morphological and genetic analyses.

Wild and wild-type are small-fruited common citrons, and might include both pure and hybrid forms.

8.5.1 Common (Non-fingered) Citron Cultivars

The common (non-fingered) citron is the most commonly cultivated type of citron in many areas of the world. However, in most of China fingered citrons predominate, because they are more suited to cultivation for medicinal and ornamental uses. In China, only in Yunnan and in adjacent western regions is common citron grown on a significant scale. The majority of the plantings are of small size, but accurate statistics of annual yield and planted area are not available. Nonetheless, it seems clear that both production and planted surfaces are substantially less for common citron than for fingered citron.

There are two basic types of common citrons in China:

(1) Common citrons with segments and juice vesicles, roughly similar to the citrons such as ‘Diamante’ that prevail in the Western world (Small-fruited wild-type citrons, which do have juice vesicles, belong in this category morphologically, but are treated in a separate section below, as are citron hybrids).
(2) Common citrons with locules in which juice vesicles are absent, or are very scanty and rudimentary.

China is notably one of the few citron-growing countries in which citrons of the second category (no or very few juice vesicles) outnumber those of the first, both in number of cultivars and areas grown (The ‘Temoni’ cultivar, traditionally cultivated in Yemen, and now grown in Israel for Jewish ritual, is the best-known example of this type in the Western world. It would be tempting to suggest that ‘Temoni’ might have been derived somehow from Chinese citrons of similar type, but in Ramadugu et al. (2015) ‘Temoni’ was clustered with Western rather than Chinese citrons).

The reason for this prevalence in China of common citrons without juice vesicles probably relates to the primary economic importance of the albedo, which is consumed either fresh or cooked. To those unfamiliar with the cultivars used this might seem surprising, since the albedo of most citrus fruits is unattractively bitter, and citron rind used for candying in other countries undergoes lengthy processing to remove this bitterness. However, the albedo of at least some forms of common citron grown in China is non-bitter, moist but firm, and reasonably pleasant to eat fresh, almost like a bland apple. Common citron rind is also candied, and dried chips of the rind reused in Chinese traditional medicine.

Most non-fingered citrons probably had juice vesicles like all other *Citrus* species, before the selective process of domestication. It would be speculative to surmise just how thick the albedo was on these ancestral citrons. However, because the albedo has long been the fruit part of primary importance, it is not surprising that farmers have over time selected cultivars in which a large part of the fruit is albedo, the segments or locules are small, and the juice vesicles are scanty or (most frequently) absent altogether. One can speculate that since the juice vesicles did not serve a useful purpose, it did not serve the interests of growers to cultivate varieties in which they were prominent.

In Yunnan, citrons with juice vesicles are sometimes called "sour" citrons, while cultivars without juice vesicles are called "sweet." These words have a different meaning in this context than in Western citrus terminology, in which "sweet" refers to the flavor of the pulp, not the rind. All of the Chinese cultivars with juice vesicles encountered by the authors have acidic pulp, not acidless pulp like 'Corsican.'

8.5.1.1 'Dog Head' [狗头香橼] (Fig. 8.8)

- *Distribution*: Mojiang and Ning'er counties and Simao District in southern Yunnan.
- *Elevation*: 1000–1800 m.

Fig. 8.8 'Dog Head' citron in Mojiang, Yunnan (*Photo credit* Xulan Hu; 3 Nov. 2010)

- *Botanical characteristics*: trees medium to large; young flush purple-tinted; shoots green, leaves large; flower buds purple-tinted; fruits large, typically 3–5 kg; fruit shape oblong, cylindrical; rind wrinkled, warty and ridged; albedo thick, sweet, and relatively juicy; c. 12 locules, juice vesicles absent; seeds numerous, monoembryonic.
- *Uses*: fresh; processing (candied citron rind); rootstock for fingered citrons; traditional Chinese medicine; religious and decorative purposes.
- *Note*: this is the major citron cultivar in Mojiang, a village near Pu'er that grows about 100 mu (7 ha) of citron, yielding about 40–50 tonnes of fruit annually.

8.5.1.2 'Jianshui Round' (Fig. 8.9)

- *Distribution*: Jianshui and Shiping counties in southern Yunnan.
- *Elevation*: 1300–1500 m.

Fig. 8.9 'Jianshui Round' citron, Bai Shi Yan village, Xizhuang township, Jianshui County, Yunnan (*Photo credit* David Karp; 23 Oct. 2011)

- *Botanical characteristics*: trees short or medium; young flushes purple-tinted, shoots dark-green, leaves large, flower buds purple to pink; fruits medium, typically 1.5–3 kg; fruit round (spherical); rind surface smooth; albedo thick, sweet, and juicy; 10–15 locules, juice vesicles absent; seeds numerous, monoembryonic.
- *Uses*: rootstock for fingered citrons; consumed fresh; traditional Chinese medicine; religious and decorative purposes.

8.5.1.3 'Jinggu' (Fig. 8.10)

- *Distribution*: Jinggu and Zhenyuan counties in southern Yunnan.
- *Elevation*: 900–1300 m.
- *Botanical characteristics*: thorns long and thin; fruits small, 300–800 g, obovate to ellipsoid, rind smooth with prominent longitudinal ridges; albedo thick and sweet; locules 11–13; juice vesicles absent; seeds numerous, monoembryonic.
- *Uses*: consumed fresh; traditional Chinese medicine; trees are used as hedges to protect from animals; leaves are used to cook meat and treat respiratory disorders.

Fig. 8.10 'Jinggu' citron, Jinggu Dai and Yi Autonomous County, Yunnan (*Photo credit* Xulan Hu; 6 Jan. 2017)

Fig. 8.11 'Jinghong Water' citron, Jinghong, Yunnan, with large central cavity and small locules with numerous seeds and scanty juice vesicles (*Photo credit* Xulan Hu; 1 Nov. 2010)

- *Note*: according to local farmers, fruits floated down a river called Weiyuan Jiang from nearby uplands, and its seeds grew into trees along the riverbank. It has characteristics typical of wild citrons, such as long, thin thorns, small fruit size, and numerous seeds. This may in fact be a form of "Wild citron, Type 2" (see below) that has entered cultivation.

8.5.1.4 'Jinghong Water' (Fig. 8.11)

- *Distribution*: Jinghong and Mengla counties in southern Yunnan.
- *Elevation*: 400–1000 m.
- *Botanical characteristics*: tree short or medium in stature, foliage dense, leaves large, relatively pointed for a citron; fruits medium, typically 1.5–3 kg, oval to pear-shaped; rind pale whitish-yellow, surface rough, ridged; albedo thick, sweet, and juicy; 12–14 locules, which are small, while the central cavity is enlarged; juice vesicles almost absent, although some rudimentary juice vesicles are present; seeds numerous, monoembryonic.
- *Uses*: rootstock for fingered citrons; consumed fresh; traditional Chinese medicine; religious and decorative purposes.
- *Note*: in microsatellite analysis performed by Ramadugu et al. (2015), this cultivar was the only one of 26 Chinese citron accession in which 0% heterozygosity was observed.

8.5.1.5 'Ning'er Giant' (Fig. 8.12)

- *Distribution*: Ning'er, Simao, and Mojiang counties in southern Yunnan.
- *Elevation*: 800–1700 m.
- *Botanical characteristics*: flower buds light purple, young flushes purple; thorns medium long; leaves oval or obovate-elliptic with round tip and fine saw margin; fruits very large, typically weighing 3–5 kg, sometimes reaching 8–10 kg; shape oblong, blocky; rind often very wrinkled or warty; albedo thick, sweet and

Fig. 8.12 'Ning'er Giant' citron weighing ca. 8 kg, held by the farmer, Li Hua Zhong, near Ning'er, Yunnan (*Photo credit* David Karp; 18 Oct. 2011)

juicy; locules c. 13, with numerous monoembryonic seeds; juice vesicles absent, although a few rudimentary vesicles can be found. Fruits on the same tree can vary considerably in size and rind texture.

- *Uses*: rootstock for fingered citrons; consumed fresh and processed (candied rind); traditional Chinese medicine; religious and decorative purposes.
- *Note*: at its largest, this cultivar may be the largest citrus fruit in the world. Ning'er is one of the major citron production areas in Yunnan, possibly producing over 1000 tonnes annually. The 'Ning'er Giant' variety, sometimes called "*zhou pi xiangyuan*" ("wrinkled citron") because of its wrinkled rind, has a long growing history and is well known in southern Yunnan. The total growing acreage of citron grown in the area is about 700 mu (50 ha). The fruit can be harvested year-round, with a peak season in fall.

Fig. 8.13 'Persistent Stigma' citron, Huaning, Yunnan (*Photo credit* David Karp; 22 Oct. 2011)

8.5.1.6 'Persistent Stigma' (*Citrus medica* var. *stigmapersistens* Liang S. H. and Pen G. N., 宿柱香橼) (Fig. 8.13)

- *Distribution*: Huaning County and Mile City in central Yunnan.
- *Elevation*: 1100–1700 m.
- *Botanical characteristics*: fruits small to medium, 1–2 kg, blocky oval to pear-shapes; rind moderately rough, sometimes ridged; 12–14 segments; juice vesicles present, sour; seeds numerous, monoembryonic; style persists on most but not all fruits.
- *Uses*: rootstock for fingered citrons; consumed fresh and processed (candied rind); traditional Chinese medicine; religious and decorative purposes.
- *Notes*: described, based on a type specimen found at Honguang Farm, Yuangjiang county, Yunnan, in an article (in Chinese only) by Liang and Peng (1980). This form appears to have vanished from Yuangjiang, but a similar form that typically retains its style was recently found in Huaning (Yuxi city), Yunnan (it is not clear that they are genetically the same or even related). Open pollinated seedling (OPS) material from this genotype clustered with the pure *C. medica* accessions in Ramadugu et al. (2015).

8.5.1.7 'Pumpkin' (Fig. 8.14)

- *Distribution*: Majie village, Xiaowan township, Fengqing County, Lincang City, in southwestern Yunnan; introduced from Shuangjiang County, Yunnan.
- *Elevation*: 1400 m.

Fig. 8.14 'Pumpkin' citron in Xiaowan, Fengqing County, Yunnan (*Photo credit* Xulan Hu; 28 Oct. 2015)

- *Botanical characteristics*: tree upright and vigorous; young flushes purple; fruit medium to large, 1.5–2.0 kg, flat, prominently lobed, uneven in shape (one side is often larger than the other), indented at the stem and stylar ends; rind rough; albedo thick; locules c. 18, with numerous monoembryonic seeds; juice vesicles absent.
- *Use*: the albedo is eaten as fresh fruit.
- *Note*: recently discovered by Xulan Hu; grown on a small scale in southwestern Yunnan.

8.5.1.8 'Weishan Bullet' (Fig. 8.15)

- *Distribution*: Weishan and Fengqing counties in western Yunnan.
- *Elevation*: 1200–1500 m.
- *Botanical characteristics*: flower buds pink; fruit small to medium, 0.4–0.8 kg, oblong, pointed at the stylar end (some specimens could be said, with a bit of imagination, to be bullet-shaped); rind moderately rough, ridged in some specimens; albedo moderately thick; c. 12 segments, juice vesicles present, sour; seeds numerous, monoembryonic.

Fig. 8.15 ‘Weishan Bullet’ citron near Weishan, Yunnan (*Photo credit* David Karp; 12 Oct. 2011)

- *Uses*: rootstock for fingered citrons; consumed fresh; traditional Chinese medicine; religious and decorative purposes.
- *Note*: in microsatellite analysis performed by Ramadugu et al. (2015), the heterozygosity observed in this cultivar was 8.70%. It clustered with other Chinese pure *C. medica* genotypes.

8.5.1.9 ‘Weishan Sour’ (Fig. 8.16)

- *Distribution*: Weishan County in western Yunnan.
- *Elevation*: 1400–2100 m.
- *Botanical characteristics*: trees medium size; young flushes light green, shoots dark green; leaves large, flower buds white; fruits large, typically 3–6 kg; fruits oblong, cylindrical, to spherical with a pointed stylar end; albedo thick, somewhat sour, and juicy; 12–15 segments, juice vesicles present, sour; seeds numerous, monoembryonic (Li et al. 1983).

Fig. 8.16 'Weishan Sour' citron near Weishan, Yunnan, China (*Photo credit* David Karp; 22 Oct. 2011)

- *Uses*: rootstock for fingered citrons; consumed fresh; traditional Chinese medicine; religious and decorative purposes.
- *Note*: this cultivar is unusual among Yunnanese citrons in having juice vesicles, which is normal for virtually all other citrus, but not typical of pure Chinese common citrons. The population structure analysis in Ramadugu et al. (2015) shows this cultivar to be intermediate between the cluster of pure Chinese citrons and the cluster of hybrid citrons.

8.5.1.10 'Weishan Sweet' (Fig. 8.17)

- *Distribution*: Weishan County in western Yunnan.
- *Elevation*: 1400–2100 m.
- *Botanical characteristics*: trees medium size; young flushes light green, shoots dark green, leaves large, and flower buds white; fruits large, typically 3–5 kg; fruit oblong, cylindrical, to spherical with a pointed stylar end; rind texture rough, ridged; albedo thick, sweet, and juicy; 15–20 locules, juice vesicles absent; seeds few, monoembryonic.
- *Uses*: rootstock for fingered citrons; consumed fresh; traditional Chinese medicine; religious and decorative purposes.

Fig. 8.17 'Weishan Sweet' citron, Tuanshan village, Nanzhao township, near Weishan, Yunnan (*Photo credit* David Karp; 12 Oct. 2011)

8.5.2 Fingered Citron Cultivars

Fingered citrons are split apically into finger-like sections, resembling a human hand. Some find the unusual appearance of the fruit bizarre (Hesser 1998), but others find it beautiful and exotic.

In addition, fingered citron has a strong, very pleasant fragrance, reminiscent of osmanthus (which in turn is described as having a fruity apricot aroma) (Lim 2012). The aroma volatile component beta-ionone is responsible for this characteristic osmanthus-like odor (Shiota 1990). Fingered citron oil is primarily composed of terpenoids, particularly limonene, beta-myrcene and terpinolene (Huang et al. 1998).

Fingered citrons generally have no seeds or juice vesicles, consisting exclusively of flavedo on the surface and albedo internally. The authors have observed a specimen of 'Yun' fingered citron that had a few sections with juice vesicles (Fig. 8.18), but such fruit appear to be rare. Hodgson (1967) mentioned a clone containing "seeds hanging free in the locules," but no such types appear in more recent literature.

Chen (2014) emasculated and bagged fingered citron flowers before they opened, found that fruit growth did not change significantly compared to controls, and concluded that fingered citron is parthenocarpic.

Fingered citrons are more commonly cultivated in China than non-fingered types, because they are more suited for the two citron uses of primary economic importance: (1) they are more suited for Chinese traditional medicine because they have a higher ratio of flavedo, in which many medicinally significant compounds occur, to fruit

Fig. 8.18 'Yun' fingered citron, showing how one fruit actually has some juice vesicles (*Photo credit* David Karp; 8 Nov. 2008)

weight; and (2) because of the unusual flower-like shape of fingered citron fruits they are better suited than common citrons for the production of dwarf (bonsai) plants for the ornamental trade.

In China, fingered citrons are grown in Sichuan, Yunnan, Guangdong, Fujian and Guangxi provinces, primarily for use in traditional Chinese medicine. In addition, they are cultivated for primarily ornamental use (bonsai potted plants) in Jinhua, Zhejiang Province; Zhaoqing, Guangdong Province, and in Yanling, Henan Province (Deng 2008).

Historically, Western citrus literature has regarded 'Buddha's Hand' citron as a single horticultural variety, *C. medica* L. var. *sarcodactylis* Swingle (Swingle and Reece 1967), much in the same way that citrus scientists wrote as if there were only one cultivar of '*Etrog*' used for Jewish ritual (Hodgson 1967; Saunt 2000). Hodgson (1967) recognized two clones, with and without seeds. However, based on Chinese publications, morphology and genetic analysis, it is clear that more than six cultivars of fingered citron exist in China alone.

Fingered citron trees vary in stature, cold hardiness, flower color, and other significant horticultural characteristics; the fruits vary in size, shape, number and thickness of fingers, proportion of fruits that are open or closed, and the point on the fruit at which the carpels become distinct, as well as rind density, color, and aroma. Because a single tree can produce fruits of widely varying shapes—for example, depending on the time of year of flowering, the proportion of fruits with fingers that are spread or closed can vary considerably, and other characteristics such as rind color can vary depending on the growing environment—it has not always been clear when varying phenotype reflects varying genotype. Indeed, it appears that fingered citron fruit is more variable in morphology than most other types of citrus. From a purely morphological standpoint, it is essential to observe many fruits on multiple trees over time. It is possible that in an orchard of 'Yun' fingered citron one might find a few fruits with atypically slender, gnarled fingers resembling 'Octopus' fingered citron grown in the same area, but it would be highly unlikely that all the fruits on a 'Yun' tree would look like that.

During the past 15 years multiple studies have confirmed that the distinctive forms of many named cultivars reflect different genotypes (Chen et al. 2002; Ma et al. 2002; Gao et al. 2007a, b; Zhang et al. 2008; Hao 2009; Sang 2011; Ramadugu et al. 2015). Ramadugu et al. (2015) was able to distinguish seven different genotypes of fingered citron, and Ma et al. (2002) could distinguish two closely related Jinhua cultivars, 'Qingpi' and 'Aihua,' using random amplification of polymorphic DNA (RAPD) analysis.

In China, several types of fingered citrons are classified into cultivars or cultivar families named after the province or area where they primarily are grown: 'Guang' for Guangdong, 'Jin' for Jinhua, 'Yun' for Yunnan, and 'Chuan' for Sichuan. RAPD analysis (Zhang et al. 2008) and simple sequence repeat (SSR) markers (Hao 2009) have found that genotypes within each of these geographical categories clustered in clades, some of greater diversity ('Guang') than others ('Jin'). Sang (2011) found a significant correlation between genetic and geographic distances. It seems clear that specimens of these geographical cultivar families are not necessarily clones identical to each other; it would not be surprising if some citrons identified by the same family name were not in fact closely related.

In addition to area of origin, fingered citron cultivars are distinguished by fruit shape, tree habit and flower color (Chen et al. 2008).

Since all other forms of citrus have whole fruits, segments and juice vesicles, it can be assumed that the original form of *C. medica* was the common (non-fingered) citron. On at least one occasion in the past, a fingered mutation occurred naturally. Since fingered citrons generally have no seeds, and have not been found growing wild, it seems likely that this mutation survived because humans found it interesting or useful, and propagated it by cuttings or grafting.

Did all fingered citrons arise from one original mutation from a common citron parent, or did such mutations occur in multiple instances, presumably from different parents? The neighbor joining tree and maximum parsimony tree investigated by Ramadugu et al. (2015) showed common and fingered citrons interspersed, implying that fingered citrons as a group are polyphyletic—that is, they do not all descend from a common ancestor of similar type. Anecdotally, scientists in China say that they do suspect that certain fingered selections mutated from common citron parents that are similar in rind aroma and flesh texture (Duowen Li, personal communication, 2008).

Because fingered citron does not have seeds and is vegetatively propagated in cultivation, it has not developed as many different forms and cultivars as might be the case if diverse genotypes had long been recombining genes through zygotic seed propagation. However, over the many centuries during which the Chinese have grown fingered citron, they have noticed spontaneous mutations, and selected genotypes best adapted to different geographical areas and uses. More recently, researchers in Zhejiang, the center of the ornamental fingered citron industry, have developed a dwarf variety, 'Aihua,' through mutation breeding (Chen and Shentu 2003; Guo et al. 2006; Wang et al. 2007; Chen et al. 2008; Sang, 2011; Zhang et al. 2009b).

In order to increase the range of fingered citron varieties available to growers, researchers in Zhejiang have started to experiment with genetic transformation methods for citron, using particle bombardment, but none of the cultivars created

Fig. 8.19 'Aihua' fingered citrons (*Photo credit* Wen-Rong Chen; 5 Dec. 2008)

using this technology has yet been introduced (Guo et al. 2005; Zhou et al. 2005b, 2006).

8.5.2.1 'Aihua' ('Qianzhi Baitai') (Fig. 8.19)

- *Distribution*: Jinhua and Lanxi districts of Zhejiang Province.
- *Elevation*: 50–800 m.
- *Botanical characteristics*: a recently developed dwarfed mutation of 'Qingpi' obtained by gamma irradiation (Guo et al. 2006), introduced in 2009. Crown dwarf and compact; average height 45 cm; leaves small and thick; thorns few; length between nodes short; fruit small, average weight 48 g.; rind golden yellow. Produces numerous fruits per tree (average on 3-year-old plants 17.3 fruits); suitable for ornamental pot culture (Wang et al. 2010).
- *Uses*: bonsai plants (Chen and Shentu 2003); dried fruit chips, flowers and leaves for Chinese traditional medicine; may be used for citron wine, tea, fresh fruit, and essential oil.
- *Note*: 'Aihua' (the name means "dwarf" in Chinese) is (with 'Qingpi') one of the two main cultivars of the 'Jin' family of fingered citrons grown in the Jinhua area of Zhejiang. In an analysis of SSR markers, Wang et al. (2007) and Zhang et al. (2009b) confirmed that the dwarfing of this cultivar has a genetic basis.

8.5.2.2 'Chuan' (Fig. 8.20)

- *Distribution*: Qianwei, Muchuan, Luzhou, Leshan, Yibin, and Hejiang districts of Sichuan Province and Jiangjin, Nanchuan, and Shizhu districts of Chongqing Municipality.
- *Elevation*: 300–800 m.

Fig. 8.20 'Chuan' fingered citrons with typical closed fingers, Shuangshi village, Xinfan township, Muchuan County, Sichuan (*Photo credit* David Karp; 7 Nov. 2008)

- *Botanical characteristics*: tree canopy extensive; shoots light brown, hanging down loosely; young flush and flowers dark purple; leaves large, deep-green; fruits relatively small, 0.3–0.7 kg; shaped like an oblong or cylindrical fist, with fingers typically closed; rind ridged, light yellow. Sensitive to cold. Yields can reach 37,500 kg of fresh fruit per hectare, which can be dried to 3600 kg.
- *Uses*: traditional Chinese medicine; considered a high-quality product, strongly aromatic, and potent in promoting *Qi*; also used to make juice, candy, preserves, tea, and essential oil, etc., and to adorn altars.
- *Notes*: a molecular marker study (Hao 2009) found that 'Chuan' clustered with 'Guang', and may have derived from it; the neighbor joining tree of Ramadugu et al. (2015) also depicts them as close. 'Chuan' dried citron chips are mostly sold in Beijing, Tiangjin, and other northern China areas.

8.5.2.3 'Guang' (Fig. 8.21)

- *Distribution*: Zhaoqing and Gaoyao districts of Guangdong Province and Guilin, Liuzhou, and Wuzhou districts of Guangxi Zhuang Autonomous Region.
- *Elevation*: 40–200 m.
- *Botanical characteristics*: tree relatively tall, with sparse canopy. Shoots light brown, hanging down loosely; young flushes and flowers purplish red; leaves larger and deep green; fruits large, 0.8–1.5 kg, fist-shaped; rind light yellow.
- *Uses*: traditional Chinese medicine; dried chips are lightly aromatic, weak in promoting *Qi*, but considered high quality. Also used to make juice, candy, preserves, tea, and essential oil, etc.; widely used as an adornment or offering at altars.

Fig. 8.21 'Guang' fingered citron in Guangdong (*Photo credit* Xulan Hu; 14 Oct. 2012)

- *Notes*: RAPD analysis by Zhang et al. (2008) identified three distinct Guang cultivars originating from different districts of Guangdong. Guangdong produced 120–150 tonnes of dried fingered citron chips in 2007. Plantings in Guangxi were less than 600 ha, producing 300 tonnes of dried chips. In 1999 'Guang' dried chips accounted for half of China's production.

8.5.2.4 'Octopus' (Fig. 8.22)

- *Distribution*: Weishan Yi and Hui Autonomous County, Yunnan Province.
- *Elevation*: 1200–1500 m.
- *Botanical characteristics*: trees medium size; shoots green; young flushes and flowers purplish-red; leaves large and deep-green; fruits medium to large, 0.5–1.2 kg, with thinner and longer fingers than are typical in other forms of citron, with distinct carpels all the way from the stem end, giving it a shape reminiscent of an octopus; rind yellow. Relatively sensitive to cold.
- *Uses*: traditional Chinese medicine; processed (candied rind); religious and decorative purposes.
- *Note*: occasionally fruit on trees of other fingered genotypes might also have the open multifingered look of 'Octopus', but only on 'Octopus' do the great majority of the fruits have this distinctive shape.

8.5.2.5 'Qingpi' ('Jinhua Qingpi', 'Baiyixiushi') (Fig. 8.23)

- *Distribution*: Jinhua and Lanxi districts of Zhejiang Province, and Jiangxi Province.
- *Elevation*: 50–800 m.
- *Botanical characteristics*: tree medium in stature with compact canopy. Trunk surface light-grayish green, young flushes light green, leaves small; flower buds

Fig. 8.22 Typical specimens of 'Octopus' fingered citron grown near Weishan, Yunnan (*Photo credit* David Karp; 12 Oct. 2011)

Fig. 8.23 'Qingpi' fingered citron plants in bonsai cultivation in Jinhua, Zhejiang (*Photo credit* Xulan Hu; 31 Oct. 2013)

and petals white; fruits medium to large with mostly open fingers. Fingers thin and long, golden, with a slightly wrinkled surface. Produces 10–15 fruit per plant, average fruit weight 0.5 kg, 11,250–22,500 kg ha^{-1} annually; potted bonsai plants produce 4–6 fruits each; average fruit weight 0.2–0.3 kg.

- *Uses*: suited both for ornamental bonsai pot culture, and for production of fruit (Chen and Shentu 2003). Chinese traditional medicine; also for citron wine, tea, fresh fruit, and essential oil.
- *Note*: 'Qingpi' is (with 'Aihua', q.v.) one of the two main cultivars of the 'Jin' family of fingered citrons grown in the Jinhua area of Zhejiang. The name refers to the greenish color of the trunk, in Chinese. It is also called also called 'Qingyi-tongzi,' meaning "white flower/green flush fingered citron." Some observers consider 'Baiyixiushi' to be a cultivar distinct from 'Qingpi,' with a white skinned tree trunk; other authorities say that the two putative varieties are the same (Dr. Wei-Dong Guo, personal communication, 2015). Yang et al. (2012) found that 'Qingpi' is less cold-tolerant than 'Aihua.' 'Qingpi' is a mutation of 'Aihua.' In an analysis with 23 pairs of microsatellites, Ramadugu et al. (2015) could not distinguish between 'Qingpi' and 'Aihua,' but Ma et al. (2002) could distinguish between them using RAPD analysis.

8.5.2.6 'Yun' (Fig. 8.24)

- *Distribution*: Pu'er, Yuxi, Dali, and Baoshan districts, Yunnan Province.
- *Elevation*: 1000–1800 m.
- *Botanical characteristics*: tree relatively tall; shoots green, young flushes and flowers purplish-red; leaves large and deep-green; fruit large, 1.5–3 kg, with numerous thick, short, stubby fingers and open shape; rind yellow. Sensitive to cold.
- *Uses*: mainly for the production of dried chips, for traditional Chinese medicine. Also used to make juice, candy, preserves, tea, and essential oil, etc.; for religious and decorative purposes.
- *Note*: Sang (2011) found that 'Yun' had the highest concentration of starch and lowest concentration of amino acids among 20 citron genotypes. The vitamin C concentration in the mesocarp and total antioxidant capacity in the exocarp of 'Yun' were significantly higher than in other fingered citrons.

8.5.2.7 'Zhaocai' ('Red Prince,' 'Chijinwangzi,' 'Red Flower') (Fig. 8.25)

- *Distribution*: Jinhua and Lanxi districts of Zhejiang Province.
- *Elevation*: 50–800 m.
- *Botanical characteristics*: young leaves, young fruit and flowers purple; fruit attractive, aromatic, golden yellow when ripe; produces 10–15 fruit per plant annually; average fruit weight 0.5 kg; fruit production is 11,250–22,500 kg ha^{-1}.

Fig. 8.24 'Yun' fingered citrons sold at a produce stand at the airport in Kunming, Yunnan (*Photo credit* David Karp; 6 Nov. 2008)

Fig. 8.25 'Zhaocai' fingered citron, Jinhua, Zhejiang (*Photo credit* Xulan Hu; 31 Oct. 2013)

- *Uses*: Mainly grown for producing fruit, but also for ornamental pot culture (Chen and Shentu 2003). Chinese traditional medicine; also used for citron wine, tea, fresh fruit, and essential oil.
- *Note*: Considered to be a distinct cultivar by some growers in Jinhua, but a leading authority there, Dr Wei-Dong Guo, considers it to be “similar to Guang *foshou* from Guangdong” (personal communication, October 2015).

8.5.3 Types Intermediate Between Common and Fingered Citron

The occurrence of forms that are intermediate between the common and fingered types is emblematic of the role of western China as a center of diversity for citron. It is unclear whether they originated as a mutation from common citron, or as a hybrid of common and fingered types (presumably with the common citron being the maternal parent, since fingered citrons rarely produce seeds). The most distinctive and fully documented of these intermediate types is ‘Muli,’ first described by Yang (1980), in which a relatively conventional round to flat fruit encloses finger-like projections that sometimes protrude from a navel-like stylar orifice.

More common, if less spectacular, are several local genotypes sometimes called “*xiang yuan fo-shou*” = “citron/Buddha’s Hand.” One such type, found in Chuanjie, Lufeng County, Yunnan (west of Kunming), has a smooth, round, bulbous stem end, and fingers developed along the rest of the fruit. Local growers clearly view it as a type intermediate between common and fingered citron, but it is not clear, without further research, that the shape is genetically based, and consistent or unusual enough to merit designation as a cultivar.

In contrast, the appearance of the fruit that we have named ‘Half and Half’ is so remarkable—the bottom half of the fruit looks like a smooth-skinned common citron, while the top half resembles a fingered citron—that it seems worthy of describing and illustrating here, despite the lack of definitive information about it.

8.5.3.1 ‘Half and Half’ (“*Xiang Yuan Foshou*” = “Citron/Buddha’s Hand”) (Fig. 8.26)

- *Distribution*: Jinghong, southern Yunnan.
- *Elevation*: 550 m.
- *Botanical characteristics*: fruit small to medium in size, 0.5–1 kg; typically round at the bottom, with a smooth rind, and little or no indication of the development of fingers, which typically starts more than halfway toward the stylar end of the fruit. In some specimens the fingers are thick and stubby, and closed in like a fist; in others, the fingers are irregular, from thin to thick, and curve outward. The interior of the fruit resembles that of fingered citrons, with no locules, seeds, or juice vesicles, just albedo straight through, aside from a narrow axial central

Fig. 8.26 'Half and Half' fingered citron at a market in Jinghong, Yunnan (*Photo credit* David Karp; 17 Oct. 2011)

cavity; the albedo is dense, moist and sweet, as in many common citrons in which the albedo is the primary part consumed.

- *Uses*: for traditional Chinese medicine; consumption as fresh fruit; religious and decorative purposes.
- *Note*: this description is based solely on observation of fruits for sale at a market in Jinghong on October 17, 2011, so it is not certain that these fruits derive from a genetically stable trait, that there was more than one tree of this type, and if so that this genotype is extant. Despite these limitations, the fruit seems of great intrinsic interest, because its morphology is so different from that of any other genotype, and seems truly intermediate between the fingered and non-fingered classes of citron.

8.5.3.2 'Muli' (*Citrus medica* L. var. *muliensis* W. D. et Y.; 木里香橼, "*xiangyangguo*," 香阳果) (Figs. 8.27 and 8.28)

- *Distribution*: Southern Sichuan Province and northern Yunnan Province, particularly the area in and around Muli Tibetan Autonomous County (Sichuan).
- *Elevation*: 1600–2200 m, mostly along rivers such as the Yalong, Muli, and Shuiluo.
- *Botanical characteristics*: small evergreen shrub or tree, height 2–3 m; leaves oval, elongated oval, or upside-down egg shape, with leaf tip rounded, leaf edge scalloped; leaves 6.8 × 4.8 cm; petioles wingless, 0.2–0.3 cm long. New shoots

Fig. 8.27 'Muli' citron in Baidiao, east of Muli, Sichuan (*Photo credit* David Karp; 10 Nov. 2008)

Fig. 8.28 Characteristic form of 'Muli' citron, Muli, Sichuan (*Photo credit* Sie-Jie Yang; 1980)

green and slightly triangular-shaped, becoming rounder and solider when mature; thorns medium in length. Short racemes with 2–13 florets. The top flower is larger and normally bears fruit. Flower buds light lavender, 1.3 × 0.8–1.1 cm; flowers 3.6 cm in diameter, with five petals; stamens 55–60. Segments 5–6 (Yang 1980; Wang et al. 1983).

- Fruit intermediate in morphology between common and fingered citron: the external carpel wall is whole and undivided, but the internal carpel is divided into several finger-like sections. Weight 1360–2378 g; dimensions 8.5–12.5 ×

13.5 × 18 cm; strong citron fragrance. In the same plant, fruits may be found in various shapes, such as flattened spheres, palms with three cracks, and lotus throne shapes. The outside carpels develop into the outer peel, and inner carpel group then develops into the finger-shaped parts. In some fruits, finger-shaped parts protrude through the stylar orifice and spread out from the fruit (Fig. 8.27). Pulp scanty, juice vesicles white and sour. Seed coats yellow white; inner part of the seed is purple red, with deep purple speckles. Cotyledons milky white and monoembryonic (Yang 1980; Wang et al. 1983). 'Muli' was traditionally regarded as a citron, and molecular analysis shows its similarity with citron, but also that its chloroplast gene might have come from pummelo, so it is likely that it is a hybrid (Yang et al. 2015).

- *Uses*: consumed as fresh fruit or preserves, as a preserved ingredient in a type of wine, and in herbal medicine. It can be used as a dwarfing stock (Yang 1980; Wang et al. 1983; Wen et al. 1986; Gmitter and Hu 1990).
- *Note*: called "Muli" or "*xiangyanggo*" (meaning, "fragrant sun fruit") by the local people. Muli Tibetan Autonomous County is a remote area of southern Sichuan, where Tibetan and Yi people are the largest ethnicities. The American naturalist Joseph F. Rock, one of the first Westerners to visit Muli, wrote about his celebrated journey in "The Land of the Yellow Lama" (Rock 1925); Muli served as the inspiration for Shangri-La in James Hilton's novel *Lost Horizons*.

8.5.4 "Wild" Citrons

Putatively "wild" citron producing small fruits grow in wild forests, in semi-wild margins between wild and cultivated areas (on the borders between forest and field, or in inhabited forest areas), and in private gardens in the subtropical forests of western and southern Yunnan. They do not seem to be cultivated on a commercial scale, at least in China. Whether these forms are truly wild, in that trees of this type existed in the area before local cultivation of citron, it is difficult, or perhaps impossible, to judge. As Bonavia noted in 1888:

> When a botanist says he found a certain plant wild in a certain place, he probably does not mean that it has been there from the beginning of time, or even from the very commencement of the citrus family on this earth. … We can rarely know to what extent man and other animals may have aided in carrying seeds of plants from place to place. … in most cases, it is next to impossible to decide, whenever a citrus is found wild anywhere, whether it was there, or in the vicinity, from the beginning of its family history, or whether it became naturalized there through the aid of birds, &c (Bonavia 1888).

From their botanical characteristics these wild-type trees appear to be pure *C. medica*, with typical growing habit and leaves, and local inhabitants refer to them simply as "*xiang yuan*" citron. However, most of the trees currently accessible (type 1—see below) produce fruits with thinner skin and juicier flesh than is typical of pure citron, and in a recent study (Ramadugu et al. 2015) these forms appeared in a cluster with known citron hybrids.

Another form which is rare and poorly documented, has thick albedo and locules devoid of juice vesicles, and thus appears to be pure *C. medica*, but the authors have not yet been able to find specimens for genetic testing to confirm this hypothesis. The habitat for "wild" citrons in western Yunnan is quickly disappearing as forests are cleared. The preservation and study of such forms, assuming that they remain extant, is critical.

8.5.4.1 Wild Citron, Type 1 (with thin rind, segments and juice vesicles) (Figs. 8.29 and 8.30)

- *Distribution*: Subtropical forests of western and southern Yunnan Province, including Dehong, Baoshan, Lincang, and Pu'er prefectures, particularly in the Mangshi and Ruili districts of Dehong Prefecture. Also in northern Myanmar.
- *Elevation*: 900–1800 m.
- *Botanical characteristics*: trees medium size, growing under the lower forest canopy. Young leaves light green, leaf blades elliptic-ovate or oblong with tip blunt, petioles wingless, margin entire or shallowly serrated; young twigs angular or rounded, shoots with medium thorns. Flowers white, fruits small with a size of 12–18 × 7–10 cm and a spindle-like shape with a sharp tip; rind may be rough, light to deep yellow/brown; albedo relatively thin for a citron, closer to the thickness typical for lemon (*C. limon*), albedo flavor sour; segments 9–13, juice vesicles sour and bitter, seeds numerous and monoembryonic.
- *Uses*: peel oil extract is used in perfumery; traditional Chinese medicine.
- *Note*: the fruits are small, fitting easily in the palm; some have the shape and bumpy rind typical of *etrog*-type citrons used in Jewish ritual celebrations, and from the outside of the fruits it might seem as if southwestern China could have served as the primordial origin for such citrons. In fruit that are cut open, however,

Fig. 8.29 Wild citron, type 1 (with thin rind, segments and juice vesicles), from a wild forest in a valley in the mountains 2 km west of Hexinchang village, Mangshi township, Luxi City, Yunnan. Elevation: 1190 m (*Photo credit* Xulan Hu; 17 Sept. 2010)

Fig. 8.30 Wild citron, type 1, growing wild in Mangshi township, Yunnan. Top: view of the valley where wild citron grows as an understory plant. Bottom: trees of wild citron, type 1 (*Photo credit* Xulan Hu; 6 Sept. 2010)

it is clear that the albedo is thinner, and the pulp much juicier, than is typical for known pure *C. medica*. That still leaves open the possibility that the original wild citrons more closely resembled this type than the kind with thick albedo that is now accepted as the standard of purity.

- However, in Ramadugu et al. (2015), four wild-type specimens—three from Ruili and one from Mangshi—all clustered in a clade that also included 'India Lemon,' a known hybrid, as well as 'Suanmaliu,' a less-known but clearly hybrid sample; both of these two contained non-citron alleles. No such hybrids appeared in the other clusters, which included Chinese and Western-type citrons. More research needs to be done to verify this result, but the preliminary conclusion is that the so-called "wild citrons" of this type (thin rind) are hybrids of citron and non-citron genotypes.

8.5.4.2 Wild Citron, Type 2 (with thick albedo, no segments or juice vesicles) (Fig. 8.31)

- *Distribution*: Subtropical forests of western and southern Yunnan Province, including Dehong, Lincang, and Pu'er prefectures, particularly in Ruili County (Dehong Prefecture).
- *Elevation*: 800–1800 m.
- *Botanical characteristics*: trees medium size, growing under the lower forest canopy. Young leaves light green/yellow color, mature leaf blades elliptic-ovate or oblong with tip blunt, petioles wingless, margin entire or shallowly serrate; young twigs angular or rounded; shoots with medium thorns. Flower buds and flushes purple-tinted; fruit size 14–20 $\times$ 5–9 cm with a long spindle shape with a sharp tip; skin light to deep yellow with some rough surface; thick albedo with sour flavor, segments degenerated, locules empty except for seeds, numerous and monoembryonic.
- *Uses*: peel oil extract is used in perfumery; traditional Chinese medicine.
- *Note*: one of the authors (Xulan Hu) encountered and photographed this citron type in Dehong prefecture during the 1990s (Fig. 8.30), but despite numerous attempts we have not been able to find similar specimens growing in the wild in more recent years (2008–2016) (As noted above, the recently discovered 'Jinggu' citron may well be a form of Wild citron, Type 2 that has entered cultivation). It would be of great scientific interest if such specimens could be found and tested

Fig. 8.31 Wild citron, type 2 (with thick albedo, no segments or juice vesicles) (*Photo credit* Xulan Hu; 1997)

with modern molecular marker methods, to determine whether they are of pure *C. medica* or hybrid ancestry. We do not know of any citrus other than pure *C. medica* with thick albedo and empty locules (no juice vesicles). It could be that such a genotype represents an early form of *C. medica*, from which modern large-fruited forms evolved through selection over the centuries.

8.5.5 Citron Hybrids

Included in this category are forms that are regarded in their growing area as citrons, but for which morphological and/or genetic evidence indicates that they are actually hybrids. Compared to other citron-growing areas such as India and Italy, citron hybrids play a lesser role in cultivation than one might expect. Probably this is because the two types most important in commerce, fingered citrons (for medicinal use and bonsai) and common citrons with very thick albedo (for candying or other consumption of the albedo) are both likely to be pure *C. medica*. Given the proximity of Yunnan to northeastern India, where a wide range of hybrid citron and other citrus exists, and the rich native citrus germplasm resources in China, it is not surprising that hybrid citrons have developed there.

8.5.5.1 Goucheng (Yunnanese) (*Citrus medica* L. var. *yunnanensis* S. Q. Ding ex Huang) (枸橙) (Fig. 8.32)

- *Distribution*: mainly western Yunnan Province, including Bingchuan, Yangbi, Weishan, and Yongping counties.
- *Elevation*: 1100–1700 m.
- *Botanical characteristics*: trees small or shrub-like, height of 2–3 m; young shoots purple, hairless, and thorns longer in each node; leaves oval or obovate-elliptic with round tip and fine saw margin; fruits broad ovate with sharp tip; small, 0.3–1.2 kg; rind yellow, rough; albedo relatively thin; segments 10–12; juice vesicles present, pulp very sour; seeds numerous, monoembryonic, occasionally polyembryonic.
- *Uses*: rootstock for mandarins and sweet orange in Yunnan. Dried seed and fruit are a traditional Chinese medicine to treat certain stomach disorders. Because of its thorniness, used as a hedge for orchards and gardens.
- *Note*: “Found at Binchuan district in Yunnan … in 1976–1978. … The flowers are rather large, each with stamens cohering in two or three whorls, ovaries different from the ordinary forms, carpels of fruits appendaged, pulp-vesicles well developed. According to the traits of flowers and fruits, they give evidence of Yunnan citron as an intermediate variety evolved from Fingered citron (*C. medica* L. var. *sarcodactylis*) to citron (*C. medica* L.)” (Ding 1979).
- Clustered with citron hybrids in Ramadugu et al. (2015).

Fig. 8.32 'Goucheng' citron hybrid, Binchuan, Yunnan (*Photo credit* David Karp; 2 Nov. 2008)

- In 1980, soon after the initial publication of this putative subspecies, Professor Tsuin Shen of Peking Agriculture University sent seeds of it to the University of California, Riverside Citrus Variety Collection. The accession derived from these seeds (CRC 3798/PI 600630) produces fruits that are small to medium in size; pear-shaped; seedless; rind moderately thin to moderately thick; pulp juicy, fruity, very tart, and very fragrant.

8.5.5.2 'Yunmao Oval' (Fig. 8.33)

- *Distribution*: Mangshi and Longling counties in western Yunnan Province.
- *Elevation*: 900–1300 m.
- *Botanical characteristics*: tree vigorous, upright; young flushes light green, shoots dark green, leaves large, and flower buds pink to purple; fruits medium, typically 1–3 kg; fruit oval to top-shaped, bluntly pointed at stylar end; rind texture smooth, sometimes slightly rough; albedo thick; 12–14 locules, small; juice vesicles absent, although a few rudimentary ones can be found; seeds few, monoembryonic.
- *Uses*: rootstock for fingered citrons; fruit consumed fresh; dried chips in traditional Chinese medicine; religious and decorative purposes.
- *Notes*: named after Yunmao village in Dehong prefecture. Ramadugu et al. (2015) found that 'Yunmao Oval' clustered with hybrid citrons.

Fig. 8.33 'Yunmao Oval' citron hybrid near Mengwan village, Dehong prefecture, Yunnan (*Photo credit* David Karp; 4 Nov. 2008)

8.6 Germplasm Status; Regional and Global Perspective

Until recently, Chinese citrus scientists paid relatively little attention to citron germplasm resources, both wild and cultivated, and made few attempts to document the diversity of available forms. Wild citron germplasm resources, in particular, may have been significantly eroded by development and neglect. More attention has been paid to citron germplasm during recent years (Zhou and Guo 2005a, b; Chen and Shentu 2003; Chen et al. 2006, 2008; Liang et al. 2006a, b; Wang et al. 2007, 2010; Zhang and Xu 2007; Deng 2008; Zhang et al. 2008; Hao 2009; Sang 2011).

In 2010, the present authors established an informal Chinese Citron Germplasm Collection in Jianshui, 175 km south of Kunming, which within a few years contained approximately 20 distinct accessions. The objectives were to collect, characterize, preserve, and distribute citron germplasm. The collection is no longer in existence onsite, but the accessions were shared with Chinese citrus germplasm collections, local and national. In addition, the material was used in a wide-ranging genetic study (Ramadugu et al. 2015) which analyzed the genetic diversity of 47 citrons—32 from China and 15 of Mediterranean origin. These citrons clustered into three distinct groups:

(1) From China, wild and hybrid citrons with pulp and seeds. Three of these, 'Suanmaliu,' 'India Lemon,' and CRC 3819 appear to be hybrids involving citron and non-citron ancestors. It seems likely that most or all of this group are of hybrid ancestry, but more work will need to be done to confirm this.

(2) From China, both common and fingered citrons. These appear to be "pure" *C. medica*. The common citrons have thick albedos; some have juice vesicles, others do not.

(3) From the Mediterranean and Western areas, common citrons, "pure" *C. medica*, both with juice vesicles and without. This cluster includes a representative selection of citrons used for Jewish ritual ('Assads,' 'Braverman,' 'Halperin,' 'Kivelevitz,' 'Temoni,' and an unspecified '*Etrog*' which clusters with 'Kivelevitz'). There are also typical Mediterranean cultivars, 'Diamante,' 'Italian,' 'Corsican,' and 'Citron of Commerce,' but no Chinese cultivars.

The *C. medica* group appeared to be monophyletic in this study, which also indicated that some citrons have a higher level of heterozygosity than previously estimated.

It is notable that Ramadugu et al. (2015) found that pure *C. medica* specimens cluster into two separate groups depending on their geographical origin, from China and from the Mediterranean area. Phenotypically there are no characteristics of tree or fruit that would serve to distinguish the groups, but a distinction is evident genetically. Assuming that citron originated in northeastern India, southwestern China or adjacent regions, it may be that the citrons from the Mediterranean and Western areas derive from ancestors of Indian origin, which may differ genetically from the citrons now growing in China. Indian scientists have started to survey the citron germplasm of northeastern India and adjacent regions (Ray and Deka 1999; Kumar et al. 2014; Barbhuiya et al. 2016). A study of how Indian citrons relate genetically to populations in China and the Mediterranean area would do much to define the spread of pure and hybrid citrons across the globe.

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Chapter 9
The Citron in Italy and Its Cultivation in Calabria

Alberto Continella

Abstract Citron has an ancient presence in Italy. Its current cultivation is mainly located in a region of southern Italy, Calabria. The chapter describes the history of the cultivation of citron in this region, the main production techniques that characterize its cultivation, and describes the most important cultivars, among all the 'Liscia di Diamante', whose special chemical and nutraceutical properties are outlined. Finally, the troubled history of producer cooperatives for the citron in Italy is summarized.

9.1 Origin and History

Citron was known in ancient times as *medica malus*, *malum felix* or simply *citrus*, the name later used by Linnaeus to describe the entire citrus genus. The name citron derives from the popularization of the Latin word *citrus* and, like all citrus fruits, citron belongs to the Rutaceae family.

It is ascertained that from 200 BC citron was firmly established in Greece and had also begun to spread westward towards southern Italy. The ancient writer, Rutilio Palladio, considers citron among the first citrus fruits brought to Italy, and his opinion is confirmed by the murals discovered in Pompei and by the discovery, in the meeting place of the Jewish community there, the "House of the Jews", of vases with flowers that contained the remains of roots of citrus trees. By the year 79 AD, therefore, citron was widespread in the Naples area (Monaco 2019).

Currently, the citron is cultivated in the Mediterranean basin (Israel, Italy and Morocco), China, India (where in certain areas it also grows naturally), Indonesia, Australia, United States and Brazil. In Italy it is present mainly in Calabria, a region located in Southern Italy, along the coastal strip of the upper Tyrrhenian coast, the so-called "Riviera del cedro" (Citron Riviera) which extends for about 80 km going from the coastal area up to an altitude not exceeding 300 m a.s.l. (Gullo 2012).

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9.2 The Citron in Calabria

It is certain that the citron has been regularly cultivated on the Tyrrhenian area of Cosenza province since 700 AD, specifically in the coastal strip between the towns of Tortora and Capo Bonifati (Fig. 9.1). As reported by Prof. Elio Toaff, chief Rabbi of the Jewish Community of Rome from 1951 to 2001, Calabria is a mandatory reference for the cultivation of citron, so that

> the market for citron grown in Calabria has never failed from Talmudic times to today. From the last century until the Second World War, the major citron merchants from Poland, Hungary, Romania, Czechoslovakia and Russia met in Trieste (the chief town of Friuli Venezia Giulia, a north east Italian region) every year in August. They went to Calabria to buy the citron at harvest and then returned to Trieste, where they agreed on selling prices to the various Jewish communities of Europe. The sad events of the Nazi persecution and the consequent destruction of the largest Jewish communities in Europe put an end to this kind of citron fair which then moved from Trieste to Israel (Fersini et al. 1973).

In this region, a single variety is mostly grown, the cultivar 'Liscia di Diamante' (Fig. 9.2). The origin of this genotype is not known but, as it is not present anywhere else in the world, it is presumably a variety of local origin, a native cultivar of the Diamante district.

From the second half of the eighteenth century, the district began to specialize in the cultivation of citron. The largest production is concentrated in Santa Maria del Cedro (60%), while 20% is distributed on a neighboring hilly area. First the rough peel (curly) variety, known as 'Cedro riccio' or 'Cedressa' was prevalent, and then the smooth variety, 'Liscia di Diamante', spread. Both varieties were present in the early twentieth century when, at that time, both were grown (Ferrari 1910). He further states that the

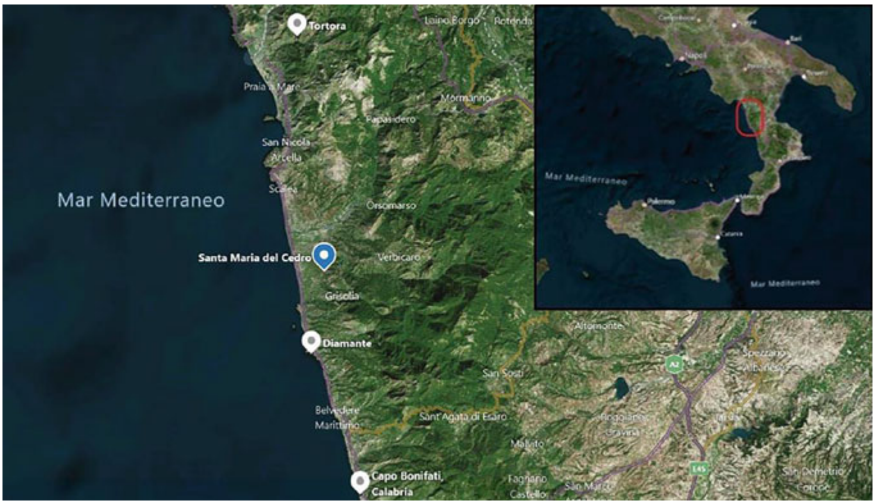

Fig. 9.1 Citron Riviera in the Calabria region

Fig. 9.2 Fruits of 'Liscia di Diamante'

> curly variety was the first to be grown in the Paola district and that it's "an old variety, destined to disappear also because the fruit, once highly appreciated in the candying industry, is no longer required and is considered as waste". He also says that "the smooth variety, which certainly came later, possesses more refined characters" (Ferrari 1910).

Historically, from North to South, *Etrog* citron was cultivated in the municipalities of Tortora, Praia a Mare, Scalea, Santa Domenica Talao, Orsomarso, Verbicaro, Grisolia, Maierà, Santa Maria del Cedro, Diamante, Buonvicino, Belvedere Marittimo, Sangineto and Bonifati. In the coastal area where the best fruits were produced, the plants had greatly refined characteristics: small canopies, a short trunk, thin and shiny bark, and delicate and aromatic fruit. Today, however, the areas of all of these crops have been reduced, especially those in the littoral riviera. Since the 1970s, within a very short time, villages and tourist residences have been built in places where there were previously many citron orchards.

Specialized crops were originally grown as the candying industry became established in Italy and abroad. At the beginning of these developments on the Tyrrhenian coast, from Tortora to Cetraro,

> the citrons were planted without any regulating principle, often disordered and so dense as to hinder the regular circulation of light. Any land was destined for them, as long as it was exposed to the South.

At the beginning of the twentieth century the candying industry in Italy, France and England underwent exceptional development. The demand for citron grew dramatically and, consequently, the cultivation on the Riviera became better organized, the growers more specialized and the production increased overall. At the same time, the initiatives of local traders began to grow, acting as intermediaries between producers and processing industries which were all located outside the region and abroad (Ferrari 1910).

After centuries of expansion and high demand, in which the cultivated area for citron exceeded 400 ha, from the end of the Second World War onwards there has been a period of gradual decline in the cultivation of citron in Calabria. The reasons for this decline are essentially to be found in the strong competition exercised by other producing countries with regard to the product destined for the processing industry, in the instability of prices, in cultivation methods that are now obsolete and scarcely sustainable in economic terms, as well as in the lack of an adequate policies for product promotion and marketing.

Currently, the citron in Calabria occupies a cultivated area of only 65 ha and the average annual production is around 1,150 tons (ISTAT 2021). Except for a few larger companies, most citron farms are characterized by having orchards of less than 1 ha. Unit production is around 20–25 tonnes ha^{-1}.

Previously, the Calabrian citron was exported to European markets, but these ceased to exist and only the Italian market has remained. Today, most of the production is absorbed by local markets. A small but profitable export is focused on meeting the demands of the annual Sukkot festival. However, that particular production mainly concerns the municipality of Santa Maria del Cedro (Fig. 9.3) (Monaco 2019).

Fig. 9.3 The castle of S. Michele in Santa Maria del Cedro and the cultivation of citron under nets

9.3 The Jewish Tradition

The Jewish tradition specifies the qualities and characteristics that citrons must have in order to be used during the *Feast of Booths*. The fruit must come from an ungrafted plant. The trees must be perfectly healthy and without cracking on the bark. To have greater value, the fruits must have a persistent style, the upper part of the pistil which is called “*pitam*” (Fig. 9.4). In Calabria on the “Citron Riviera” the growers cultivate whole citron groves expressly reserved for the Feast of Booths (also known as the *Feast of Tabernacles* or by its Hebrew name, *Sukkot*). All the citrons cultivated for the Jewish Sukkot are guaranteed by farmers for the “purity of the fruit.” The citrons requested by the Rabbis must be without imperfections but, above all, trees must come from ungrafted plants (Fig. 9.5); consequently, plants are propagated by cuttings. In contrast, in most of the other Calabrian citron orchards, the trees are propagated by grafting on sour orange, a very common technique that ensures greater tolerance to diseases. In the dedicated citron fields, the Rabbi carefully examines the skin, color and shape of the fruit (Fig. 9.6). If the required quality standards are met, the small fruit that does not exceed 200 g, is wrapped in a special towel and placed in a box. The price for each fruit varies from year to year. It is always a significant price and is usually very rewarding, even for a farmer who has only a small sized farm. The product destined for Sukkot represents less than 10% of the annual production of all citron fruit (Monaco 2019).

Fig. 9.4 Fruits with a persistent style, called the *pitam*

Fig. 9.5 Ungrafted trees of citron, considered "pure" by Jewish tradition

Fig. 9.6 Etrog citron fruit with highly attractive peel characteristics

9.4 Citron Cultivars

Following the classification proposed by Swingle, the citron belongs to the Aurantioideae family, Citreae tribe, Citrineae sub-tribe, *Citrus* genus, *Eucitrus* subgenus, *Citrus medica* species (Hodgson 1967).

The citron (*Citrus medica* L.), together with the mandarin and the pummelo, is considered to be one of the ancestral species of citrus fruits (Barrett and Rhodes 1976), or one of the species from which, through intra and interspecific crossings, other species and hybrids have originated over the centuries. There are numerous citrus species of which the citron is the progenitor. Various evidence indicates that the citron contributed primarily as the pollen donor in the origin of these crosses (Luro et al. 2012; Goldschmidt 2017).

The very ancient cultural traditions of the species, together with the remarkable diversity of the cultivation environments favored, over the centuries, the birth of a rich germplasm which had highly diversified phenological and morphological characteristics. However, when the diversity and phylogeny among citron types was investigated using RAPD, SCAR and cpDNA analysis (Nicolosi et al. 2000), the results from this genetic analysis are unequivocal and do not leave much room for interpretation. In spite of diverse geographical origin and the notable morphological variation in fruit size and shape, and the presence of pulp and persistence of the style, all of the citron types examined revealed a high degree of similarity. Focusing on the polymorphisms obtained, highest levels of similarity were found for those genotypes sharing the same geographical origin (Nicolosi et al. 2005).

Conventionally, citron cultivars are classified into three groups: acidic, sweet and pulpless citrons. Acidic citrons are characterized by the apical part of the buds being a pink color, the flower buds being purple, the pulp being acidic and the inner part of the seed integument being dark. Sweet citrons, in contrast, have shoots without pink pigmentation, yellowish white flower buds, sweet pulp and the inner part of the seed integument is colorless. Citrons without pulp completely lack pulp and consist only of flavedo and albedo.

The leaves are rich in oil glands, glabrous, oval-oblong with a toothed margin, a prominent main rib and a leathery consistency; the color initially is reddish, while fully expanded the leaf becomes glossy and intense green on the upper side, light green in the lower side. The petiole is short and not winged. The flower is large, fragrant, carried by a racemous inflorescence of a purplish color in bud. It has a gamosepalus calyx with five lobes, a corolla with five white petals, basically fleshy, and a variable number of filamentous stamens (3–30), a fairly elementary pistil with a lobed style and stigma. The flowers can be ascribed to two types: complete ones and unisexual ones, due to abortion of the gynoecium. Complete flowers are usually positioned at the ends of branches, while the unisexual ones develop along the axis of the branch. Unisexual flowers usually abscise. Citron flowers in two or three waves or phases, with major blooming taking place in spring and in mid-summer. The fruits are of various shapes, oblong with an obtuse apex, pronounced mamelon and a persistent style. The skin, smooth or lumpy, is rich in glands that produce a particularly fragrant oil. The pulp is low in juice (Gullo 2012).

9.4.1 Acid Citrons

9.4.1.1 'Liscia di Diamante' or 'Italiana' or 'Calabrese'

This cultivar was selected in Calabria in the second half of the eighteenth century. The fruit, of oval-ellipsoidal lobed shape, is large when reaching maturity; it has a wrinkled peduncle cavity, surrounded by a low collar. The apex is mammellonar. The fruit has a thin, smooth, sometimes lobed and ribbed skin which, when ripe, reaches a lemon-yellow color. It has an intense aroma, fleshy pith, crunchy endocarp, little juice with an acid flavor. It replaced the homonymous cultivar 'Calabrese' (also known as 'Vozza Vozza' or 'Rugosa' for its particular irregular to lumpy shape). It is the most widespread cultivar in Italy and, as well as for religious uses, it is highly appreciated by the processing industries (Continella and Tribulato 1992).

9.4.1.2 'Riccia' or 'Bitorzoluta' or 'Rugosa'

The fruit has a thick, wrinkled, lumpy skin, with the presence of grooves that correspond with the peduncular cavity. The color is lemon-yellow. Sub-spherical in shape, the fruit is smaller in size than that of 'Liscia di Diamante'.

Other cultivars of acidic citrons, which are present in the field collection at some Italian research centers (University of Catania, CREA-OFA), are briefly described below.

9.4.1.3 'Policarpa'

This is a popular cultivar in Greece. The fruit is medium in size, sub-spherical in shape, globose, with a rounded, asymmetrical apex. The peel, citrine yellow in color, is thick and strongly furrowed in correspondence with the peduncle cavity. The pulp is not very juicy and is acidic.

9.4.1.4 'Limoniforme'

This is the most important citron cultivar grown in Greece. It is similar to the 'Liscia di Diamante', from which it differs due to the deep longitudinal ribs and the presence of lumps on the epicarp.

9.4.1.5 'Etrog'

This is the main variety of citron cultivated in Israel. It is characterized by producing fruits of medium-small size, with an ellipsoidal or fusiform shape, with a poorly developed neck and a persistent style. The peel is slightly wrinkled and irregular, the albedo is thick and fleshy while the pulp is crunchy, firm, with little juice and is acid. The fruits of this cultivar are those most used in the ritual of the Feast of Tabernacles.

9.4.2 Sweet Citrons

9.4.2.1 'Corsicana or Corsa'

This is widely cultivated in Corsica where it is used for the production of jams, sweets and soft drinks. In addition to production on this island, the cultivar is also cultivated currently in other areas of France (Provence), in southern Spain, in the islands of Puerto Rico and in the United States (Florida and California). The fruit is large, ellipsoidal or slightly obovate in shape, with a wrinkled and slightly ribbed skin and a thick and fleshy albedo. The pulp is crunchy, not particularly juicy and sweet.

9.4.3 Semi-acid Citrons

9.4.3.1 'Earle' Citron and 'Digitate' or 'Buddha's Hand'

The 'Earle' citron was identified in California and subsequently cultivated in Puerto Rico and Cuba. It is of little importance in Florida and California. Of medium size, it is characterized by a radial depression in the center and by the presence of a mammellonar apex. The skin is smooth, slightly lobed and ribbed. The pulp is scarce and slightly acidic.

The 'Digitate' citron or 'Buddha's Hand', has been cultivated since ancient times in Indochina, China and Japan, for religious use or for ornamental purposes. It has a large fruit, with an almost smooth skin, of a lemon-yellow color. Characteristic is the longitudinal subdivision of the fruit into numerous sections which, due to their fusiform shape, recall the fingers of a hand.

9.4.4 Citron Lemons

Citron lemons are hybrids between lemon and citron. The fruits are similar to citron in size and thickness of the mesocarp, while the pulp resembles that of lemon. The

Fig. 9.7 'Spadafora' citron lemon is largely consumed in Sicilian and Calabrian traditional food

plant is also closer to lemon than to citron, being more resistant to low temperatures. Citron lemons are used as a substitute for citron in the preparation of candied fruit. Among the citron lemons, the most popular cultivars are 'Spadafora', also known as 'Pirittuni', and the 'Piretto', with smaller fruits.

9.4.4.1 'Spadafora'

Fruit is very large, symmetrical and elliptical in shape, of a deep yellow color; the surface is papillate, ribs are absent with a very thick skin (Fig. 9.7). It presents scattered oil glands with a low yield of essential oils; the aroma is weak, and it has a yellow flesh with fine texture, very high acidity, and a sour taste; seeds are completely absent. The plant has a medium vigor, and the canopy has a semi-compact density, while thorns are absent. The grafting affinity with sour orange is mediocre.

9.4.4.2 'Piretto'

It has a yellow fruit with a smooth surface, ribs are absent; fruit size is medium, with a symmetrical shape, from obovoid to elliptical. The peel is very thick with dense oil glands and a regular yield of essential oils; the aroma is weak, the flesh has a fine texture, very high acidity, and a sour taste. The seeds are present and are small and few. The plant has strong vigor, a rounded compact canopy while thorns, even if short, are present; leaves are thin and the pollen almost absent. The grafting affinity with sour orange is mediocre.

9.5 Chemical and Nutraceutical Characterization of 'Liscia di Diamante' Fruit

9.5.1 Chemical Constituents

In ancient times and in the Middle Ages, *C. medica* was considered as a remedy for seasickness, pulmonary troubles, intestinal ailments and other disorders. In India, the fruit peels are currently a remedy for dysentery and are eaten to overcome halitosis. The candied peel is sold in China as a stomachic, stimulant, expectorant and tonic (Meena et al. 2011; and see also Chap. 8 "The Citron (*Citrus medica* L.) in China" in this volume). In West Tropical Africa, *C. medica* is used as a medicine, particularly against rheumatism (Arias and Ramon-Laca 2005). The health benefits of citrus fruit have mainly been attributed to the presence of phenolic compounds, such as flavonoids.

Some research studies have analysed the main phytochemical constituents of *C. medica* 'Liscia di Diamante', including the content of naringenin, naringin, hesperetin, hesperidin, rutin, nobiletin, tangeretin, quercetin, diosmin, and apigenin (Menichini et al. 2011a). Apigenin was identified in all extracts, except for those from the mesocarp of mature fruits. The floral extract was characterized as having the highest content of different flavonoids (Table 9.1). Besides apigenin, quercetin and diosmin were found in significant quantities. Naringin was identified only in the mesocarp of immature fruits while hesperidin was identified in immature fruit extracts. Hesperidin and hesperetin were abundant in the floral extracts. Rutin was abundant in the endocarp extract from immature fruits, followed by leaves and floral extracts.

A total of forty-three components were identified in the essential oil obtained from the fruit peels by hydrodistillation (Table 9.2), representing 95.3% of the total oil (Menichini et al. 2010). Thirty-six constituents were identified in the essential oil obtained by cold pressing, representing 93.4% of the total oil. Extracts using both methods exhibited high amounts of limonene (35.4–44.5%), and γ-terpinene (24.5–26.2%). Other abundant constituents were geranial, α-pinene, and β-pinene. The high content of limonene and γ-terpinene is a characteristic of this citrus cultivar. The essential oil obtained by hydrodistillation possesses a high content of terpinen-4-ol, α-terpinene, and α-terpineol in comparison with the essential oil obtained by cold pressing (Tundis et al. 2014).

Table 9.1 List of main flavonoids extracted from different organs of *Citrus medica* 'Liscia di Diamante' identified by HPLC (modified from Menichini et al. 2011a)

	Naringin	Hesperidin	Hesperetin	Rutin	Quercetin	Diosmin	Apigenin
Organs							
Flowers	NI	IDENT	IDENT	IDENT	IDENT	IDENT	IDENT
Leaves	NI	NI	NI	IDENT	IDENT	NI	IDENT
Immature fruits							
Mesocarp	IDENT	IDENT	NI	NI	IDENT	NI	IDENT
Endocarp	NI	IDENT	NI	IDENT	NI	MI	IDENT
Mature fruits							
Mesocarp	NI	NI	NI	NI	NI	IDENT	NI
Endocarp	NI	IDENT	NI	NI	NI	NI	IDENT

NI: Not Identified; IDENT: Identified

Table 9.2 List of the main flavonoids and terpenoids identified in *Citrus medica* 'Liscia di Diamante' (modified from Menichini et al. 2010, 2011a)

Flavonoids	Terpenoids	
Apigenin	(E)-β-Ocimene	Terpinolene
Diosmin	2,3-Dihydrobenzofuran	Tetradecanal
Hesperetin	Camphene	Thujene
Hesperidin	*cis*-Sabinene hydrate	*trans*-β-Farnesene
Naringin	Citronellal	α-Bergamotene
Quercetin	Citronellyl acetate	α-Humulene
Rutin	Citropten	α-Phellandrene
	ɗ-Cadinene	α-Pinene
	Docosane	α-Terpinene
	Eicosane	α-Terpineol
	Geranial	β-Bisabolol
	Geraniol	β-Santalene
	Geranyl acetate	β-Bisabolene
	Limonene	β-Caryophyllene
	Linalool	β-Cubebene
	n-Decanal	β-Elemene
	Neral	β-Myrcene
	Nerol	β-Pinene
	Neryl acetate	γ-Cadinene
	n-Nonanal	γ-Terpinene
	p-Cimene	
	Perilla aldehyde	
	Sabinene	
	Terpinen-4-ol	

9.5.2 Antioxidant Properties

Several studies have identified the potential antioxidant effects of *C. medica* 'Liscia di Diamante'. The best free radical 1,1-diphenyl-2-picrylhydrazyl (DPPH) scavenging activity was shown in the extract obtained from the mesocarp of immature fruits followed by those from flowers and leaves. These extracts showed antioxidant activity in a β-carotene bleaching test (Menichini et al. 2011a).

The *n*-hexane extract from the *C. medica* 'Liscia di Diamante' peel demonstrated antiradical scavenging (Conforti et al. 2007). A higher level of antioxidant activity in the β-carotene-linoleic acid test system was observed. The antioxidant activity may be related to the presence of monoterpenes, such as γ-terpinene, limonene, nerol, geraniol and α-terpineol that were the most abundant compounds identified in the extract (Ruberto and Baratta 2000; Grassmann et al. 2001).

Citrus medica 'Liscia di Diamante' has also demonstrated anticholinesterase inhibitory activity. Moreover, in in vitro and in vivo studies, citron showed interesting anti-hyperglycaemic effects. In particular, *C. medica* 'Liscia di Diamante' peel extract was shown to confer protection against induced hyperglycemia, at least in part by direct stimulation of β-cells to secrete insulin. In addition, the capacity of the extract to reduce glucose, triglycerides and plasma cholesterol levels may contribute to its beneficial effects in vivo.

9.5.3 Potential Health Effects

9.5.3.1 Inhibitory Activity Against α-Amylase

Diabetes mellitus is a condition in which homeostasis of carbohydrate and lipid metabolism is improperly regulated by the pancreatic hormone insulin resulting in an increased blood glucose level (Wild et al. 2004). One of the therapeutic approaches for reducing post-prandial hyperglycemia in patients with type 2 diabetes is to prevent absorption of carbohydrates after food intake (Tundis et al. 2012).

The α-amylase and α-glucosidase inhibitory activity of *C. medica* 'Liscia di Diamante' flowers, leaves and fruits (endocarp and mesocarp) at two maturity stages was investigated by Menichini et al. (2011a) and the leaf extract demonstrated an inhibitory activity against α-amylase.

In an earlier study, *C. medica* 'Liscia di Diamante' peel extracted with *n*-hexane inhibited α-amylase (Conforti et al. 2007). This activity was related to the content of terpenoids considering that the lipophilicity of these phytochemicals may facilitate access to the enzymatic site (Ali et al. 2006). The hydroalcoholic extract of *C. medica* 'Liscia di Diamante' peel was shown to inhibit both α-amylase and α-glucosidase. This extract was characterized by high phenolic content as previously reported, and by the presence of apigenin, quercetin and hesperetin as the main flavonoids (Menichini et al. 2011b).

The effects of *C. medica* 'Liscia di Diamante' on insulin secretion were also assessed in vitro using the mouse insulinoma MIN6 β-cell line. Cell viability was assessed and, at concentrations ranging from 1 to 24 mg mL^{-1}, the extract exerted direct stimulatory effects on the exocytotic release of insulin from monolayers of MIN6 cells, initiating a concentration-dependent stimulation of insulin secretion at both 2 and 20 mM glucose (Menichini et al. 2011b).

9.5.3.2 Anticholinesterase Properties

Alzheimer's disease (AD) is a degenerative neurological disease that is clinically characterized by progressive cognitive dysfunction that interferes with social and occupational functioning (Jacobsen et al. 2005). Increased levels of cholinesterase enzymes found in post-mortem brain samples of AD patients have led to the hypothesis that the cognitive decline in AD patients is related to progressive cholinergic degeneration (Loizzo et al. 2008). Promising approaches for the treatment of AD are, therefore, aimed at enhancing the level of cholinergic neurotransmitters in the brain by using cholineresterase inhibitors. Two cholinesterase enzymes, acetylcholinesterase (AChE) and butyrylcholinesterase (BChE), play an important role in decreasing choline levels in the body. Among natural sources, essential oils are attracting special attention. The essential oil obtained by hydrodistillation of the peels of *C. medica* 'Liscia di Diamante' demonstrated inhibition of both AChE and BChE (Menichini et al. 2011c). A selective AChE inhibition was observed with the oil obtained by cold-pressing, while the essential oil obtained by supercritical fluid extraction was completely inactive against both enzymes. The instituted bioactivity could be explained by the presence of some terpenes that have been identified as major constituents (Miyazawa et al. 1997; Choi et al. 2000; Loizzo et al. 2009a, b). However, several studies demonstrated that the activity exhibited by the essential oil is probably due to the synergistic activities of several components. In fact, the monoterpenes identified in the *n*-hexane extract obtained from the peel of *C. medica* 'Liscia di Diamante' peel may be responsible for the inhibitory activity against AChE (Conforti et al. 2007).

9.6 Citron Cultivation in Calabria

Among citrus fruits, citron is certainly the most sensitive to low temperatures, as values below 12 °C can cause damage to the leaves and fruits, while above 35 °C the fruiting cycle manifests phenomena of floral abortion and fruit drop.

Citron, therefore, needs environments that are characterized by a very mild and, above all, a constant climate throughout the year. For this reason, most of the orchards are in coastal areas or no more than 100 m a.s.l. Citron also requires fresh, deep, sandy-loam soils. In the Citron Riviera, trees are placed in valleys created and shaped by rivers, in areas not far from the coastline. The ideal environment is one where

Fig. 9.8 Citron cultivation under nets

orchards are protected from the cold winds coming from the Pollino massif and mitigated by the breeze coming from the Tyrrhenian Sea. Furthermore, nets used by growers to protect trees provide further mitigation of the microclimate (Fig. 9.8), consequently enhancing the productivity of citron and the quality of the fruit (Gullo 2012).

9.6.1 Rootstocks

Grafting is not permitted for *etrog* trees that produce fruits for the Sukkot Holiday, but it is widely practiced in Italian groves that produce fruits destined for the industrial/processing market. In Southern Italy, citron is mainly grafted on sour orange (*C. aurantium* L.), which was previously the most used rootstock for many citrus species before the Tristeza virus disease spread in Italy (Fig. 9.9). The grafting of citron on other citrus species as an alternative to *C. aurantium*, has been studied to evaluate the growth, yield, and fruit quality of citron 'Liscia di Diamante' on different rootstocks under Mediterranean conditions. 'Volkamer' lemon, sour orange and 'Carrizo' citrange showed significantly higher yields, particularly in comparison with 'Flying Dragon' and 'Rubidoux' trifoliate orange. 'Volkamer' lemon induced the highest fruit weight. Among the studied rootstocks, no relevant graft-incompatibility was recorded. Some of these rootstocks could be successfully used in the environmental conditions of Southern Italy. Both 'Flying Dragon' and 'Rubidoux' trifoliate orange induced reduced tree growth and could, therefore, be suitable for high density plantations along with the adoption of appropriate production techniques to obtain high yields (Ferlito et al. 2016).

Fig. 9.9 Citron trees trained with a palmette system and grafted onto sour orange rootstock

9.6.2 Farming Systems in Calabria Agriculture

The cultivar 'Liscia di Diamante' is the most widely grown in the Citron Riviera, while 'Limoniforme' and 'Policarpa' are only present in small quantities. The plants are evergreen, and trees are kept at a maximum height of two or three meters. Unlike other citrus, the branches are fragile and cannot withstand wind. Main branches need support during the ripening of the fruits that can reach two or even three kilograms in size. For this reason, the plant and the branches are placed on a pergola system to support the weight of the fruits and covering nets are installed during the winter to protect from cold temperatures.

The farming system that is used has changed considerably over the years: initially, a pergola was used which provided for a scaffolding to protect two rows, with close distances between the beams (2.5 × 2.5 m or 2.5 × 3.5 m), separated by a service corridor subsequently occupied by the canopy. Currently, a pergola with wider rows (3 × 3 m or 3 × 4 m) is used, with trees trained to a spread double T system (Fig. 9.10). The pergolas are made with a totally metallic upper structure, with a central piling of wood and prestressed concrete, with transverse supports placed at two heights, 100 and 180 cm. The double T is used extensively in the coastal area and in about 40% of the inland areas, with a production that is close to 21 kg per plant and a total yield of about 21 tonnes per hectare. A higher plant density (1500 plants per hectare) and a greater fragmentation of farms is characteristic of the inland area of the Citron Riviera, while the area adjacent to the coast has a lower planting density of 900–1200 plants per hectare (Perrone 2011). In the double-T form, trees are cultivated next to the supports, with timely pruning of the apical regions to contain the vigor and the horizontal training of branched to promote flowering and fruiting. The result

Fig. 9.10 Citron trees cultivated with a pergola system under nets

is a low pergola, with a tier at 1.1 m that corresponds with the first T. The material used overhead is an anti-hail net with 50% shading. This is removed in the spring period in orchards that produce fruit for processing, while in the orchards used for Jewish religious purposes, nets remain throughout the year. In the latter, a greater amount of labor is required (Fig. 9.11), as the branches with fruits need to be tied to the structure to avoid mechanical damage due to fruit contacting adjacent fruits, branches or spines (Fig. 9.12). Selective pruning is also carried out.

Citron crops must be placed in areas where the trees are not exposed to strong winds. Systems used for protecting citron from winds are made from natural or artificial windbreaks, with nets being widespread, while some trees are cultivated as hedges.

9.7 Consortia and Cooperatives. A Troubled History

The cultivation of citron for the processing industry has historically not been profitable for the growers. Ferrari (1910) reports of a

> "badly ordered, irregular and often dishonest trade". He states that "the sale is in the hands of manufacturers who send agents and interested local buyers who absorb a large part of the profit drawn from the farmer".

This difficult situation progressively became worse over time. Initially, the traders sold the fresh product directly to the industrialists in northern Italy. In time, the traders

Fig. 9.11 Citron is a labor intensive crop

Fig. 9.12 Citron fruits fixed to a branch in order to avoid mechanical damage

themselves became industrialists. They took care of the storage and brining of fruit and sold the brined citrons to companies in northern Italy that were dedicated to candying and selling on Italian and foreign markets. This was a deleterious situation for the growers who, isolated and divided, were the weak link of the whole process and who received only low returns for their produce.

The first idea of organizing associations of growers dates back to the Fascist period (1922–1943). On the initiative of the "Provincial Agricultural Federation", the "Consorzio Diamante s.a." was established as a company where membership was confidential. It was based in Belvedere Marittimo with the purpose of collecting, storing, brining and candying the citron. This initiative was characterized by considerable disorder, large waste and widespread cheating that was systematically covered up by the authorities. The consortium operated for only two years, after which it was liquidated with large debts (Monaco 2019).

In 1956 a group of provincial councilors, led by Prof. Vincenzo De Paula, presented the "*Socialist Motion for the Citron*". Having examined the serious exploitation of growers, the proposal was to set up a consortium of producers as being

> the only instrument capable of eliminating all forms of speculation to permanently protect the interests of the area, of farmers and small owners.

In the same year, an obligatory consortium for citron was proposed which had to collect 70% of the production if it was to be formed. In August of the following year, the Consortium became a reality with 80% of the producers and 84% of the total production of citrons being within the organisation. This was an ephemeral victory as the new body, which was without a statute and without a governing body, failed (Monaco 2019).

In April 1964, ten cooperatives were set up in ten different municipalities on the Riviera. This required considerable organizational effort which did not, however, produce immediate results. In October, with a campaign to collect fruit during the harvest season, the situation became very serious and the exasperated growers decided not to collect the fruits. They preferred to lose the product rather than sell it at very depressed prices to local traders and industrialists. The Prefect of the region intervened initially and then the Ministry of Agriculture and Forestry became involved and approved the expenditure of 250 million Lire, a significant amount of money at that time, for the construction of a collective storage facility and a brine plant in the municipality of Diamante. The following year (28 May 1965) there was the ceremony for laying the foundation stone for the plant. However, this was not in Diamante but in Santa Maria del Cedro, which came about at the end of an animated controversy in which the entire Calabrian political community was involved. In 1965, the farmers contributed 12 thousand quintals (1200 tonnes) of citron fruit to the storage facility, and 18 thousand quintals (1800 tonnes) in the following year. This too was an ephemeral success. Growers again began withholding fruit and the contributions to the storage facility continued to diminish. Once again, local traders gained the advantage from fruit sales. The activity of the agricultural consortium continued as best as possible but in 1972 it ceased operations (Monaco 2019).

With origins in Santa Maria del Cedro, a new cooperative was organized in 1973. The main architect of this initiative was Don Francesco Gatto, a parish priest from a small town in the center of the problems involving the citron growers. Convinced that collaboration and unity of purpose would be the basis of success, he chose the name "TUVCAT" for the cooperative, an acronym that stood for "Tutti Uniti per la Valorizzazione del Cedro nell'Alto Tirreno cosentino" (All united for the valorization of citron in the upper Tyrrhenian of Cosenza). The initial membership was 300 which, in a short time, became 400. Despite a total lack of funds, 18 thousand quintals (1800 tonnes) of green citron were supplied to the consortium which, at the end of the campaign, provided more than double the financial returns offered by local traders. But this too was a short-lived dream. For two or three years everything progressed well and TUVCAT expanded to involve almost all the citron growers of the Riviera. However, from 1982 a new decline began. From 1982 to 2011 there was a long period of stalemate. Processing plants were created for candying, which were perhaps oversized, and candied citron were produced. The candying of orange peels was also realized. However, market demand visibly decreased over this period, building speculation, especially for holiday homes, took away the most suitable coastal areas from citron production, and the workforce increasingly moved from citron orchards to construction sites. Important orchards disappeared in Diamante, Scalea, Belvedere Marittimo, Bonifati, Santa Domenica Talao and Grisolia. Some remained in the other villages, especially in Santa Maria del Cedro, where the land halfway up the coast is considered less attractive by construction companies. In November 2011, TUVCAT was put into liquidation and in December 2018 it ceased operations.

While TUVCAT was experiencing its challenges, a group of citron growers moved away from that consortium and formed, in 2000, a parallel association, the "Consorzio del Cedro di Calabria". Its declaired purpose was "the promotion of the culture of the citron and the territory in which it is grown". Four years later, the government in the Calabria Region approved a regional law that aims to "safeguard, improve and promote the cultivation and production of citron" in eighteen municipalities of the Riviera and entrusts the "Consorzio del Cedro di Calabria" with the implementation of the purpose of the law, with a commitment to "determine annually the expenditure to be allocated to support cultivation". For several years, both TUVCAT and the Consortium operated in parallel but, when TUVCAT went into receivership, all of its assets, including the warehouses and associated processing equipment, passed into the hands of the new consortium (Monaco 2019).

In reality, citron production is constantly decreasing as old farmers abandon existing orchards and few young people plant new citrons. Production is currently in the hands of two or three large-scale and a dozen medium-sized producers. There are about a hundred families with small farms, not included in the census, that often make their production available through direct sales to small intermediaries. A few of the growers are also involved in on-site production of liqueurs, jams and syrups. The brining process is limited to one or two small plants and most of the citron is sold fresh. It is only the production that is reserved for Rabbis that is paying well and those returns continue to increase year by year. Within this situation, the

Consortium promotes the Citron Museum with a food shop, organizes the Citron Festival, and evaluated the installation of an industrial plant for processing, with the on-site production of liqueurs, syrups and jams. In 2013, a group of producers left this consortium and started another association. The headquarters of this new entity are in Scalea, and it is called the European Consortium of the Mediterranean Citron "Terre di Calabria". Article 4 of their Statutes specifies, once again, that the association aims to "promote and protect the production, marketing and possibly the transformation of the citron of Calabria" (Monaco 2019).

Recently, "Consorzio del Cedro di Calabria" applied to the Italian Ministry of Agriculture for the assignment of the Protected Designation of Origin (PDO) mark: "Cedro di Santa Maria del Cedro", obtaining it in 2021. The registration of the PDO in the Official Journal of the European Community is now pending. PDO is a European mark of origin which is attributed to those foods whose peculiar characteristics depend mostly on the territory where they are produced; with this aim, stages of production, processing, and preparation must take place in a defined geographic area.

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Chapter 10
The Citron in Corsica

Franck Curk, David Karp, Pierre-Jean Campocasso, and François Luro

Abstract 'Corsican' is an acidless citron derived from 'Poncire Commun' and has long been the cultivar almost exclusively grown on Corsica. Citron arrived there by the eighteenth century and was commercially important from the 1820s to the 1920s. Its cultivation boomed in the second half of the nineteenth century, when Corsican citron was renowned for its high quality, sometimes brought high prices, and was perceived as a path to quick riches. Cultivation started on Cap Corse and shifted to the Eastern Plain. Most of the crop was brined, candied, and sold to northern Europe, Great Britain, and the United States for use in baking cakes. Livorno was the center of the citron candying industry. The greatest obstacles for Corsican producers were mainland France's disadvantageous sugar tariff policy for Corsica and growing international competition, which resulted in the commercial industry's decline by the 1930s. Currently Corsican growers raise citron on c. 15 ha and harvest 60–100 mt annually.

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10.1 Introduction

Corsica produces a namesake citron cultivar renowned for its high quality, which in the second half of the nineteenth century started a horticultural gold rush. Its saga encompasses many puzzles and ironies. Modern genetic analyses have elucidated the probable parentage of 'Corsican', but the date and provenance of its arrival on the island remain unclear. Corsicans rushed to plant citron, hoping to cash in on high prices, but most of the profits went to foreign entrepreneurs. Corsican citron was an object of desire and intrigue so intense that the founder of the United States Office of Seed and Plant Introduction, David Fairchild, made his reputation by filching 'Corsican' budwood. Competition and disadvantageous tariffs eventually undermined the Corsican citron industry, and Corsican emigrants finished it off by transferring their germplasm and expertise abroad. Citron was emblematic of Corsica, but its consumption never really caught on there. While the dream of wealth proved ephemeral, the prestige and fascination of Corsican citron endure.

In recent decades French scholars have painstakingly researched this history, and many previously obscure documents have been scanned into searchable databases. These sources, old and new, now reveal an intriguing, multifaceted story.

10.2 Citron in the Ancient and Medieval Western Mediterranean

Citron (*Citrus medica* L.) originated in the Himalayan foothills (Talón et al. 2020). It is unclear when this species reached Corsica, but it is possible to trace the approximate timeline of its introduction to the Mediterranean and to its western half. There is some weak evidence for a find of citrus seeds in Cyprus dated to the twelfth century BCE, but the oldest secure archaeobotanical evidence for citrus in the Mediterranean area is fossil citron pollen found near Jerusalem in a Persian royal garden dating to the fifth-fourth centuries BCE (Langgut 2017). Pollen grains and organic residues in Sardinia and Campania provide some evidence that citrus may have reached Italy by the sixth century BCE (Frère et al. 2012). Well-preserved mineralized seeds from Pompei dated to the third-second centuries BCE represent the earliest secure find of citron in Italy; citrus cultivation was well established in Campania by the first century CE (Celant and Fiorentino 2017).

No archaeobotanical remains of citron or citrus have been identified from Corsica in antiquity. The earliest source for citron cultivation on the nearby island of Sardinia is the Roman agricultural author Palladius, who wrote in the late 4th or early fifth century CE that he had observed citron flowering and fruiting year-round "in lands which I possess in the territory of Naples and in Sardinia, where the soil and the climate are warm, and where water abounds." (*Opus agriculturae* IV, 10:11–18). He also described in detail citron propagation by cuttings, seeds, and grafting (Palladius 1898).

The first mention of citron in Muslim Spain was by ʻArīb ibn Saʻd in the The Calendar of Cordoba for the Year 961. Ibn al-'Awwâm, who lived in Seville in the later twelfth century, included in his Book on Agriculture a substantial chapter on citron in which he distinguished two kinds, acid citrons with dark buds and many long thorns, and sweet citrons with light-colored buds and few, short thorns (Ibn al-'Awwâm 2000). Of course, it is uncertain that this sweet citron was related to the modern 'Corsican', but it is noteworthy that an acidless citron was present in the Western Mediterranean before 1200 CE.

It is unclear when and from where 'Corsican' citron, the cultivar that has dominated citron cultivation on Corsica, reached its namesake island. Although it is not known to have been cultivated in Italy (apart from recent exchanges with Corsica), it could nevertheless have originated there, then transferred to Corsica, and eventually disappeared from its birthplace. Corsica was ruled by the Republic of Genoa for almost four centuries (1299–1768) before it was ceded to France by the treaty of Versailles in 1768. During this period the Genoese dominated the Mediterranean maritime trade and played a crucial role in introducing the Chinotto (a small-fruited sour orange mutation, *C.* × *aurantium* var. *myrtifolia*) and distributing sweet orange (*C.* × *aurantium* var. *sinensis*) throughout the Mediterranean area (Tolkowsky 1938; Pic et al. 2017; Curk et al. 2022). The Genoese brought sweet orange to the Corsican village of Aregno in the late seventeenth century. So it seems possible that citron was one of the citrus types brought to Corsica by the Genoans. Nivaggioli (2002) mused that "it would be very surprising if wealthy people [on Corsica] did not have a citron tree in their garden." But no evidence to verify this has been discovered yet.

Sardinia, which is only 12 km from Corsica and was ruled by Genoa for many centuries, also developed a tradition of candying the rind of an indigenous citrus cultivar, 'Pompia', which resulted from a natural cross of sour orange and citron (Luro et al. 2019; Viglietti et al. 2019). Genetic studies exclude the possibility of a direct link between 'Pompia' and 'Corsican', suggesting rather a link with 'Diamante'.

10.3 Beginnings of Corsican Citron Cultivation

The earliest record of citron cultivation on Corsica dates from the first years of the eighteenth century in the small hamlet of Minerbio on the western coast of Cap Corse, the island's northernmost peninsula (Indekeu 2020).

Citron was certainly grown on Corsica by 1768, when France gained control over the island. A "*Mémoire sur le commerce et les établissements qu'on peut faire dans l'isle de Corse*", undated but addressed to the "Philosopher King" (Louis XV, ruled 1715–1774) noted that Bastia province "produced many orange, lemon, citron, and sour orange trees" (Bérard et al. 1996).

However, according to an agricultural survey of 1801–1802, citron's presence on Corsica was still insignificant at the beginning of the 1800s (Indekeu 2020). Furthermore, both of the great contemporary French citrus treatises, Gallesio (1811) and Risso and Poiteau (1818), do not mention an acidless citron such as 'Corsican'.

Limperani (1872), Lorenzi (2002), Ambrogi (2003), and Indekeu (2020) considered that commercial citron cultivation on Corsica began in the 1820s. In both 1827 and 1835 there was enough Corsican citron production that some growers cut down their trees because they weren't able to sell their crops (Piccioni 1864). But it was only towards the middle of the nineteenth century that Corsican citron cultivation became economically important (Maillot 1875).

Boitel (1875) noted that only one variety of citron was known in Corsica, and thought that it had been constantly reproduced from cuttings of the original type cultivated in Cap Corse. It is unclear when this genotype, now known as *cédrat 'de Corse'* (in French) or 'Corsican' citron (in English), was recognized as a distinctive variety and given these names.[1]

In the Corsican language the word for citron was and is "*alimea*", which is cognate to names of other citrus types, such as "lime" and "lumia". "*Alimea*" can refer both to the tree and the fruit. This spelling is the most common throughout the island, but variants such as "*alimia*", "*alimeia*", "*a lùmia*", and "*a limea*" are used in some regions (Nivaggioli 2002; A Mimoria 2003). It is also worth noting that the whole candied citron was formerly marketed under the name of "*Poncire*" (Huet et al. 1986).

10.4 'Corsican' Citron Morphology

The most distinctive characteristics of 'Corsican' citron are its acidless pulp and the absence of anthocyanin pigmentation in the flowers and young shoots, whereas most citron cultivars have acidic pulp, and purple flowers and young shoots (Fig. 10.1). The 'Corsican' citron tree is smaller and less vigorous than other commercial cultivars such as 'Diamante', typically reaching a height of 2–3 m when fully grown. Its growth habit is open and spreading, and the density of its foliage is low (Fig. 10.2). Like other citron cultivars the trunk is creamy white. The thorns are numerous but short and continue to be present on mature trees. The leaves are typical of pure citron cultivars, medium large, oblong, blunt-pointed, rounded at the base, with a crenate margin. In Corsica the primary flowering takes place in April, but trees can bloom year-round (Hodgson 1967; Curk et al. 2022).

The morphology of 'Corsican' citron fruit is quite variable. The shape can be spheroid, ellipsoid, or slightly obovate, and weight ranges from 200 to 1,500 g (Fig. 10.3). The apex can be mammiform, acute, rounded, or truncated. The base is rounded. The color of the skin ranges from light green to cadmium yellow. Skin texture is also quite variable, typically rough and bumpy, occasionally indistinctly ribbed, rarely somewhat smooth. The rind is thick, typically representing between 85 and 92% of the fruit diameter, depending on the rootstock, higher than for many

[1] In this chapter, 'Corsican' refers exclusively to the 'Corsican' citron cultivar, which can be grown in many areas around the world. "Corsican citron," without the single quotation marks around the cultivar name, refers to any citron grown on Corsica. In practice most citrons grown on Corsica are 'Corsican', but the distinction between the two terms remains important.

Fig. 10.1 'Corsican' citron flower and leaves (*Photo credit* F. Curk, INRAE)

Fig. 10.2 'Corsican' citron trees (*Photo credit* F. Curk, INRAE)

other pure citron cultivars (Fig. 10.4; Marchal and Jacquemond 1988). The oil glands are medium in size, and globose to ellipsoid. 'Corsican' citron essential oil is distinguished by its elevated content of (*E*)-phytol (Venturini et al. 2010). The albedo is very firm and before processing is relatively sweet, without bitterness (Venturini et al. 2014). The average number of segments is 11–14. The pulp is pale straw-colored, and not very juicy. The juice averages 7.8 ºBrix; titratable acidity averages 0.36% (unpublished data from Luro et al. 2012). The fruits contain from 25 to 40 monoembryonic seeds (Hodgson 1967; Curk et al. 2022).

Fig. 10.3 'Corsican' citron fruit on the tree (*Photo credit* F. Curk, INRAE)

Fig. 10.4 'Corsican' citron cut open to show thick albedo (*Photo credit* D. Karp)

‘Corsican’ fruits intended for candying and liqueur are usually harvested green in October and November.

10.5 The Genetic Origin of ‘Corsican’ Citron

A study of the genetic diversity and essential oil composition of citron cultivars in the INRAE-Cirad citrus collection in San Giuliano, Corsica revealed the distinctiveness of ‘Corsican’ citron and also provided evidence for its genetic origin (Luro et al. 2012). Because citron is cleistogamic, it can fertilize itself before the flower opens. It appears that ‘Corsican’ derived from two successive self-fertilizations of the Italian variety present in the San Giuliano collection called ‘Poncire Commun’ (SRA 701). This hypothesis is based on the sharing of common characteristics between these two citron cultivars, both in terms of the morphology of the fruit and the composition of the essential oils of the rinds and leaves. Indeed, the chemical profile of these two cultivars differs from those of other citron cultivars by having higher levels of geraniol (14–32%) and nerol (20–24%) compared with less than 10% in the other cultivars (Fig. 10.5). ‘Corsican’ citron stands out from all the other citrus fruits by its higher content of (E)-phytol and lower content of limonene in the leaf essential oil. The chemical profile of the zest of ‘Corsican’ is very similar to that of ‘Poncire Commun’ (Fig. 10.6).

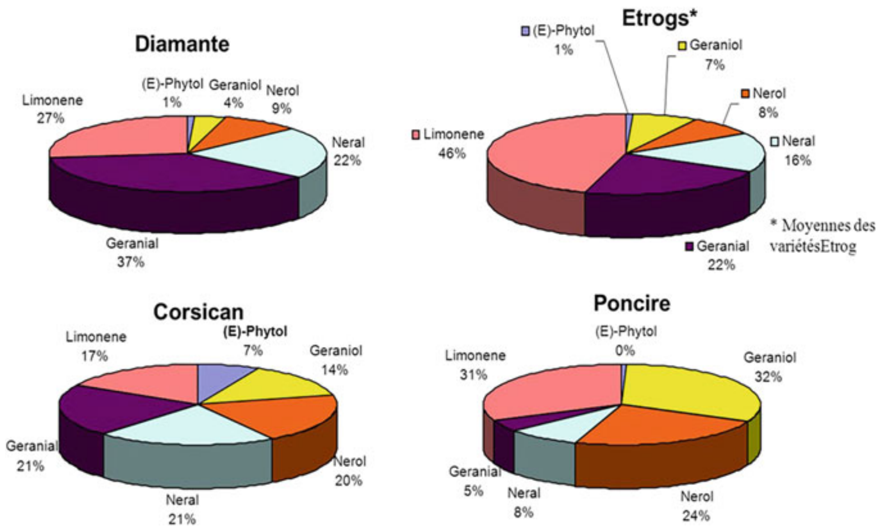

Fig. 10.5 Proportions of the six major compounds of citron leaf essential oil. Etrogs is an average of four varieties called Etrog in the INRAE-Cirad citrus germplasm collection in San Giuliano. Based on data from Luro et al. (2012)

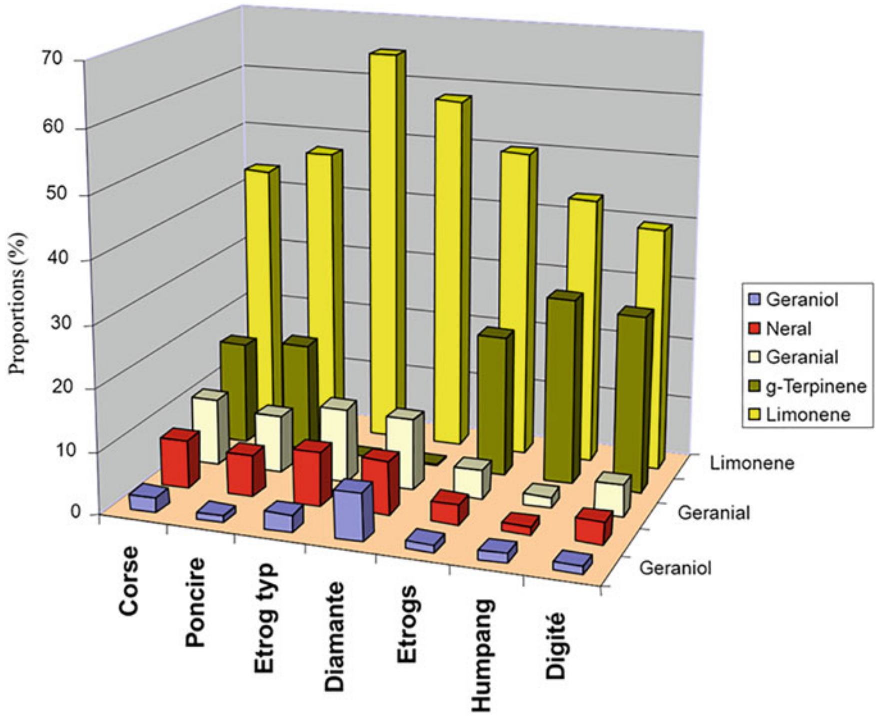

Fig. 10.6 Proportions of the five main compounds of the essential oil of the zest of 10 varieties of citrons. Etrogs is an average of four varieties called Etrog in the INRAE-Cirad citrus germplasm collection. Based on data from Luro et al. (2012)

This closeness between 'Corsican' and 'Poncire Commun' is also revealed by genetic markers that are common to both cultivars but different from others (Fig. 10.7). More precisely, all markers of 'Corsican' are present in 'Poncire Commun', but not the reverse. Moreover, the proportion of markers with different alleles between the two homologous chromosomes of the same cultivar (heterozygosity) is four times lower in 'Corsican' (9%) than in 'Poncire' (36%). Since each cross by self-fertilization reduces the heterozygosity by half, the results suggest that 'Corsican' was born of two successive self-fertilizations from 'Poncire Commun' (Fig. 10.7).

This phylogeny of 'Corsican' citron has been confirmed by other genetic studies (Curk et al. 2016). The information offered by DNA markers is unambiguous. This is not always the case with phenotypic traits, which can sometimes lead to erroneous assumptions about parentage. 'Corsican' has two distinctive morphological characteristics: the production of all-white flowers (citron flowers are usually purple due to the presence of anthocyanins) and the absence of acidity in the pulp. However, there is another citron cultivar in Morocco, 'Assads' (erroneously called "Etrog type" in Luro et al. 2012), which also has these same two characteristics. Based on other

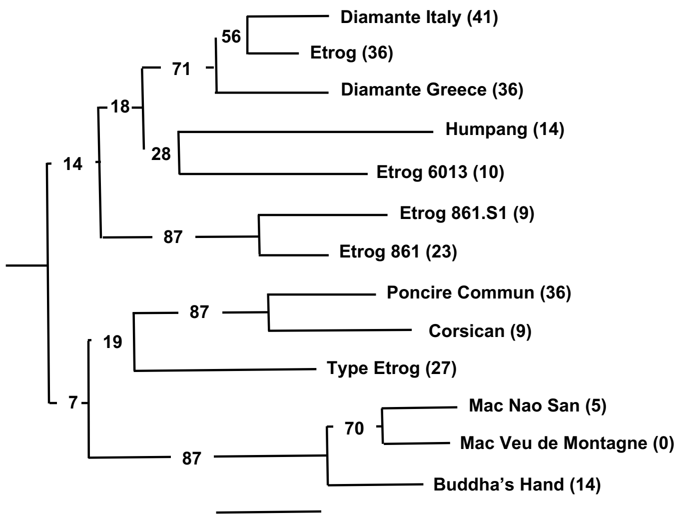

Fig. 10.7 Tree of phylogenetic relationships of citron varieties estimated by a similarity index calculated from genetic markers. The length of the branches is proportional to the genetic distance. Values in parentheses indicate heterozygosity (Based on Luro et al. 2012)

traits such as essential oil composition and genetic profiles, there is no doubt that these two varieties are very different. Given that the genetic relationship between 'Poncire Commun' and 'Corsican' is unquestionable, it seems likely that 'Assads' and 'Corsican' could share a common ancestor.

All the 'Corsican' citron trees now grown on Corsica derive from one standard clone, SRA 613. Very often when a citrus cultivar has been grown for many years, clones with distinctive characteristics have developed through spontaneous mutation and selection by farmers and nurserymen; for example the 'Dr. Strong Lisbon' and 'Limoneira 8A Lisbon' lemon clones. Sometimes the mutations are so significant that they are recognized as new cultivars, for example 'Cara Cara' navel orange, a pink-fleshed mutation of 'Washington'. For 'Corsican' citron minor clonal selections may have existed in the past, but since the 1960s, soon after the establishment of the agronomic research station (SRA INRA-CIRAD) at San Giuliano, all new plantings of 'Corsican' have derived from one selection, SRA 613, which is a virus-free clone that is used exclusively by local nurseries. Since citron trees are relatively short-lived, any previous diversity within 'Corsican' selections has very likely been lost. It's possible that some diversity may have been preserved in 'Corsican' trees in other countries that were propagated by seeds or cuttings brought from Corsica long ago. In any case, 'Corsican' appears to be relatively stable genetically, so that major mutations with distinctive morphological variation are not known.

10.6 'Citron Fever'

It might seem odd that in the nineteenth century Corsica became a major producer of citron, which historically had been nonexistent or of minor importance there. Moreover, citron is among the most cold-tender of citrus, and Corsica is at the northernmost limit of commercial citrus cultivation. Overcoming these factors, the great Corsican citron boom resulted from the confluence of increased demand and the ability to supply a lucrative market.

In the nineteenth century, as transportation and refining technology improved, and sugar beets were cultivated on a large scale in Europe, sugar became cheaper and sweets became readily available to the middle classes. The introduction of the cast-iron cooking stove made baking easier, and in Great Britain, Holland, Germany, and the United States, fruitcake and other desserts made with candied citron became increasingly popular (Goldstein 2015).

Meanwhile Corsican cultivation of cereals, vines and olives declined, mainly due to competition from French flour, oil from Italy and Tunis, and the phylloxera pandemic in the vineyards (Orengo Serra 2002). By 1870 gummosis (causal organism *Phytophthora* sp.) destroyed many citron plantings in Italy (Lorenzi 2002).

Add to these factors that Corsican citron enjoyed a unique reputation as the finest in the world. Limperani (1872) insisted that fruit from other growing areas "does not have the same qualities for candying as the citron which comes from our island." At the height of the product's prestige the British consul to Corsica rhapsodized:

> I attribute the size, aroma, and general superiority of the Corsican citron, which always commands a higher price in the market than that produced in other countries, in a great degree to the soil of Corsica; which being not only extremely rich in ferruginous qualities, is also strongly impregnated with the various salts and chemicals necessary for the production of the numerous aromatic plants in which the island abounds (Drummond 1891).

In the early 1870s the prices paid for citron by processing firms in Italy quadrupled from 0.25 franc per kilo to 1 franc or more. Many Corsicans tore out their gardens to plant citron trees, making substantial investments to prepare the land and build sheltering walls and irrigation canals. "The owners, excited by the extraordinary increase in prices for this product, developed citron fever," wrote Boitel (1875).

10.7 Corsican Citron Plantings and Production

Many sources trace the arc of Corsican citron, particularly from the 1860s through the 1920s, when it was a significant crop on the island. A summary appears in Table 10.1.

Corsican citron plantings were never very extensive, just 500–600 ha at peak in the last quarter of the nineteenth century—relatively modest compared to the 1,450 ha of other citrus that are grown on the island today. Competition from Greece and Italy reduced plantings to 300 ha by 1910.

Table 10.1 Corsican citron plantings and production, 1864–2022

Year	Area (ha)	Yield (mt)	Notes
1864		800	
1865		841	
1866		2160	
1869		400	Cold winters of 1868 and 1869 almost wiped out production
1870		500	Strong demand, low production, many orchards planted
1871		873	
1873		963	
1875	500	1667	
1877		2229	
1880		6600	Peak of production
1885		2000	
1886		2500	
1887		1897	
1890		2000	
1892	600	4500	Corsica #1 in world; Greece 2nd (3000 MT); Italy 3rd (2500 MT)
1894		4000	Disastrous low prices
1898		2017	
1900		3914	
1902		2059	
1905		6270	
1908		986	Freeze reduces harvest
1910	300	2000	
1914		2400	Wartime sugar shortage harms Corsican citron trade
1920		2000	
1923		1062	
1924		1200	
1925		1725	
1926		1600	
1927	150	2715	Overproduction/beginnings of agricultural crisis
1930/1934	100	1000	Competition from Puerto Rico begins
1945/1947		100	
1950	15	180	
1955		32	
1958		10	
1960	10	14	Commercial export of Corsican citron ends

(continued)

Table 10.1 (continued)

Year	Area (ha)	Yield (mt)	Notes
1969	10		
1982	5	40	
1996		40	
2022	15	80	

The lack of sugar during World War I was disastrous for Corsican producers. Many of the smaller growers with just a few citron trees uprooted them (Lorenzi 2002).

There was a resurgence in the early and mid-1920s, but citron plantings decreased again in the late 1920s and 1930s, due to overproduction and competition from Italy and Puerto Rico.

From 100 ha in 1930–1934, citron hectarage collapsed to just 15 in 1950, and 10 in 1960 and 1969 (Blondel 1969). It was further reduced to 5 in 1982 (Huet et al. 1986) but has since recovered to an estimated 15 ha today.

The scale of individual plantings was always small. Limperani (1872) observed that no one owner had more than one hectare of bearing citron trees; but as the citron boom was taking off, some groves as large as 2 or 3 ha were being planted. Boitel (1875) mentioned *cedrateries* (citron plantings) of 5–10 ha in Porto and Chiavari but considered them exceptional. Spoturno (1901) similarly noted that plantings of one hectare or more were very rare.

The harvest varied far more than plantings, mostly because of the effects of occasional freezes. Production increased from 841 mt in 1865 to 2,162 mt the following year, but the cold winters of 1868 and 1869 almost wiped out production, which fell to 400 mt. Demand, which was already strong, greatly exceeded supply, leading to exorbitant prices; this in turn led to greatly increased plantings. Production peaked at 6,600 mt in 1880. In 1892 Corsica was the world's largest producer of citron, harvesting 4,500 mt, ahead of Greece (3,000 mt) and Italy (2,500 mt).

Between 1890 and 1914, Corsica's harvest reached 5,000 to 6,000 mt in the best years, with strong variations from one year to the next, caused by freezes and crises of overproduction. After 1900 the island lost its dominant position in favor of Calabria and the Peloponnese, but nevertheless remained a substantial producer, averaging around 2,600 mt.

In the 1920s, Corsica experienced a new wave of plantings and growth in production, which reached 2,715 mt in 1927. During these years, the island produced nearly a quarter of the world's citron supply. But Corsican citron production was virtually destroyed by the overproduction and economic crisis which began for some crops even before 1929.

Corsica continued to export citron, with difficulty, until 1960 (Lorenzi 2002). For most of the postwar era production did not exceed 100 mt (Blondel 1969).

10.8 Citron Growing Areas

Citron cultivation on Corsica began on Cap Corse, which was closest to and most in contact with the markets of Genoa, Livorno, and Marseilles (Fig. 10.18; Galletti 1863; Enquête agricole 1867; Boitel 1875). For several decades it remained confined to low-lying, well sheltered spots on the western coast of that peninsula. Around 1870, as demand increased from England, Italy, and the United States, Corsican citron cultivation surged and spread to other parts of the island (Limperani 1872; Boitel 1875).

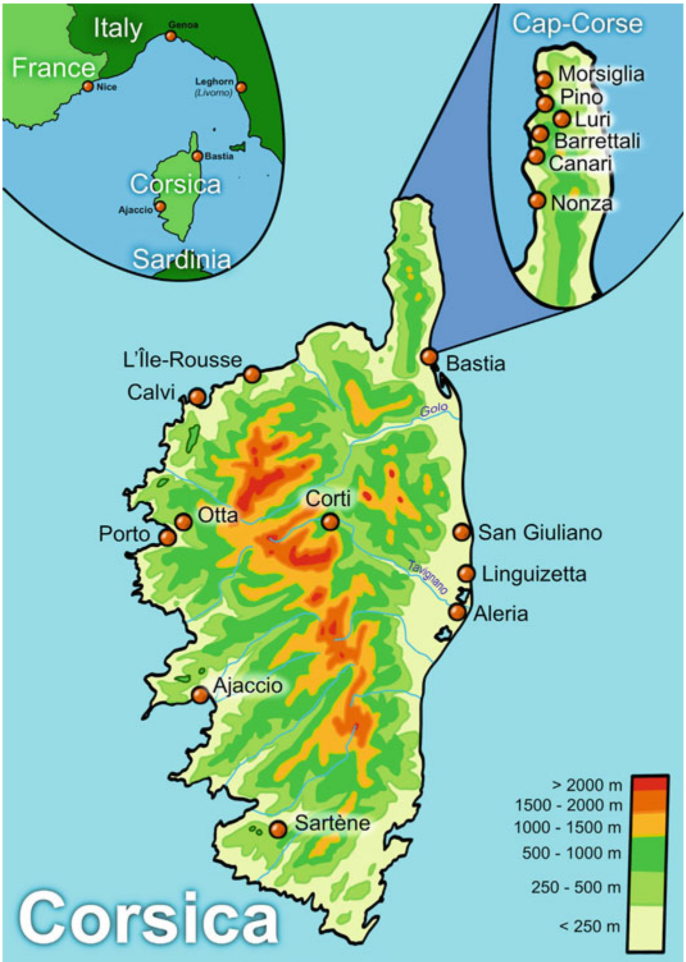

Fig. 10.8 Map of Corsica (*Credit* F. Curk, INRAE)

Of the 310,330 citron trees cultivated on Corsica in 1874, 225,307 were in Bastia/Cap Corse; 57,516 were in the area of Calvi, on the northwest coast; 15,147 were in the district of Ajaccio, on the southwest coast; 3,157 were in the area of Corti, in the center of the island; and 9,203 were in Sartène, near the island's southern tip (Maillot 1875). Notably absent from this inventory was the eastern coastal plain, despite its good soil and equable maritime climate, because malaria was rife there.

> [This zone] is infected with malaria for part of the year, [so] it is deserted and uninhabitable during the hottest and driest months. The workers occupied with the watering and the various ways of the citron tree can, if need be, remain there during the day without too much danger to their health; but, to escape the often fatal attacks of fever, they are forced to sleep in the mountains, at distances more or less distant from the citron trees. This condition, which is subject to exceptions only in special situations, makes the labor that citrons demand in the heart of summer rare and expensive. There are even localities so unhealthy that it would be impossible to find workmen who would agree to stay there at the time of the greatest heat of summer (Boitel 1875).

Starting in the 1890s production spread to the Aléria plain, on the east coast of the island (Cameron 1924; Bérard et al. 1996). From the early twentieth century the draining of the marshes and control of mosquito larvae greatly reduced the prevalence of malaria (Toty et al. 2010). By 1924 Chadefaux listed the main areas of citron cultivation on Corsica as Aléria, Casaglione (on the west coast), and Cap Corse. In a report of citron production from 1922–26, 82% of the plantings were on the east coast, from Golo to Aléria; the leading communities were Aléria/Tavignano 26%; Verde 24%; Moriani 23%; Balagne 9%; Cap Corse 5%; Casinca 5%; Fiumorbo 4%; Ajaccio Porto 3%; and Sartène 1%.

Competing citron production areas in the Mediterranean included Greece, Calabria, and Sicily in the late nineteenth century (Alden et al. 1886); and Greece, Italy, Sicily, Sardinia, and Spain in the 1920s (Chadefaux 1924).

10.9 Historical Horticultural Practices

Corsican citron cultivation required an extraordinary amount of laborious, expensive work to prepare the land by building terraces, windbreaks, and irrigation basins, which was justified only if the crop could be sold at high prices. Contemporary sources describe these measures, as well as horticultural practices, in considerable detail.

On Cap Corse, where citron cultivation started on Corsica, the sloping terrain in many areas required the construction of stone retaining walls for terraces (Fig. 10.9; Galletti 1863). These and other structures such as irrigation basins, hedges, and an old stone warehouse are still visible today in the picturesque old town of Nonza (Fig. 10.10; Nugues and Guillet 2018). To protect the cold-sensitive citron trees against the cold north winds that are particularly fierce in this area, growers topped these walls with hedges of tightly braided dry heather (*Erica terminalis*), strawberry

Fig. 10.9 Terraces for citron plantings in Nonza, on Cap Corse (*Photo credit* D. Karp)

tree (*Arbutus unedo*), and other shrubs. These vertical shelters typically reached 3–4 m in height (Piccioni 1864; Boitel 1875). In the colder areas growers also covered citron trees in winter with large horizonal mats of entwined maquis, reeds and straw (Boitel 1875; Marius and Morati 2003).

Growers mostly propagated citron trees by cuttings in the nineteenth century (Piccioni 1864; Boitel 1875; Maillot 1875; Drummond 1891). Drummond observed that trees grown from cuttings started bearing sooner than trees raised from seed, but seedlings were more vigorous and long-lived. Chadefaux (1924) noted that some growers grafted citron on sour orange rootstock, but Cameron (1924) maintained that Corsican citrons mostly were still grown from cuttings.

The trees were planted between 3 and 5 m apart (Piccioni 1864; Limperani 1872; Boitel 1875; Drummond 1891; Ardouin-Dumazet 1898). At a spacing of 4 m, one hectare contained 600–625 trees.

In the early days of Corsican citron cultivation on Cap Corse, many growers trained their trees on trellises composed of vertical piles joined together by one or more levels of horizontal crosspieces (Fig. 10.11; Boitel 1875). These supported the branches laden with heavy fruits, maintained them in a horizontal position, and kept the tree close to the ground, to protect against violent winds (Limperani 1872; Boitel 1875).

Citron trees, like most citrus, required frequent watering, usually 100 to 200 L per tree twice a week, during the six warmest months of the year. Few locations in Corsica adjoin streams that run year-round, so growers constructed elaborate

Fig. 10.10 Irrigation tank and hedge in Nonza (*Photo credit* D. Karp)

Fig. 10.11 Trellis from Boitel, *Culture du cédratier en Corse* (1875)

networks of basins, canals, and ditches to store and transport water (Boitel 1875; Nivaggioli 2002; Marius and Morati 2003).

Citron trees needed copious fertilizer to produce bountiful crops. Ideally they required 300 kg per tree, applied in December, immediately after the harvest, and in April. However, Corsica produced very little manure, and most growers had to make do with a fraction of that amount (Piccioni 1864; Boitel 1875; Nivaggioli 2002). "The soil of most of our citrus gardens being exhausted, now only bears fruit of small size," wrote Vincentelli (1926), quoting an article from 1913.

Citron trees flowered from February to August or September, but the early flowers usually aborted because of bad weather; fertile flowers were most abundant in May and June and produced fruits that were ready for harvest in late October and early November. The late blooms produced fruits salable in December (Piccioni 1864; Boitel 1875).

Citron growers harvested when the fruits were still light green; at full maturity they would be a bright attractive yellow, but would be more susceptible to decay. They were naturally different sizes, since they resulted from successive blooms, but averaged 1–1.5 kg (Boitel 1875).

Corsica had a limited workforce for the arduous manual labor of citron cultivation, much of which was done by "*Lucquois*" (Lucchese), a term that by extension referred to all Italian migrant laborers. Boitel (1875) noted that they were paid 1.75–2 francs per day. They not only did the hard work of digging and masonry, but ensured the transmission of horticultural knowledge (Nivaggioli 2002).

10.10 Diseases, Pests, and Freezes

A primary horticultural challenge for Corsican citron growers came from pathogens of the genus *Phytophthora*, which caused root rot, gummosis, and fruit brown rot.

> The diseases of citron trees in Corsica are basically reduced to a single one: gummosis. When the tree is gummy, it withers; parasites invade it, its bark peels off; perhaps even the roots rot (Maillot 1875).

Maillot recognized that the disease was caused by a fungal pathogen, and was exacerbated by excessive irrigation or by fertilization, cold, unsuitable soil, and parasites. To protect against the disease, he suggested sheltering trees against temperature fluctuations, adjusting irrigation according to the permeability of the soil, using slow-acting fertilizers, and pruning branches that interfered with air circulation (Maillot 1875).

Boitel (1875) also thought that the best way to guard against the disease was to protect the trees against sudden cold. The remedy for sick trees was "repeated treatments of the soil, abundant manuring and watering in relation to the needs of the plant."

Maillot (1875) realized that grafting citron scions on sour orange rootstock protected the trees, but heard from a Corsican grower that such trees bore fruits that were hard, dark and bad for confectionery.

The most harmful insects Maillot observed on citron trees were:

> 1) cochineal [scale], commonly called *ragnata* or white louse; 2) citron worm [citrus flower moth, *Acrolepia citri* Millièr], larva of a small nocturnal moth; 3) various aphids; 4) various sorts of *Cetonia* [beetles]; 5) thrips (Maillot 1875).

Growers used one special local treatment to combat these pests: spraying a mixture prepared with strong tobacco leaves (*Nicotiana rustica* L.), on the bark of the tree, its leaves, its flowers, or its fruit (Nivaggioli 2002; Marius and Morati 2003).

Diseases and insects slowed the development of citron cultivation, Maillot concluded, but did not threaten its existence (Maillot 1875).

At least in some areas, winter freezes presented the most serious threat to citron growers:

> Winter cold and late frosts are often fatal to citron plantings. In general, only the small branches are frozen, but from time to time intense cold leaves only the strongest branches, or even the trunks only. Then it takes three years for the roots to produce bearing shoots, which represents a very considerable loss. It is estimated, for example, that the frost of February 12, 1874 killed to the roots more than 30,000 citron trees on Corsica, about one tenth of the existing trees (Maillot 1875).

According to Piccioni (1864) citron trees were likely to be harmed by freezes at least four times during their average 30-year lifespans. Freezes continued to be a major problem throughout the history of the Corsican commercial citron industry. As the era was drawing to a close, Vincentelli (1928) lamented that once again the cold had caused significant damage and suggested the acquisition of orchard heaters from California to alleviate the threat.

10.11 Brining and Candying

Unlike most citrus fruits, which are either eaten fresh or juiced, citron is inedible raw, and the rind—including both the flavedo and the albedo—is the only part of economic use. During the era of large-scale citron production on Corsica, from the 1820s to the 1930s, most of the fruit was exported in brine to Genoa and Livorno, where it was candied and commercialized on a large scale. Guillaumin (1841) mentioned “large citrons which come to us from Italy or Corsica candied in sugar.” But no more than a small portion of Corsica’s harvest ever was candied in Corsican workshops; most was brined, and the rest was used to make a citron liqueur called *cédratine* (Piccioni 1864; Bérard et al. 1996).

Soon after harvest, Corsican citrons were transported in crates, bags or bins to the coast, and deposited in small heaps on the ground (Hollande and Chadefaux 1924). In 1864 growers sold 40% of the fruit fresh in bins, but they were under great pressure to dispose of them before decay set in, so they stabilized the other 60%

through a natural process of fermentation and brining (Piccioni 1864). This gave growers several months to try to sell at a favorable price (Piccioni 1864; Alden et al. 1886), and the processing also changed or destroyed any bitter principle in the rind (McCulloch 1927).

On the quays of the port, workers known as "*saleurs*" ("salters"), seated on small benches, cleaned the citrons, and either hollowed them out using a corer, or cut them in half longitudinally. The fruits were packed in wooden barrels holding c. 250 L, which were filled with sea water by hand pumps, and closed by a large slab. Within two or three days fermentation set in and caused an abundant release of carbonic gas, so strong that the sea water seemed to boil (Chadefaux 1924).

Chadefaux (1924) studied the fermentation process and found that a yeast, *Saccharomyces citri medica* n. sp., and a bacillus, *Bacillus citri medica* n. sp., which both lived on the rind of the fruits, were the active agents in the proper curing of Corsican citrons.

In this process the barrels were lined up on the quays and left for 15 days (Fig. 10.12); at that time, the liquid was drawn off and replaced with new sea water. (According to Boitel [1875] the sea water was renewed 3 or 4 times.) By the 40th day, once the citrons had become tender and spongy, with a glassy, translucent appearance, the workers added 15–20 kg of rock salt per 200 L of sea water to ensure the preservation of the product, and closed the barrels hermetically with metal plates. In this state the citrons were loaded on ships, where they served as ballast, and sent to confectioners in various countries (Chadefaux 1924).

Fig. 10.12 Old postcard illustrating the weighing of brined citrons in barrels at the Vincentelli factory in Bastia

During the candying process the citron rind was saturated with a sugar syrup that ensured its preservation while retaining as much of its flavor as possible (Lorenzi 2002). Initially, 80 kg of sugar was used for 100 kg of citron. The brined fruits were taken out of the barrels; if they still had pulp, workers scraped it out. They were then packed into large terracotta jars filled with sugar syrup for three to four weeks, during which the strength of the syrup was gradually increased. They were then put into boilers, cooked, allowed to cool, boiled again until they could absorb no further sugar, and placed on a wire netting to dry. Finally, they were packed in wooden cases of 10–25 lbs. (4.5–11 kg) each (Alden et al. 1886).

A Corsican manufacturer based in Antwerp, Belgium, A.F. Vincentelli, invented a dicing machine that cut candied citron into small cubes, which made them easier to use in baking, especially for cakes (Lorenzi 2002; Indekeu 2020).

10.12 Structure of the Citron Trade

The structure of the Corsican citron trade changed markedly over the century of its prominence. When commercial citron cultivation began on Cap-Corse in the 1820s, citron was exported directly in brine by sailing ships from marinas on the peninsula to Genoa, Marseille, Nice, and Livorno (Leghorn). After 1830, steam-powered ships started replacing sailing vessels. From 1860, Corsican trade was restructured as roads were constructed and ports were reorganized to provide access to larger steamers. Citron merchants centralized the purchase and sale of fruit by transporting the harvests from all over Corsica to warehouses in the Toga district of Bastia (Lorenzi 2002; Indekeu 2020), which was near the groves on Cap Corse, had the best port on the island and was closest to major buyers in Livorno and Genoa.

The citron factories of Nice ceased production after France annexed most of the county in 1860, but Genoa was still a major processor in the 1860s, and Marseille was also still active (Enquête agricole 1867).

While Bastia established itself as the regional center for citron commerce on Corsica, in the late nineteenth century Livorno, a Tuscan port 120 km northeast of Bastia, became the principal center of the citron candying industry. Italy enjoyed a considerable advantage over Corsica in this industry because it allowed a drawback (the refund of duties collected upon importation) on the sugar used in candying fruit that was subsequently exported; this amounted to a virtual bounty on citron exports (Drummond 1891).

Even so, Lelong (1902) was puzzled by Livorno's predominance:

> There appears to be no known law by which one can understand why certain industries establish themselves in given localities. Why, for example, should the candied citron and lemon peel industry become centered in Leghorn? The lemons and citrons are all imported from Corsica, Sicily, Calabria, and even from Tunis, Tripoli, and Morocco. The fuel comes from England, the sugar is imported from Egypt, the wood for the boxes from Trieste, and the earthenware vessels from Florence. The peel is sent away to Britain, Germany, America, etc.

One likely explanation is that from the 17th through the nineteenth centuries Livorno had a thriving Jewish community, which for some time was the foremost in Italy (Trivellato 2004). These Jews of course obtained etrogs for their own religious use, so these links could have formed the basis of the culinary citron trade.

In the 1880s Livorno had nine factories for candying citron, employing about 300 workers and producing 2,000 mt annually. Of this the United States took about 42%, while the rest was sent to Holland for distribution to northern Europe and England (Alden et al. 1886).

From 1904 to 1908, Livorno annually imported an average of 860 mt of citron, 56% from Corsica, 26% from Calabria, and 18% from Greece. Candied citron accounted for nearly 90% of shipments by weight, and citron in brine less than 11% (Cameron 1924).

At that time Corsica exported 2,400 mt of citron on average, of which 98% was brined, and 2% candied. Belgium took 51% of these shipments, Italy 22%, Great Britain 10%, Germany 8%, and continental France 5%. Belgium took such a large share because the Vincentelli company, founded by a Cap-Corsin family, operated a confectionery factory in Antwerp. Belgium was a major producer of beet sugar, and citron could be candied more cheaply there than in Italy or France (Cameron 1924).

After the First World War Americans started buying brined citron directly from Corsica, an average of 200 mt annually from 1920 to 1924 (Cameron 1924).

10.13 Corsican Confectioners

The price paid for citron fluctuated wildly depending on the harvest in Corsica and other producing areas, but also—much to the annoyance of Corsican growers—on the machinations of speculators (Alden et al. 1886). Candied citron was far more valuable than raw or brined fruit, and most of the profits were earned by candying companies and traders.

From the 1850s to the 1930s Corsicans passionately advocated the establishment of a local citron candying industry and the changes in customs duties necessary for it to flourish (Tomei 1860; Piccioni 1864, 1872; Enquête agricole 1867; Vincentelli 1931):

> [It] is evident that it would be impossible for the manufacturers of Corsica to compete with the confectioners of Geneva and Livorno (which both enjoy the advantages of free ports), without obtaining in advance from His Excellency the Minister of Commerce, at least, the excise regime which we have just brought to your attention (Piccioni 1864).

Artisanal confectioners prepared candied citron on Corsica before the middle of the nineteenth century. In the 1860s there were four in Ajaccio, three in Corte, three in Ile-Rousse and nine in Bastia. From the 1870s larger confectioners in Bastia emerged. The first was Vincent *Canugli et Cie*, which was established in 1876 in the Lupino district of Bastia, employed 15 workers, and marketed as the "*Confiserie des cédrats de la Corse*".

Fig. 10.13 "Genuine Citron of Corsica" label for candied citron from *Gregori et Cie*, Bastia

Another company was started by an Englishman, Arthur Southwell, in the late 1870s. It was taken over by Paul Michel Cesarini and operated on the docks of Bastia as the *Société Cesarini et Cie*. Louis-Napoléon Mattei started *Mattei et Cie* in Bastia in 1885 and took over the Cesarini business in 1896 (Indekeu 2020).

The Gregori de Canari family, citron growers at Canari on Cap Corse, started a candying factory at Bastia in 1880 (Fig. 10.13). The company struggled and passed through several transformations, until Pierre Vincentelli, a grower from Morsiglia on Cap Corse, took over the business (Indekeu 2020). Vincentelli and his family eventually gave up citron production, but flourished after establishing a confectionery factory in Antwerp in 1883. Between 1870 and 1970 the Vincentellis processed citron in Bastia, Antwerp, Holland, and Norway (Lorenzi 2002; Indekeu 2020).

By 1902 the citron candying business on Corsica was concentrated in three businesses in Bastia, the Battisti brothers, Vincentelli, and Mattei.

Corsicans long strove to seize the value added by candying for themselves and to escape dependence on Livorno, but because of the foreign drawback on customs duties for sugar, and taxes on the export of Corsican candied citron, it was an uphill struggle. The lack of specialized technicians, the sizeable investment required, the impossibility of controlling regional harvests, and the competition from Livorno merchants also proved strong obstacles.

As late as 1931 Ange-François Vincentelli proposed to resolve "the crisis that citron cultivation is currently going through" by establishing a First Corsican Preserving Company, "a candied fruit factory … to come to the aid to our arborists, to save them from ruin" (Vincentelli 1931). But his proposal failed to gain traction, and by 1936 Corsican manufacturers had abandoned the large-scale candying of citron.

10.14 Causes of the Decline

Contemporary sources agree that Corsican citron enjoyed a premium over the foreign competition because of its superior quality and flavor (Drummond 1891; Cameron 1924). So why did the Corsican industry virtually disappear while its competitors thrived?

From the beginning, Corsican citron cultivation was risky, because of erratic production—sometimes excessive, sometimes catastrophically small because of freezes—and inherently limited demand for a product that was inedible fresh. Already in 1827 and 1835 some growers had to cut down their trees because they weren't able to sell their crops (Piccioni 1864). When the high prices and good harvests came together, growers could make extraordinary profits. But this was rare, and could lead to unjustifiably high taxes on citron properties (Piccioni 1864).

The cycle of boom and bust seems to have been particularly severe for citron. Even at the peak of production and prosperity in the late nineteenth century, many years were calamitous. Gustave de Molinari, a Belgian economist, observed in 1884:

> The splendid valley of Luri, to name but one, is nothing but a vast and superb garden. The citron tree, in its heyday, made great fortunes there. I say in its good old days, because the owners of Cap Corse, for lack of having sufficiently studied the law of supply and demand, ended up overloading the market for citrons, and being victims of this law, no more no less than simple proletarians. Citrons suffered a crisis, prices fell, and many a citron owner was ruined (Indekeu 2020).

Candied citron can be stored for years, so in theory Corsicans should have been able to ride out the economic cycles, but that depended on a viable local candying industry, and this never took more than a small portion of citron production. The main reason was that local candying factories were hindered by the French tariff policy on sugar, which represented almost 50% of the weight of candied citron, and two-thirds of the cost of production. The other barrier was the French tax on manufactured products shipped from Corsica to mainland France. A modification of the customs regime in 1912 was too late to save the Bastia confectioners, who had already closed or moved production abroad.

The agricultural crisis of World War 1, accompanied by depopulation of the countryside, emigration to cities, and interruption in international markets, exacerbated the decline (Indekeu 2020).

But the death blow for the Corsican citron industry was competition with Italian and Puerto Rican citron growers. These two main producers soon controlled the citron market and imposed their prices. They benefited from infrastructure (large estates, commercial networks), technology (steam engines and new preparation techniques), and cheaper sugar (Puerto Rico was a producer and Italy benefitted from competition among European producers).

The success of Puerto Rico at Corsica's expense was ironic, because it was Cap-Corsins who brought scions of 'Corsican' citron to the tropical island at the beginning of the twentieth century. When they settled in Puerto Rico, the Corsicans also had the technical knowledge and commercial contacts in the citron industry that enabled the success of their production, manufacturing, and export to the United States and European markets (Orengo Serra 2002). While Corsican citron production declined, the Puerto Rican harvest rose from 1,950 mt in 1931 to 5,100 mt the following year, and 9,300 mt in 1934. This surge, along with declining demand during the economic crisis of the 1930s, swiftly ruined many Corsican producers.

10.15 '*Vittime*': Citrons Harvested for Jewish Ritual Use

Although most of the citrons grown on Corsica in the nineteenth century were intended for brining and candying, some were sold for Jewish ritual use for Succoth, the Feast of Tabernacles. These fruits were harvested as a sideline by Christian growers whose primary market was culinary; they exported to Livorno and Genoa, where the Jewish communities were substantial, and etrog traders resold to mainland Europe (Lorenzi 2002; Indekeu 2020).

Jews had lived for centuries in most of the Western Mediterranean region, notably on Sardinia since 19 CE. But it was only in the eighteenth century that Jews were encouraged to settle on Corsica, and at the end of the nineteenth century that a few families settled in Bastia; the Corsican Jewish population remained stable at about 150 through the end of the twentieth century (Skolnik 2007).

The trade in etrogs for Jewish use appears to have developed after the start of cultivation for culinary purposes. Shortly before 1820, the French consul in Trieste informed the subprefect of Bastia of the commercial potential of citron for sale to the Jewish community (Lorenzi 2002). By 1841 Jews from Genoa and Livorno bought citrons grown in Cap Corse (Indekeu 2020).

Contemporary sources, including Galletti (1863), Piccioni (1864), and Boitel (1875), called the citrons sold for Jewish use "*vittime*" (plural; the singular was "*vittima*"):

> Towards the months of July and August, in certain localities of Cap Corse, a few young and green fruits are collected from the trees for the Jews, who use them, under the name *vittime*, at their Feast of Tabernacles (Boitel 1875).

The word "*vittima*" means "victim", which now seems odd, even sinister, but apparently no prejudice was intended. Piccioni (1864) misconstrued the fruit as being for "Jewish priests to celebrate their Easter", and the name as representing "an offering, innocent sacrifice, first fruits, or probable symbol of the immaculate lamb they are still waiting for". More recently, Lorenzi (2002) surmised that the *vittima*'s "ridged appearance could make one think of the sacrificial sheep which could have been its substitute."

Of course, Yiddish-speaking Ashkenazi Jews did not call etrogs *vittima*; their name for Corsican fruits in the nineteenth century was "*Korsikaner*" (Schwarzfuchs 1991).

According to Galletti (1863), the *vittima* usually sold for 60 centimes to one franc. Since one franc contained 0.29 g of pure gold, according to a Historical currency converter, at the price for gold ($1,718/oz.) on 14 Sept. 2022, this would be $17.63 in 2022 dollars, or €18.37 in 2022 euros; or in silver 4.71 g, worth $3.29 at $19.80/oz.

Galletti also related how Genoese merchants who were selling etrogs from other sources (probably from Calabria, from which the etrogs have long been marketed as "Yanaver") disparaged the kashruth of Corsican etrogs:

> The Genoese stirred up religious doubts in the minds of the Israelites, by making them believe that our *vittime* were produced by grafted plants, and that thus they did not meet the requirements of the Hebrew rite. The ruse was soon unmasked. A rabbi from Frankfurt went to Corsica, where he was able to assure himself that, for the sake of lucre, his co-religionists had been misled. Since then our *vittime*, which had fallen into disrepute, have taken on an even greater value than in the past (Galletti 1863).

This episode reflected the increasing prevalence of grafting in Mediterranean citriculture starting in the mid-nineteenth century, in response to the epidemic of foot-rot caused by various species of *Phytophthora* (Klotz 1978). Rabbinical authorities do not consider etrogs grown on grafted trees to be suitable for ritual use, so as the practice of grafting spread, controversies erupted over whether the etrogs grown in various regions were halachically pure, most prominently over Corfu etrogs (Salmon 2013; see also The Corfu Etrog Citron Polemic (Chap. 20) and The Grafted Etrog Citron Controversy (Chap. 21)).

The *Peri Ets Hayyim* published in Lemberg (Lviv, now in Ukraine) in 1846 considered Corsican etrogs acceptable because they were like fruits from wild trees (rather odd, considering how much care went into citron cultivation on Cap Corse). After doubt was cast on the halachic validity of Corfu etrogs, some rabbis recommended Corsican fruits as a suitable replacement, but they do not seem to have played a major role in the etrog trade (Schwarzfuchs 1991).

The commerce in Corsican-grown etrogs continued at least into the early twentieth century, and a few Corsicans still remembered it at the end of the century (Nivaggioli 2002). But this trade seems to have largely ceased by the postwar era, when Corsican culinary citron cultivation had collapsed. Since on Corsica today virtually all the citron trees are grafted, and the lineage—the "*yichus*", in a Hebrew-derived Yiddish term—of ungrafted etrog cultivation has been lost, the marketing of 'Corsican' citron for Jewish ritual use faces substantial challenges, at least for anyone trying to sell to the Orthodox and Ultraorthodox Jews who are the main buyers for high-quality etrogs.

However, in about 2020 one grower, Xavier Calizi of *Les cédrats du Cap Corse* in Barrettali, planted 100 ungrafted 'Corsican' citron trees, propagated by cuttings, intending to sell the fruits for Jewish ritual use. So this longstanding tradition may yet return.

10.16 Citron Cultivation on Corsica Today

Although the cultivation of ‘Corsican’ citron on its namesake island is far lower than at its historical peak more than a century ago, there is still an active industry whose production is highly appreciated by connoisseurs.

In 2022 there are five commercial growers who each have from 0.3 to 6 ha, amounting to a total of about 15 ha across the island, about half of which is in full bearing. Cultivation has increased slightly in recent years, but is now stabilized, because there’s only a limited market.

The main production area is on the east coast of the island, called the Eastern Plain, or “*Plaine Orientale*” in French. The advantage of this area is that the land is flat, making cultivation easier than in the hilly districts where citron was grown historically. Also, this is Corsica’s main production area for its most widely grown citrus, such as clementines and grapefruit, and a few of these growers also grow citron.

The area has a typical Mediterranean climate, with average rainfall of 600–800 mm, most of which falls in autumn and spring, less in winter; summers are dry. Frosts are now very rare and tend to be light and brief. The humidity brought by maritime breezes, frequently above 80%, favors regular flowering.

However, the area is susceptible to damage by high winds, which are so feared and well-known that the Corsicans give them their own names, such as the *Libecciu* from the west and southwest, the *Sciroccu* from the south, and the *Livantu* from the east. These winds defoliate the trees, and scar both the young and mature fruits (Fig. 10.14). Most farmers install windbreaks, traditionally cypress trees, and since the 1960s and 70s, the rose she-oak or forest oak, *Allocasuarina tortulosa*.

Fig. 10.14 ‘Corsican’ citron fruit with typical scarring (*Photo credit* F. Curk, INRAE)

This area has ancient alluvial soils, moderately stony, and acidic, with an average pH of 6. The soils are non-calcareous clay loam, low in assimilable phosphorus and organic matter. Few citrus-growing areas in the Mediterranean Basin have soils with such favorable characteristics, which allow the use of a wide range of rootstocks for citrus production (Jacquemond et al. 2013).

Almost all of the citron trees on Corsica are grafted. The majority of the trees are on 'Volkamer' lemon (*C.* × *limonia* var. *volkameriana*), which imparts vigor and productivity to the scion, but has the disadvantages of bud union undergrowth and short tree life (Blondel et al. 1986). Second in importance is sour orange, which is well-adapted to many types of soils, and is highly compatible with citron, so tree life is longer than on 'Volkamer'; on the downside, yields are lower than on 'Volkamer'.

Corsican growers usually plant citron trees in May and June, as for other citrus. The usual spacing is 6 m between rows, and 4 m between trees in a row; so about 416 trees are planted per hectare. Young trees are planted with a stake to facilitate growth but mature trees grow in open fields without trellises. Growers prune to shape the tree in the first few years after planting, to ensure a regular, well-distributed structure. Once the tree starts to bear, three or four years after planting, they don't prune as much, mostly seeking to cut out dead wood and thorns, limit water sprouts, and ensure the equilibrium of the tree's architecture.

Farmers irrigate their orchards during the dry period, approximately from May to September. The quantities required depend on rainfall and soil type; including rain, trees need 3,000–4,000 cubic meters of water per hectare annually. Some growers use sprinklers, situated either on top of trees, or at ground level; others use microjets.

Citron trees require 120–160 kg ha^{-1} of pure nitrogen annually, a bit less than for clementines or oranges; organic farmers use organic fertilizers containing 2–10% nitrogen, usually of animal origin. These are usually given in three to five applications yearly, starting in January and ending in October (G. Benaouf, pers. comm.). Corsican citron growers control weeds mechanically, without using herbicides.

The main pests are the citrus blossom moth (*Prays citri*), leaf miner (*Phyllocnistis citrella*), aphids (*Aphis* spp.), spider mites (*Panonychus citri* and *Tetranychus urticae*), and scale insects such as red scale (*Aonidiella aurantii*), cottony cushion scale (*Icerya purchasi*), and citrus mealybug (*Planococcus citri*). A Mediterranean ant (*Tapinoma magnum*) is a particularly severe and growing problem because it cuts the spring shoots to suck their sap, limiting growth.

Over the past two decades virtually all of the citron production on Corsica has become certified organic. Growers control citrus blossom moth with *Bacillus thuringensis*. To suppress aphids, mites, and scale insects, growers use mineral oil. Growers control leaf miners on young trees by spraying azadirachtine, which is not approved for organic farming, so it cannot be used to produce organic citron on bearing trees. No treatments are available to deal with ants.

The most serious disease affecting citron on Corsica is still gummosis (*Phytophthora sp.*), which can attack the scion even when the rootstock is resistant. Also important is bacterial blast (*Pseudomonas syringae*), which appears in humid autumns and at the end of winter; growers prevent this disease by using copper spray. Mal secco (*Plenodomus tracheiphilus* (formerly *Phoma tracheiphila*)), which is present in southeastern mainland France and in Italy, is not currently found in Corsica, after two previous outbreaks were eradicated. Keeping Corsica free from mal secco is a major concern for growers, who therefore avoid bringing plant material from infected areas.

For harvest, workers clip 'Corsican' citron fruits by hand directly into small boxes, or into 200-kg bins. The fruits are stored in a location that is cool, but not refrigerated; fruit decays more quickly at temperatures below 8 °C. Mature 'Corsican' citron plantings can produce 10–15 t ha^{-1} annually. Corsica's citron production is estimated at between 60 and 100 t annually, based on the fresh fruit equivalent.

The main uses for 'Corsican' citron are for candying, preserves, *cédratine* and other liqueurs and spirits, which together account for 80–90% of production. The rest are sold fresh on local markets and to mainland France (10%) and for use in cosmetics such as shampoos and cold creams, and in perfumes (<10%). There would be more interest by cosmetics and perfume makers in the essential oil of 'Corsican' citron, but the economic production of citron rind oil is impractical because the fruit is so large it has a low ratio of flavedo to fruit mass, and the bumpy rind makes the standard rasping devices used to obtain rind oil inefficient.

Corsican citron growers don't compete that much anymore with low-cost foreign growers of bulk candied citron, and so diced candied citron is only rarely produced in Corsica (Fig. 10.15). *Cédrat confit*, candied whole citron with the pulp scooped out, as well as halves, quarters, or strips of candied rind, has enjoyed renewed popularity as a Corsican specialty much appreciated by gourmets (Fig. 10.16). It had practically disappeared from the markets in Corsica, but is gradually becoming easier to find, especially during the end-of-year celebrations. The Corsicans sell to local markets and to high-end chefs and *pâtissiers* who are proud to use a high-quality product from Corsica.

Drummond (1891) imagined the possibilities for such a trade when he wrote:

> There is a certain method of candying the *cédrat* which produces an exquisite fruit, and of whose delicious flavour it is impossible to form any idea if one is only acquainted with the ordinary candied *cédrat* of commerce.

French buyers are very attracted to the local and national origin of Corsican citron. However, there is no protected denomination for "*Cédrat de Corse*", which would be difficult in any case because there is already a cultivar of that name, which has become a generic denomination. Calabrian candied citron is more abundant and less expensive than Corsican, and it is unfortunately possible to find on the Corsican markets elongated candied fruits, bright green with smooth skin, that are generally 'Diamante' citrons processed in Italy and resold under the false name *cédrat de Corse*.

Fig. 10.15 Diced candied 'Corsican' citron (*Photo credit* D. Karp)

10.17 Citron Liqueur (*Cédratine*)

A major use of Corsican citron, aside from candied citron and citron preserves, is for making citron liqueur. Corsican citron liqueur is often generically called "*cédratine*", after the best-known brand, but according to the World Intellectual Property Organization Global Brands Database, in France "*Cédratine*" is a registered trademark of Distillerie L.N. Mattei, based in Borgo, just south of Bastia.

The Corsican spirits manufacturer Louis-Napoléon Mattei introduced a citron liqueur under this name in 1880 (Figs. 17 and 18). However, liqueurs made with dried zest of citron macerated in brandy had existed at least since the eighteenth century, and it's possible that such beverages were made in Corsica at that time. Liqueur factories operated in Bastia in the 1830s, but it is not known what flavors they produced; Bérard et al. (1996) maintained that "it is more than likely that a citron liqueur was already made on the island and that the *Cédratine* that we know is only the heir to a long tradition."

Currently there are at least six Corsican producers of citron liqueur, which is a colorless or golden yellow liquid, depending on the manufacturer, with a sour taste. It is made from citron extracts, distillates of aromatic plants, syrup, and alcohol, and contains from 24 to 35% alcohol by volume. In the distillation process citron extract is macerated with alcohol in a special kettle called a "*conge*" for at least one year.

Fig. 10.16 Whole candied 'Corsican' citron, and two strips (*Photo credit* D. Karp)

Then the whole is inverted in a still heated by a container filled with hot water called a "*bain-marie*". The mixture boils for half a day, then is cooled in a tank filled with cold running water, and bottled (Bérard et al. 1996).

10.18 Citrons Other than 'Corsican' on Corsica

The vast majority of the citron trees grown on Corsica are of the 'Corsican' cultivar, but there are scattered trees of fingered citron in home gardens and one grower, near Linguizeta on the Eastern Plain, has a commercial planting of less than 1 ha which he uses to sell fresh fruit to a wholesale buyer.

The INRAE-Cirad research station in San Giuliano houses one of the world's largest and most diverse citrus germplasm collections, which was established in 1958 with cultivars from the colonial collections in Morocco, Algeria, and Guinea. With the addition of varieties from other countries, it now has more than 800 genetically distinct accessions, including 21 citrons and citron hybrids. It has several rare cultivars such as 'Fourny' from Corsica and 'Humpang' from Bhutan. F. Luro et al.

Fig. 10.17 *Cédratine* Mattei advertisement with recipe for candied citron

(2012) surveyed the citrons and relatives using genetic and chemical markers to determine for each cultivar whether it was a pure citron, a citron hybrid, or something else not directly related to citron (Fig. 10.19; Table 10.2).

10.19 Bioindexing Using 'Etrog' Citron

The SRA citrus collection founded in the late 1950s in Corsica started with virus-free material. Many viruses and viroids can affect citrus plants. In order to be sure that healthy material is propagated, the French researchers control all new arrived accessions and regularly test all the trees in the collection's orchard. In order to produce and test disease-free plants, different techniques or a combination of techniques have been applied. For many years, before the use of molecular techniques, exocortis, cachexia-xyloporosis and other citrus viroids were tested by biological indexing, using citron as an indicator plant. The test for exocortis by indexing on 'Etrog' citron was developed in 1963 in California by E. Clair Calavan (Calavan et al. 1964) and applied the same year in Corsica. Using this method, symptoms appeared after a few weeks, about 8 weeks in good growing conditions (Vogel 1966). Previously, the indexing was done either on trifoliate orange (*Poncirus trifoliata*), which

Fig. 10.18 *Cédratine* sculpture at the old Mattei building in Bastia (*Photo credit* D. Karp)

required about 8 years for results, or on Rangpur lime, on which some viroid strains were not detected.

This new biological indexing by graft inoculation through direct contact between a tested plant and 'Etrog' citron as an indicator plant was used routinely at the San Giuliano research station from the end of the 1960s to the early 2000s. Virus-free 'Etrog 861-S-1' citron buds were grafted onto 'Volkamer' lemon as a rootstock (Vogel et al. 1988). Once the citron plant reached a suitable size to be grafted, one or two blind bark samples of the tested accession were grafted directly on the trunk of the citron plant. Depending on the growing conditions, about 8 weeks later, an

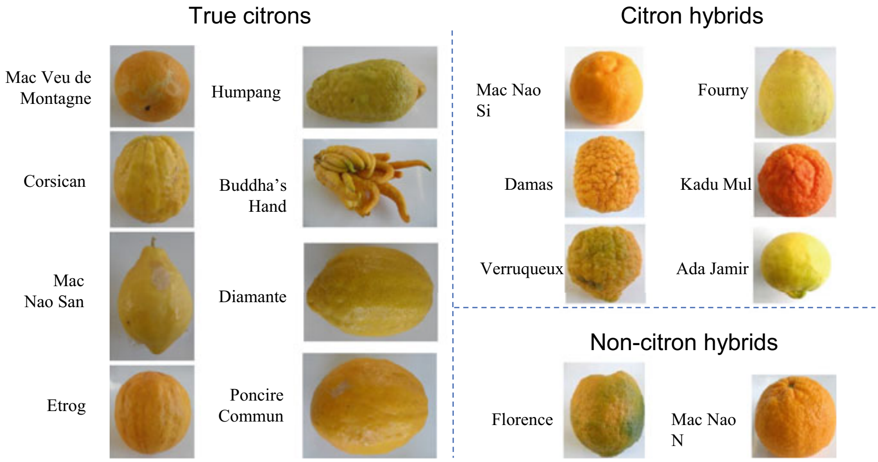

Fig. 10.19 Citron diversity of the INRAE-Cirad citrus germplasm collection

observation of the symptoms was made in comparison with a negative citron plant as a control. Citron plants with tip browning and epinasty were considered as positives.

In the late 1980s, viroid detection was improved by combining indicator plant inoculation (using 'Etrog' citron) and denaturing acrylamide gel electrophoresis (sPAGE, Duran-Vila et al. 1988). At the San Giuliano research station (SRA), this detection technique used the highly susceptible 'Etrog 861-S1' citron tree as a viroid amplifier, and sPAGE allowed the detection and identification of 11 possible viroids, 6 months after their inoculation, even for those not causing symptoms (Caruana et al. 1992). To allow identification of viroids, the SRA had a greenhouse collection of 11 viroids inoculated separately to the 'Etrog 861-S1' citrus trees which came from the IVIA station in Moncada, Valencia, Spain. Nowadays this technique of detection of virus and viroids by biological indexing on 'Etrog' citron combined with sPAGE has been replaced by the more reliable RT-PCR detection procedure.

10.20 The Citron in Corsican Culture

The citron in Corsica represented chiefly a cash crop intended for export and was very little transformed and consumed on the island, even during the golden age of its production in the late 19th and early twentieth centuries. It therefore never became a food rooted in the island's culture, as is the case today with cheese or *charcuterie*, which represent the traditional ways of preserving milk and meat in Corsica's mountain villages. The cultural and therefore artistic appropriation of this citrus fruit has never really taken place, unlike the cases of sweet and sour oranges, which both play roles in essentially Corsican religious traditions. For example, the fruits and flowers of the *bigaradier* (sour orange) were used as symbols of purity

Table 10.2 Citron, citron hybrid, and citron-like cultivars in the INRAE-Cirad citrus germplasm collection

	Cultivar	Putative origin	Description	Notes
True citron	Assads		Fruit shape irregular bumpy, flowers white, pulp soft, acidless, like Corsican	Phenotypically close to Corsican but chemically and genetically distinct
	Buddha's Hand		Fruit fingered, pulp lacking	
	de Chine		Fruit small, shape acute and mamiform, rind smooth, yellow; very dense	
	Corsican		Fruit size variable, shape irregular, rind bumpy, dark yellow when fully ripe, flowers white, pulp soft, acidless	
	Diamante		Fruit very large, shape mainly oblong, very dense	
	Etrog or Ethrog	861 S1 is backrossed 861	Fruit resembles Corsican but with acidic pulp and purple petals	Three accessions genetically distinct
	Humpang		Fruit very large, ovoid-pyriform, rind bumpy	
	Mac Nao San		Fruit small, shape acute and mamiform, with a persistant style and stigma	
	Mac Veu de Montagne		Fruit small, shape mainly ovoid, rind dark yellow, texture very dense	
	Poncire Commun		Fruit resembles Corsican but with acidic pulp and purple petals	Putative ancestor of Corsican
Citron hybrids	Ada Jamir	Papeda? × citron	Fruit spheroid, rind light yellow green, with floral aroma	

(continued)

Table 10.2 (continued)

	Cultivar	Putative origin	Description	Notes
	Damas/Ommeyades	Sour orange × citron	Fruit midsize, oblong, rind very bumpy, rough, yellow-orange; texture very dense	Genetically identical and close phenotypically in San Giuliano collection
	Fourny	Pummelo × citron	Fruit large (600 g), pyriform, rind green, smooth, thin (<2 cm)	Name of the nurseryman who gave it to San Giuliano collection
	Kadu Mul	Mandarin × citron	Fruit midsize (200 g); rind very red, rough	
	Mac Nao Si	Sweet orange × citron	Fruit midsize, spheroid, with a mamelinated apex with a very hollow groove at the base of the apex; rind yellow-orange	
	Pompia/Rhobs el Arsa	sour Orange × citron	Fruit 400 g, oblate with a very hollow groove at the base of the apex; rind yellow-green, rough, albedo 30% of fruit diameter	Genetically identical in San Giuliano collection
	Verruqueux	Papeda? × citron	Fruit large, oblong, with a prominent mamelinated apex; rind yellow-orange, very bumpy, rough, very thick, not very dense	
Other	Florence	Sour orange × lemon	Fruit large, very light, with a large pointed nipple; rind lumpy with two sides colored orange, the other green, very thick, pulp orange	Not a direct citron hybrid
	Mac Nao N	Papeda? × sour orange?	Fruit spheroid, rind orange, pulp orange	Not a direct citron hybrid

and fertility at weddings. The fruits were hung at the top of huge heather arches that decorated the entrance to the home of the bride, who wore a crown adorned with white orange blossoms. The sweet orange, present in Corsica since the seventeenth century, is celebrated every first Sunday following January 17 (St. Anthony) in the village of Aregno in Balagne, where a statue of St. Anthony adorned with oranges is carried through the streets of the village.

In contrast, the citron has inspired only weak artistic interest on the island, almost always linked to its economic importance, and in particular thanks to Louis-Napoleon Mattei, the founder of Mattei and Co. This Corsican entrepreneur, ahead of his time in terms of advertising, promoted his products around the world, including his eponymous quinquina-based aperitif and, above all, his *Cédratine*, of which we can still enjoy posters in the style of the Belle Epoque (Fig. 10.17). One of his stores, still open today, is a remarkable building in Bastia with bas-reliefs on the facade representing citron fruits at the foot of a bottle of *Cédratine* (Fig. 10.18).

In homage to the Mattei house, a mazurka and a java for mandolin, both named "Cédratine", were composed respectively in 1913 and 1928 by François Menichetti (or Menighetti, 1894–1969) a French composer born in Bastia, also known under the pseudonym François Detoga.

More recently two novels speak of the forgotten culture of the citron in Corsica. In *Le Jardin des Cédrats* by Bernard Farinelli (2007), the author describes a son's journey to Corsica with the ashes of his father, who was born on the island and died on the continent (Fig. 10.20). During this initiatory journey he rediscovers his roots and his family history closely linked to the cultivation of citron in Corsica. In *Les Cédrats Confits*, Valerie Denarnaud-Mayer (2013) shows that the candied citron is a product so special that it affects those who taste it like Proust's madeleine, as it unites beings separated by an ocean but who share a common heritage: Corsica and its candied citrons (Fig. 10.21).

The return to grace of this almost forgotten fruit may well inspire new generations of creators and artists so that finally the Corsican citron can enter the Pantheon of island products that define the *terroir* and the people who live there.

10.21 Citron's Place on Corsica Today

Considering that Corsican citron cultivation was economically important for a century, it seems odd that Corsicans never really took to eating it. It is almost reminiscent of colonial crops such as chocolate, which was grown in the South and almost exclusively consumed in the North. In other areas around the Mediterranean where citron had been established much longer, it played a far more significant culinary role. However, once commercial cultivation faded away, Corsicans often didn't even recognize the fruit, rarely grew citron trees in family gardens, and recipes were even scarcer (Nivaggioli 2002). Part of the explanation was that citron couldn't be eaten fresh, and the process for making candied citron required more than a week (Marius

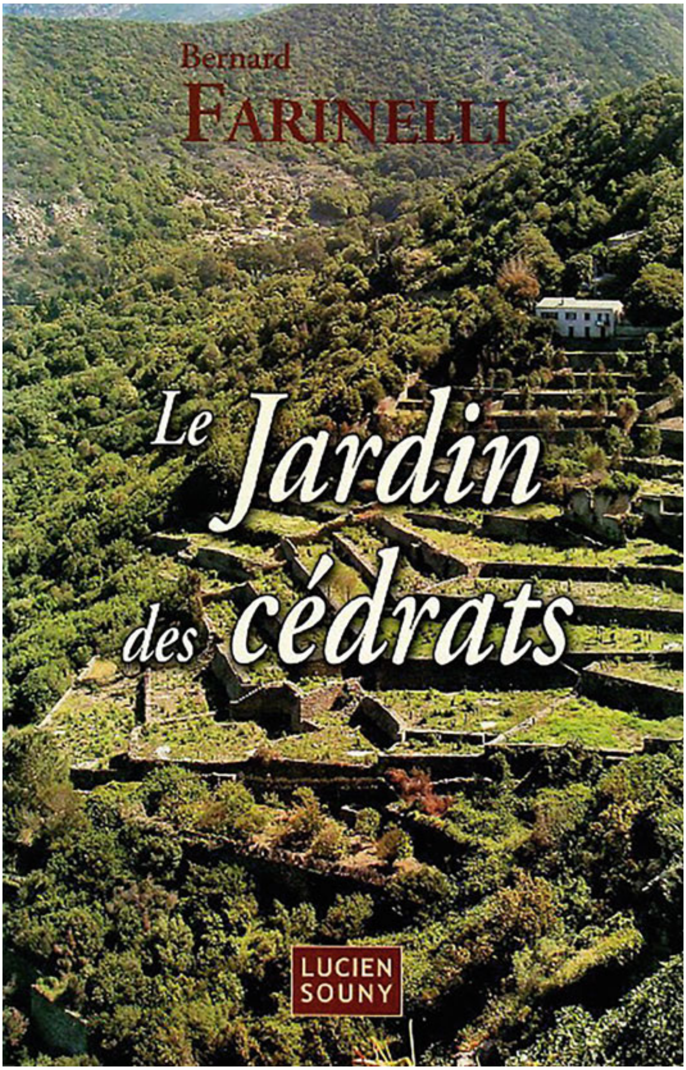

Fig. 10.20 Cover of *Le Jardin des Cédrats*, by Bernard Farinelli (2007)

and Morati 2003). But even citron jam, which "can easily be made at home in small quantities, is hardly consumed in Corsica" (Nivaggioli 2002):

Even *Cédratine* isn't all that popular for drinking on Corsica itself:

> Brief informal surveys have shown us that the Corsicans buy it above all to offer it, and tourists to taste something original... Moreover, in cafés, when *Cédratine* is not absent, the bottle lasts a very long time (Nivaggioli 2002).

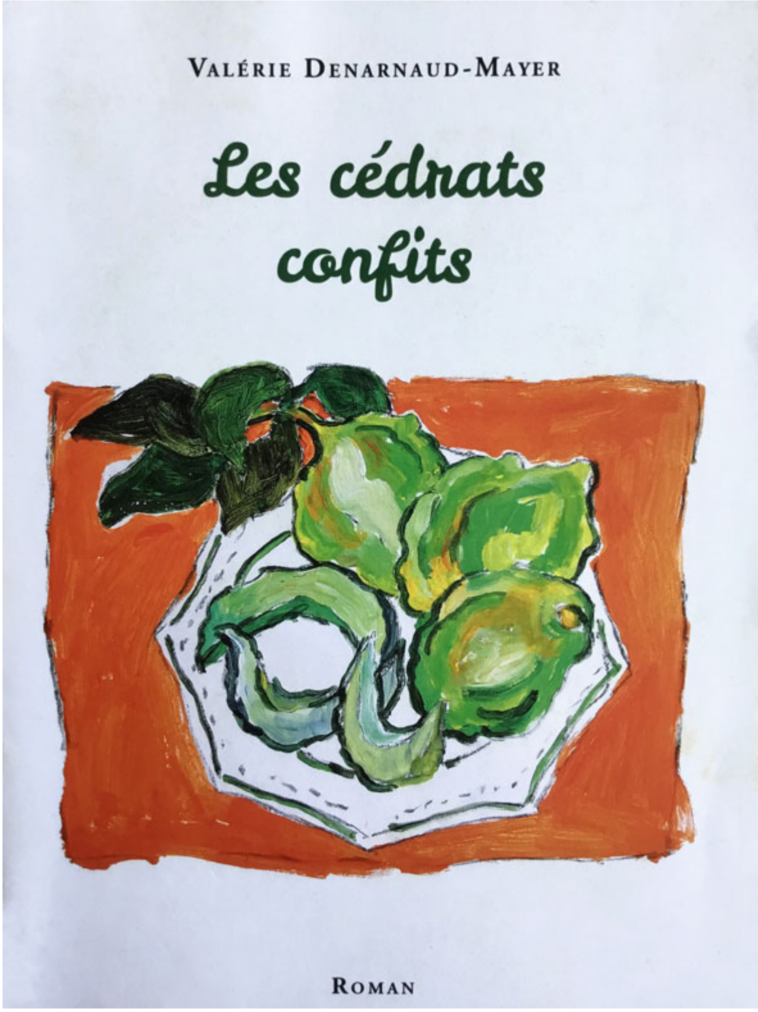

Fig. 10.21 Cover of *Les Cédrats Confits*, by Valerie Denarnaud-Mayer (2013)

Candied citron was one of the "thirteen desserts" traditionally used to celebrate Christmas in the French region of Provence, and the area's fruit and nougat factories historically were good customers for Corsican citron (Cameron 1924). But overall mainland France only used minimal quantities of candied citron (Vincentelli 1931).

Corsicans saw citron cultivation as a path to quick riches (Limperani 1872), and as a way to limit rural depopulation. So citron was basically a cash crop on Corsica, and when the profitability disappeared, so did the citron. For a century the rewards justified the risks, but when the end came, it came fast.

Nivaggioli (2002) perceived citron as having been “precipitated by time and contemporary society into the abyssal depths of Corsican memory. … Planted, but never really established in Corsica…”.

When she wrote that two decades ago, hardly any in-depth scholarly works about Corsican citron had appeared since the crop’s precipitous decline, aside from Bérard et al. (1996). However, since then, at least four significant studies have been written: Nivaggioli (2002), Lorenzi (2002), A Mimoria (2003), and Indekeu (2020). These studies are rooted in a keen and growing interest in culinary history and local products. That doesn’t mean that Corsican citron will or should be planted widely again—historical growers suffered enough dashed hopes—but current plantings seem well positioned to benefit from the renewed taste for this historic crop.

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Chapter 11
The Citron in the United States

David Karp

Abstract Citron (*Citrus medica* L.) arrived in the New World with Christopher Columbus, and was grown to a limited extent in the Atlantic colonies and the early United States. The rind was candied for use in baking for dishes such as fruitcake. Growers made many attempts to commercialize citron cultivation in California from the 1870s to the 1990s, and several developed successful businesses that lasted for decades. However, over time it was difficult for them to withstand competition from lower-priced imports, and no commercial plantings of culinary citron exist today in California. Since the 1990s one grower who raises etrogs for Jewish ritual use has flourished in California, as well as limited plantings of fingered citron. In Florida there were several attempts to grow citron for culinary use from the 1880s to the 1930s, but none succeeded. Tariffs significantly affected the incentive to grow, brine, and candy citron in the United States. Puerto Rico was the world's largest producer of culinary citron for most of the second half of the twentieth century, but diseases, hurricanes, and foreign competition destroyed the island's industry by 2017.

11.1 Introduction of the Citron and Its Spread in Colonial America

Like all forms of *Citrus*, citron (*Citrus medica* L.) is not native to the New World. As far as is known, it first arrived there with Christopher Columbus on his second voyage. According to Bartolome de Las Casas in his *Historia de las Indias*, which was written between 1520 and 1556, Columbus brought "seeds of oranges, lemons, and citrons" obtained on Gomera Island in the Canary group to the island of Hispaniola (today Haiti and Dominican Republic), where he arrived on Nov. 22, 1493 (de las Casas 1875). He then planted orchards and gardens in the new colony of Isabella (Webber 1967). Candied citron was one of the delicacies that Columbus requested from Spain for his household use in Isabella in 1494 (Deagan and Cruxent 2002).

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The naturalist Oviedo y Valdez, who visited Santo Domingo, Haiti from 1514 to 1525, found "great quantities" of citrons growing there, of "uniformly good quality" (Oviedo y Valdez 1851–1855).

In the sixteenth and seventeenth centuries citron was widely distributed in the Americas. About 1550 José de Acosta found citron trees growing in abundance in the West Indies (Acosta 1590). Citron arrived on the Mexican mainland before 1580 (Dunmire 2004). Garcilaso de la Vega wrote of citron growing abundantly in Peru in 1609. Citron was introduced to Puerto Rico by 1640 (Morton 1987).

Webber (1967) assumed that citrons were among the citrus fruits introduced to Florida in 1565 when the first colony was established there, in St. Augustine. In January, 1766 Bartram (1942) observed citron trees in St. Augustine devastated by a freeze. Citron is the most cold-tender of citrus fruits, and so could not have been cultivated successfully in open air on the East Coast except in southern and perhaps central Florida.

Further north, in the British colonies and the early United States, citron was grown along with other citrus in the eighteenth and nineteenth centuries in hothouses or greenhouses, which only the wealthy could afford to build, since glass was expensive. Some of the properties where citron is recorded as being grown include (National Gallery 2021):

- Springettsbury, Thomas Penn (son of William Penn), Philadelphia, PA (greenhouse built 1740; citron described 1745)
- Peter Schuyler's greenhouse and garden near the Passaic River, NJ (citron described 1760)
- Oxon Hill, Alexandria, VA (citron described 1808)
- Elgin Botanic Garden, David Hosack, midtown Manhattan, New York, NY (established 1801; citron described 1810)
- Lemon Hill, Henry Pratt, Philadelphia, PA (established 1799; citron described 1830)
- Montgomery Place, Janet Livingston Montgomery, Dutchess County, NY (established 1802; citron described 1847).

No doubt many of these trees served as ornamentals. For consumption citron was grown primarily for its rind, which was brined to remove the bitterness, soften the texture, and make it possible to absorb high concentrations of sugar when it was candied. Then it was used for baking, as documented in recipes for "A Rich Cake" and a "Bride Cake" in early American cookbooks (Carter 1772; Briggs 1792). By the 1820s citron was frequently sold in New York City markets (Taylor 1898). American pomological works from the second quarter of the nineteenth century described the citron and its use (Kenrick 1833; Downing 1845).

11.2 Increase in Consumption of Candied Citron

The candying of citron peel in sugar dates back at least to an Arab manuscript of the thirteenth century, when sugar from sugarcane grown in the Mediterranean was an expensive luxury. In the following centuries sugarcane cultivation spread to islands off the west coast of Africa, Brazil, and the Caribbean, relying on slave labor, and consumption in Europe increased. In the nineteenth century, as transportation and refining technology improved, and sugar beets were planted on a large scale in Europe, sugar became much cheaper, and sweets became readily available to the middle classes (Goldstein 2015).

Fruitcake was made with candied citrus peel at least as far back as the mid-seventeenth century, but really took off during the nineteenth century, as the cost of sugar fell and the introduction of the cast-iron cooking stove made cake baking easier. In addition, other Christmas desserts using candied citron such as *pannetone* in Italy and *weinacht stollen* in Germany became popular (Goldstein 2015). Citron also was used in sweets eaten at other times, such as *cassata*, wedding cake, and hot cross buns.

Immigrants from Europe brought the taste for these cakes to the United States, and as the country's population and wealth increased, a substantial transatlantic trade in brined and candied citron arose. Consequently, interest in American citron cultivation surged in the last third of the nineteenth century, when most of the candied citron available in the United States was imported from Europe.

11.3 Beginnings of Citron Cultivation in California

On the United States mainland, it was in California that citron cultivation eventually made the most progress, although it never became a major crop like oranges and lemons. Citrons grew at Mission La Purísima in Baja California (de Mora et al. 1774), and were very likely brought to Alta California in the late eighteenth century (De Grenade et al. 2014). Citron grew at Mission Santa Barbara by the early nineteenth century, and at Mission San Gabriel in 1826 and 1834 (Hardwick 2005).

William Wolfskill and Manuel Requena grew citron in Los Angeles in the 1850s, and it was listed in the nursery catalog of J.L.L.F. Warren of Sacramento in 1853 (Butterfield 1963). Trask (1854) reported that in coastal Southern California citron "was formerly cultivated to a considerable extent, and flourishes well at the present time." In 1866 just 4,000 to 5,000 citron fruits were marketed in San Francisco, according to an observer who also noted that "citrons of unsurpassed excellence and size are to be had in the south coast district, but are as yet only valued for their perfume or aroma and beauty" (Dunn 1868).

Starting in the 1870s, as commercial citrus cultivation in California accelerated, boosters (i.e., enthusiasts) and growers touted lucrative prospects for the citron. However, obtaining suitable citron cultivars, and discovering how to grow and process them proved difficult, and most early attempts failed. An article in the Los Angeles Herald (1874) stated the challenges:

> The great difficulty seems to be… to get rid of the intense bitterness of the rind. There are many varieties of the citron; is the citron growing here one of a bitter variety, and are there other kinds free from this objection? If this is the true citron of commerce, what is the process needed to free the fruit from this objectionable feature?

Excitement over the prospects for citron cultivation in California really increased in the 1880s. At the second annual citrus exhibition of Southern California, held in Riverside in 1880, growers displayed several lots of preserved citron (Hoag 1880).

In 1882 Thomas Garey, a pioneer of commercial citrus cultivation in California, wrote of the citron in the first book on citrus published in the state:

> The tree grows to perfection in this State in localities in which there are no heavy frosts. It is a good bearer, and the fruit is very large, some specimens weighing as much as four pounds and having a diameter of some four inches, but with a small pulp, three-fourths of the fruit being rind (Garey 1882).

Garey continued by quoting an article from the Los Angeles Commercial:

> For many years our orchardists have cultivated the citron, with the desire and belief that some individual or firm would be found capable of utilizing them for commercial purposes. But many seasons passed without any encouraging demand. The growers became discouraged and gradually neglected their trees; some indeed, unfortunately uprooted them. We are now about to hold forth the olive branch of promise, and a happy moment it is for us. We are authorized to state that a San Francisco firm, Messrs. James, Parisen & Co., have succeeded in preparing California citron, orange and lemon peel in so satisfactory a manner as to compare favorably with the best imported; and no better guaranty can be given than the fact that Messrs. Wm. T. Coleman & Co. have accepted the exclusive agency for the goods of this firm. Now, our advice to orchardists is, plant citron, China lemon, bitter and Seville oranges, as this firm will purchase, at fair prices, all that can be produced. This is certainly a bright outlook—a good outlook for products so easily raised, and which have hitherto proved so utterly unprofitable (Garey 1882).

However, just three years later Spalding (1885) reported that the San Francisco citron processing venture "was probably a failure."

In the same year the United States government sent out a request to its consuls in Italy for information about citron growing, processing, and trade in the Mediterranean Basin. They reported that the French island of Corsica was the leading citron-producing district. Most of the crop was brined, sliced, and candied at Leghorn (Livorno in Italian), a port on the western coast of Italy, and shipped from there. The United States bought 1.8 million of the 4.4 million pounds (about 816 of the 1996 mt) shipped from Livorno in 1884. Citron was also grown in Greece, Calabria, and Sicily. Speculation on citron was common on the New York City markets (Alden et al. 1886).

European citron producers were not eager to assist American competitors. In 1885 W.D. Smith tried to establish a citron orchard near Duarte, 30 miles east of downtown Los Angeles, in the foothills of the San Gabriel Mountains. He planted young citrus trees as rootstock, then sent for citron cuttings to Corsica, and budded over the young trees. But after tending them for at least two years, he was dismayed to find that he had been swindled: experts declared the scions to be lemons (Morris 1905). (The French word "*citron*" means "lemon"; the French word "*cédrat*" means "citron" in English.)

It may seem odd that a grower would have found it necessary to import citron budwood, when deliberately procured cultivars already were available in citrus-growing areas of the United States. In 1871 agents of the U.S. Department of Agriculture had collected a "selection of commercial citrons… intended to establish the manufacture of commercial citron" in the United States (Saunders 1898). But these did not include the prized 'Corsican'.

11.4 The "Citron of Commerce"

The type most in demand was the so-called citron of commerce (Fig. 11.1). Originally "citron of commerce" was a generic term for culinary citron, including any cultivars grown for brining and candying in the Mediterranean area (Daily Alta California 1867; Los Angeles Herald 1874; Garey 1882). Only much later, in the second edition of The Citrus Industry (Hodgson 1967), did the phrase become firmly linked with a specific cultivar, 'Corsican.' There is no name in Corsica or France (such as "cédrat de commerce") that is equivalent to "Citron of Commerce" (Boitel 1875). Originally and primarily it was a descriptive or group name, like "juice orange"; it served like "etrog," which can apply to multiple citron cultivars used for Jewish ritual (Karp 2009a). Alden et al. (1886) and most writers in the late 19th and early twentieth centuries classified as "citron of commerce" several citron cultivars used for brining and candying in the Mediterranean area. The American Pomological Society's Catalogue of fruits (Barry 1871) and Lelong (1888) considered 'Citron of Commerce' to be a synonym for 'Lemon', also called 'Sorrento', which was regarded by Schoonover (1939) as a synonym for 'Diamante', the most prevalent citron cultivar in Italy. Lelong (1900) described 'Lemon' as follows:

> This variety was among the first introduced, and has fruited regularly ever since. Shape oblong, like the lemon, with a very pleasant aroma, which is much esteemed. Skin bright yellow, smooth and very glossy; inner skin white, coarse and thick, with very little trace of bitterness. Pulp very bitter and deficient in juice.

Van Deman (1888) and the American Pomological Society Catalog of Fruits (Lyon 1891) also considered 'Lyman' (Fig. 11.2) to be a citron of commerce. Imported from the Mediterranean without a name, and christened 'Lyman' in 1887 after the Rev. Lyman Phelps of Sanford, FL, it was described as midsize, oval-oblong, with an orange-yellow rind that was sweet and edible (Van Deman 1888; Powers 1902).

By the first decade of the twentieth century, because Corsica was the best-known producer of culinary citron at the time, and 'Corsican' was the cultivar grown there, writers sometimes conflated "citron of commerce" with 'Corsican', which has acidless pulp. One of the first such examples refers to "Corsican citron, or citron of

Fig. 11.1 Watercolor illustrations of "Citron of Commerce" drawn for the USDA by Deborah G. Passmore, 1896. The caption describes the fruit as having been provided by the Los Angeles Chamber of Commerce

commerce" (Los Angeles Herald 1901). Reasoner (1903) called 'Corsican' "the real commercial citron, the only sort worth growing." Bailey (1914) referred to "the Corsican citron of commerce", but as in all of these examples, "citron of commerce" was in lowercase, indicating that it was a generic rather than a cultivar name, which generally would have been capitalized in the pomological literature of the era.

In the first edition of The Citrus Industry, Webber (1943) did not include a 'Citron of Commerce' in his list of citron varieties, evidently because he did not consider it to be a variety; but after Hodgson (1967) did treat 'Citron of Commerce' as a synonym for 'Corsican,' other writers followed him.

The 'Citron of Commerce' (CRC 3518) in the University of California, Riverside's Givaudan Citrus Variety Collection, which traces back to a budded tree bought from San Dimas Citrus Nurseries in 1907, has acidic flesh and more closely resembles 'Diamante' (Givaudin Citrus Variety Collection 2022; Toni Siebert, pers. comm. 2022). Recent concordance and phylogeny analyses show that CRC 3518 clusters most closely with 'Corsican' and 'Diamante', but is not identical to these or any other citron accessions in the collection (Y. Hiraoka, pers. comm. 2022). Perhaps CRC 3518 derived from one of the cultivars called "citron of commerce" before the phrase became synonymous with 'Corsican'.

When commercial citron cultivation started in California around 1890, numerous scattered dooryard trees already grew there. The Eleventh Census (1896) recorded

Fig. 11.2 Watercolor illustration of 'Lyman' citron grown in Florida, drawn for the USDA by Deborah G. Passmore, 1894

76 acres of bearing and nonbearing citron trees in 1889, broken down by county: Los Angeles, 5; Orange, 29; San Bernardino, 2; San Diego, 37; Ventura, 2. Most of the state's trees were located in coastal districts with relatively temperate climates, as suited the cold-tender citron.

11.5 Attempts to Import Elite Mediterranean Citron Cultivars

In 1890–1891 the USDA imported 15 citron cultivars, from Naples, Palermo, Catania, and Bastia, Corsica to distribute to prospective growers (Rural Californian 1892). Frank Kimball of National City, near San Diego, received 100 plants of 'Amalfi', 'Sorrento', and 'Calabria' citron, all shipped by the USDA from Naples, Italy—and all described as "Citron of Commerce" (Lelong 1891; Morris Nurseries 1892)! ('Calabria' is another synonym for 'Diamante', according to Fersini et al. 1973.) Kimball declared to the USDA pomologist, Henry E. Van Deman:

> I am satisfied there is a mine of wealth in the growing of the citron. … I hope to see every family in Southern California growing their own citron. …From all I can learn the citron will pay an enormous profit. … I have distributed nearly one hundred of the original importation, and thousands of buds (Lelong 1891).

In 1891 the United States consul at Bastia sent to Washington, DC 10 rooted cuttings of 'Corsican', "the choicest variety of the citron cultivated there" (Van Deman 1892). Kimball was among four recipients, in Florida and California.

The same year Kimball sent a sample of citron he had prepared to a San Francisco grocery house, and received a lucrative bid for 10 tons, which he was unable to supply (Los Angeles Times 1892). He eventually wrote a 133-page manuscript on citron cultivation, now preserved in the National City Public Library (M. Nye, pers. comm. 2008). According to Van Deman (1904) he sold the property with the citron trees to another owner who destroyed them; Kimball died in 1913.

As of the mid-1890s many of the citron cultivars imported by the USDA in 1871 and 1890–91 had proved spurious. According to Van Deman (1904), in 1890–91 the Italians had been incensed by reports of "the famous Mafia murders and lynching at New Orleans", and "this together with the jealousy with which they guarded the industry caused the Italians to send fraudulent trees." The Department's assistant pomologist, William A Taylor, declared "the results thus far obtained are somewhat disappointing" (Taylor 1895). 'Corsican' had not yet fruited and its budwood was still unobtainable or unsatisfactory for American growers. But Egbert N. Reasoner, a prominent nurseryman in Oneco, FL still held out hope:

> It has long been our desire to get the best type of commercial citron. Private and government agencies have signally failed, until this past autumn the Department of Agriculture has probably succeeded in introducing the best known sorts from Corsica (Reasoner 1895).

The hero, David Fairchild (Fig. 11.3), who later achieved renown as a botanist, plant explorer, and founder of the USDA's Office of Seed and Plant Introduction, was a 25-year-old traveling in Germany in autumn 1894 when he received a letter from a USDA assistant pomologist suggesting that he visit Corsica and send back authentic cuttings of 'Corsican' citron.

In Fairchild's account:

> It was the first time I had ever tried to get from a foreign people the plants with which to start an industry that would eventually remove one of its best buyers from the field and might some time lead to the appearance of a rival industry. I was nervous and had been advised that the Corsicans were not inclined to let scions of their fine citron trees go out of the country (Fairchild 1906).

Later he related how it was an "an ill-fated expedition from the start". When he climbed to Borgo, a picturesque citron-growing village, a gendarme arrested him on suspicion of espionage. But he managed to talk his way out of jail, snipped some

Fig. 11.3 David Fairchild, founder of the USDA's Office of Seed and Plant Introduction, who visited Corsica in 1894 to obtain bud-sticks of 'Corsican' citron

citron bud-sticks on his way out and hid them under his coat. "I am glad to report that they reached home successfully and proved of real value to our citrus growers," he wrote many years later (Fairchild 1939).

By the end of the nineteenth century Lelong (1900) cited 23 citron cultivars as being present in California. He mentioned three main cultivars: 'Lemon' aka 'Sorrento'; 'Lyman', as described above; and 'Orange', which he described thus:

> Fruit somewhat cone-shaped, more pointed than common variety; color that of an ordinary orange; rind cream-colored; pulp yellowish; rind sweet and highly aromatic; fruit possesses less bitterness than the common variety; tree a small stiff erect grower.

Harcourt (1886) described 'Orange' differently:

> Shape round, like an orange; size large; skin pale yellow, rough and glossy; inner skin white, coarse, and thick; a very desirable variety.

"Orange' may have been a hybrid of sour orange and citron, perhaps 'Poncire de Cotlliure', which was used for candying in Europe (Bachès and Bachès 2002). For the other 20 varieties only the name is mentioned; most of them, such as 'Testa de Turco', 'Incompio', and 'Simoniformis', are no longer extant in California, at least under those names, and little or nothing is known about them. Curiously Lelong (1900) did not yet mention "Corsican', about which such a great fuss was made in contemporaneous sources.

11.6 Early 20th Century Citron Plantings in California

In 1898 the USDA sent ‘Corsican’ trees and buds to W.D. Smith, who previously had been duped in trying to obtain that cultivar. He sold out to Dr. Henricus W. Westlake, a Canadian doctor who arrived in Los Angeles in 1888, and after whom the Westlake neighborhood west of downtown was named. In 1899 the farm planted 5,000 trees or 20 acres (8 ha) of ‘Corsican’ citron, the largest orchard of its kind in the United States, on the Duarte property, “high up in the foothills free from frosts and fogs” (Los Angeles Times 1902, 1905a). That was a major gamble, because according to the Pacific Rural Press, in 1900 only 4,780 citron trees were grown in California (Pacific Rural Press 1901).

In 1904 the leading citron processor in Southern California was the Barnard Densmore Company of Los Angeles, whose president, Emmet Densmore, was a prominent advocate of the alternative medical belief system called natural hygiene, and promoted a fruit and meat diet (Van Deman 1904).

In 1902 Westlake built a factory nearby in Monrovia to brine and candy his citrons, which were harvested in November and December. In 1904 he sold $50,000 worth of stock in his California Corsica Citron Company, and moved the processing plant to Los Angeles, planning to enlarge it (Los Angeles Times 1904a). Westlake’s orchard was yielding 272,000 kg annually, sold locally and throughout the Southwest for $0.25/lb. ($0.56/kg) retail, and he planned to plant another 24 ha of citrons. “The growth of this industry will stimulate the planting of citron trees all over Southern California,” boasted an article in the Los Angeles Times. “Others are also contemplating budding over their orange trees to citron” (Los Angeles Times 1904a, 1905a).

On May 13, 1905, however, Westlake died at his home at the age of 48 (Los Angeles Times 1905b). His citron orchard was neglected after his death, and in around 1909 was replaced by orange, avocado, and other trees (California State Board of Agriculture 1915).

In 1899 the USDA provided ‘Corsican’ citron cuttings to D.W. McLeod, one of the earliest settlers of Riverside (Los Angeles Times 1901). Two years later he was able to send the USDA a fruit, which was depicted by Deborah G. Passmore in two watercolors (Los Angeles Times 1904b; Fig. 11.4). In the first edition of The Citrus Industry, H.J. Webber related the history of this planting:

> …about 1900, a grove of 15 acres [6 ha] of the Corsican budded on sour orange was planted near Riverside, California. This grove for several years produced a fairly good crop of fruit which was processed and candied in a special plant constructed for the purpose. The candied product was pronounced equal to the best imported article and sold readily in the markets. Unfortunately, this grove was in a comparatively cold section and the trees were several times severely frosted. They were almost all killed in 1913 and a few years later the remnants were removed (Webber 1943).

Citrus cultivation was a major economic engine in Southern California’s Inland Empire in the early twentieth century, and was surrounded by an aura of romance and prestige, particularly in the Riverside area (Klotz et al. 1989; Boulé 2013). In

Fig. 11.4 Watercolor illustrations of 'Corsican' citron grown by D.W. McLeod in Riverside, CA, drawn for the USDA by Deborah G. Passmore, 1901

about 1905 wealthy English investors started planting citron on the West Riverside Estate, Ltd., in the area west of Riverside now known as Pedley. By July 1908 the groves had been sold to the San Jacinto Land Company, which had 9 acres (3.6 ha) of established trees, producing 36,300 kg of candied citron that were processed by the company. At that time John R. Newberry, the founder of one of Southern California's first grocery chains, J.R. Newberry and Company, signed an agreement to handle all the citron grown at West Riverside for the next 10 years (Los Angeles Times 1908a, b; California Fruit Grower 1908).

In 1910 this planting was in fine condition and covered 6 ha, which was said to be the largest in California (Wright 1910). In 1911 J.R. Newberry started winding down his business (Retail Grocers' Advocate 1912). All of the citron groves on the West Riverside Estate were sold to two Indianapolis businessmen, W.B. Westlake (unrelated to H.W. Westlake) and B.W. Crowe, who claimed to have perfected a process to produce candied citron of the highest quality (Los Angeles Times 1911). In 1913, when the citron groves covered 20 acres (8 ha), they were hit hard by a severe freeze, suffering more than neighboring lemons (California Citrograph 1916b). Statistics from 1915 show Riverside County as having 20 acres (8 ha) of bearing citron, and 36 acres (14.5 ha) nonbearing (Riverside Daily Press 1915). In 1916 the West Riverside citron grove was described as "unique and profitable" (Riverside Daily Press 1916); but in 1918 J. Elliot Coit referred to the citron "formerly grown" at West Riverside

(Coit 1918). In 1919 it was still the only major citron orchard in the state (California Cultivator 1919). By the early 1920s, however, most of the West Riverside Estate had been sold off for homes and small farms, and nothing more was heard of its citron planting.

11.7 Demand for Etrogs During World War I

Before the First World War, most of the world's supply of citrons for Jewish ritual use came from Palestine and the Greek islands. During the war these shipments were interrupted, and some observers considered that American growers had a potentially lucrative opportunity:

> Smooth, perfect specimens of Cedrats of the most desired size sometimes sell at $5 or more apiece. Even the average run of fruit brings well over a dollar a pound, so that the Cedrat is probably the most costly fruit in the world. … As a considerable quantity of Cedrats are imported into the United States annually it is possible that the production of this fruit on a small scale might offer an attractive possibility to a few growers in Florida or California (California Citrograph 1916a).

A group of 25 rabbis visited Los Angeles in August 1918 offering "almost any sum" for citron fruits grown on seedling trees, which of course would not have been the case for commercial plantings for culinary use. So great was the demand, that orthodox Jews in New York shipped seeds from the few imported etrogs that were available to a nursery in Monrovia (California Citrograph 1918).

In November 1918, when the etrog trade in the United States and Canada amounted to about $200,000 annually, Coit wrote that "Prices of good Etrogs range from fifty cents to five dollars each, and even to twenty-five to one hundred dollars for very rare and perfect specimens." The ordinary citron of commerce as grown at West Riverside was not satisfactory on account of its rough exterior and great size. Coit speculated that if "Palestine is turned over to the Jews and they go into the Etrog business, they could supply their own people throughout the world to better advantage, perhaps, than California." Meanwhile several "interested parties" considered planting small etrog orchards in California (Coit 1918).

Once the war ended and normal shipments resumed, the urgent need should have ceased. According to Colman (1933), however, even after the war etrog imports from Palestine were forbidden for phytosanitary reasons and so the domestic sourcing of etrogs continued.

11.8 California Citron Cultivation, 1923–95

The major interwar grower of culinary citron in California was Edwin G. Hart, a prominent real estate developer and pioneer in the development of the avocado industry. He knew Herbert J. Webber, the first director of the University of California Citrus Experiment Station in Riverside, and in 1923, at Webber's suggestion, Hart started planting citron in La Habra Heights (then part of Whittier), 20 miles east of downtown Los Angeles (Fig. 11.5; Colman 1933; Schoonover et al. 1939). By 1939 he had 4 ha of bearing and 6 ha of nonbearing citron orchards, which was said to be the only large commercial planting of citron in California at the time. He experimented with several cultivars, which were picked green to size in November or December and produced about 90,000 kg in 1938 (Madera Tribune 1938; Time 1938; Schoonover et al. 1939). In the beginning he shipped most of the crop loose in boxes to San Francisco to be processed, but in 1938 he built a factory near Hacienda Boulevard and East Road in La Habra Heights to brine, candy, and pack the citron. Other growers planted citron, and at peak about 16 ha were grown in the area. In 1939 there were at least five citron processors on the West Coast, and eight on the East Coast (Schoonover et al. 1939).

On Dec. 6, 1939, Edwin Hart was killed by a car while crossing a Los Angeles street. His son Giles took over the citron acreage and the processing business, California Foods Inc., which flourished during the Second World War, when citron shipments from Italy and Greece were cut off (La Habra Star 1941, 1944a, b). In 1943 the company sold about 75,000 kg of brined citron; by 1945 the company shipped 450,000 kg of citrus peel, and would have sold more were it not for the shortage of sugar (La Habra Star 1945). After the war imports resumed, but information about

Fig. 11.5 Citron fruits on a tree grown in Whittier (now in La Habra Heights), CA, c. 1935. *Photo credit* Works Progress Administration Photo Collection/Los Angeles Public Library

the citron business fades after 1947. The ruins of the citron factory were demolished a few years after 2000 (K. Wilch, pers. comm. 2008).

"Citron cultivation died out because it was a lot of work, and it wasn't that profitable," said Leila Langston, a La Habra Heights resident who researched local citrons (pers. comm., 2008).

One of the members of the California Foods board, C. Mavro Warren, was a prominent nurseryman and citrus grower in Ventura County, northwest of Los Angeles. In the late 1930s or early 1940s he planted 6–8 ha of budded citron trees, probably 'Diamante', at his Broadway Ranch in Moorpark. [Chandler (1958) noted that 'Diamante' was then the citron cultivar most commonly grown in California, replacing the 'Corsican' of earlier plantings, because "it made the best candied product."]

Clifton W. Warren lived on the ranch with his father Leonard Warren, son of C. Mavro, and remembers the citron planting well:

> We grew the citrons on the hillier terrain. The trees were very thorny, and very hardy and tough. We'd pick the fruit, slice it in half, and then core out the center section; what we saved was the rind. We'd put them in bulk bins, 4 feet × 4 feet × 2 feet high. They'd have plastic liners and we'd fill them with water. It was super labor-intensive. We'd drain all the water off and ship it down to a company in Los Angeles called Westco Products. They unloaded them, put them in their briners, and candied them for fruitcake mixes. Then all of a sudden Westco Products decided they weren't going to do it any more. And bam! It was over (C. Warren, pers. comm., 2007).

Leonard Warren sold the property around 1980, and the buyer bulldozed the citron trees.

His brother, Victor Warren, son of C. Mavro, recalled another outlet for the citrons during the Second World War:

> During the war, the Orthodox rabbis from Los Angeles couldn't get the etrogs from Palestine, so they bought them from my father. They'd come pick them themselves, and it was quite a lesson for me. They had to be a perfect shape, and the pistil had to be on them. They offered five cents a fruit at the beginning; and at the end they created two grades, the lowest class was 25 cents, and the more perfect fruit was 75 cents apiece; that was a lot of money. My father stopped selling citrons for Jewish purposes shortly after the war, in 1945-46. The rabbis preferred Holy Land fruit to domestic (V. Warren, pers. comm., 2008).

Probably the last traditional grower of culinary citron in California was Gene H. Belk, who grew 1.6 ha of 'Diamante' on sour lemon rootstock in Redlands from 1975 to 1995. Most of the crop was processed by Gene Belk Fruit Packers in Fontana, but Gene and his son, Curtis, also would sell the most attractive fruits for Jewish ritual use, for as much as $100 a fruit (C. Belk, pers. comm. 2022).

The Citron Melon

The citron melon, a watermelon (*Citrullus amarus*) native to Southern Africa, has been used to make jams since the fifteenth century (Dane and Liu 2007; Chomicki and Renner 2015). Since at least the eighteenth century it served in

Fig. 11.6 Citron melon grown in Riverside County, CA by Gene Belk, 2009

the United States as a substitute for the citrus form of citron. The whitish flesh is inedible, but the rind, thick, dense, and rich in pectin, was brined, candied and used like candied citron (Bush 1978). There was enough confusion between the two forms that the United States Board of Food and Drug Inspection ruled in 1912 that the term "Candied citron" should apply only to the citrus product, not to the citron melon (Doolittle et al. 1912). Use of the latter, which was also known as pie melon and preserving citron, declined after the 1920s. But from the 1950s to 2010 Gene Belk and his son, Curtis, grew or processed up to 20 ha of citron melon, in Moreno Valley and Romoland, in Riverside County, CA (Fig. 11.6; C. Belk, pers. comm. 2022).

11.9 A Successful Etrog Grower in Central California

In recent decades the most successful California citron grower has been John Kirkpatrick, a citrus grower in Lindcove, CA. In 1980 he received a phone call from Yisroel Weisberger, an ultra-Orthodox Jewish teenager in New York who was looking for a domestic source for etrogs (Wartzman 1999; Arax 2019; the account in this section is based primarily on J. Kirkpatrick, pers. comm. 1998–2022).

Intrigued by the high prices for etrogs, Kirkpatrick obtained seeds from 'Kibilevetz' and 'Chazon'Ish' etrogs grown in an orchard of recognized pedigree in

Fig. 11.7 Left: Greg Kirkpatrick lights an orchard heater, as he and his father, John, fought the severe freeze that struck their farm in Lindcove, CA in January 2007 by running water, covering the rows of trees, and lighting orchard heaters. Right: The scene the next morning, with icicles hanging from trees

Bnei Brak, Israel and planted 52 in pots under the supervision of Avrohom Teichman, a Los Angeles rabbi. A year or two later Kirkpatrick planted the trees on their own roots, and the rabbi eventually provided a hechsher certifying that the fruit complied with halachic requirements.

In most of his area, the prime citrus belt of the San Joaquin Valley, occasional hard freezes make growing tender citrons problematic, but the site of Kirkpatrick's farm, Lindcove Ranch, is on a thermal slope from which cold air drains down, providing a few crucial degrees of protection during freezes (Fig. 11.7).

Kirkpatrick is not Jewish, but he allied with Weisberger and his brother-in-law, Yaakov Rothberg of Lakewood, NJ, who became his marketing partner in the New York area. He started shipping Rotherberg etrogs in 1987, but only a few met the high cosmetic standards required for Jewish ritual use. Kirkpatrick recalled:

> He would sell them and send us a little money. It wasn't a lot, but it was enough that we kept at it for another several years. Then we thought, if we could do this well with mediocre fruit, we should see what we could do with some good fruit.

In 1995, when Kirkpatrick had 0.6 ha of mature etrog trees, Rothberg and his brother-in-law hired an Israeli etrog grower, Yaakov Zaks, as a consultant. He travelled to Lindcove, took one look at the makeshift trellis system Kirkpatrick had installed to support the trees, and declared it useless. He showed Kirkpatrick how to construct a proper trellis (Fig. 11.8), how to prune the tree to fit the trellis, and how to tie branches and fruits to the trellis to stabilize them. Such practices are indispensable to producing high-quality etrogs, because the slightest blemish or thorn touching a fruit, or a leaf casting a shadow on the fruit, can disqualify it for Jewish use.

Just as important are the knowledge and experience of the workers. For example, following bloom they try to distinguish between fruits that have a good chance of bringing a good price for Jewish use, and those that will only be fit for culinary use,

Fig. 11.8 Growing citrons for ritual use demands specialized structures to protect the delicate, precious fruits from scars or blemishes: a wooden frame structure to which fruiting limbs are tied, with a shadecloth on top. At John and Shirley Kirkpatrick's Lindcove Ranch, Lindcove, CA 2006

for sale to distilleries and grocers; over the years Kirkpatrick and his workers have culled more, throughout the season, to devote the resources of the trees to producing high-quality etrogs.

As Kirkpatrick's quality and quantity improved, his fruit, marketed by Rothberg as Esrogei California, developed a high reputation among ultra-Orthodox Jewish communities. He added trees of the 'Braverman', 'Halperin' (Fig. 11.9), 'Temoni', and 'Assads' cultivars to his planting, which covered 2.8 ha by 2022.

The trees live about 18 years, on average. Propagation is by cuttings and air layering. "The rabbi comes and he watches us cut off those air layers, so he knows where they came from," said Kirkpatrick.

Because etrog trees have to be grown on their own roots, they're susceptible to *Phytophthora* spp. and other root-aging problems. Kirkpatrick controls *Phytophthora* diseases by applying phosphite salts, which inhibit the pathogens and enhance host defense responses (Cohen and Coffey 1986).

The main insect pests of concern for Kirkpatrick's citrons are citrus thrips, red scale, and six-spotted mite. To suppress these pests he has introduced six-spotted thrips and encourages *Euseius tularensis*, a predatory mite. He does use pesticides when needed, but unlike many growers in the Mediterranean who have induced pest resistance through overuse, he is careful to use them responsibly.

In most years he starts harvest in the first half of July, and finishes just before Rosh Hashanah, the Jewish New Year, which falls in September or early October. His

Fig. 11.9 'Halperin' etrog on the tree at Lindcove Ranch, 2006

partner and East Coast distributor, Rothberg, flies to California to carefully inspect, grade, and pack the fruits (Fig. 11.10). They are stored at 15 °C until they are shipped, to vendors in Brooklyn and Monsey in New York, and in Lakewood, New Jersey (Fig. 11.11). In the two weeks between Rosh Hashanah and Sukkot, synagogues, Judaica stores, and special pre-Sukkot street market vendors sell Kirkpatrick's etrogs, carefully wrapped and in a padded carton, for a price that averages $50 to $100—but a truly exquisite specimen has been known to fetch as much as $1,000.

Such high prices, and the perceived mystique of etrog growing, have tempted at least a dozen aspiring growers to establish plantings in California and Arizona. None truly succeeded in creating a lasting, profitable business. Many were ultra-Orthodox Jews living on the East Coast, who tried to get a California farmer to grow etrog trees for them. Even if the farmer was already experienced in growing citrus, the growing of high-quality etrogs, as noted above, requires very specific expertise, which is not readily acquired from books or internet searches.

There are many components, halachic and horticultural, required for a successful etrog farm, and even one oversight can doom the venture. Some growers did not realize that etrogs for Jewish ritual use need to come from trees derived from an impeccable ungrafted lineage; some even planted *murkavs*, grafted trees. One grower planted in Yuma, AZ, where the ferocious heat sunburned the fruit; others planted in

Fig. 11.10 Yaakov Shlomo Rothberg, an observant Orthodox Jew and etrog expert, carefully examines the etrogim (citrons) grown by John Kirkpatrick, at the University of California Lindcove Research & Extension Center packing facility, Lindcove, CA. Using a jeweler's lamp and loupe, he looks for flaws that could disqualify the fruit from being kosher for celebration of Succot, and grades them by quality

Fig. 11.11 Customers examine etrogs for sale at a store in Crown Heights, Brooklyn (left) and at an open-air market in Borough Park, Brooklyn, 2007

cold spots where the trees were killed by winter freezes. A respected Brooklyn rabbi tried to grow etrogs organically, which is almost impossible because the slightest blemish can render a fruit valueless except for culinary use.

The underlying cause of most failures was that the growers "underestimated the intensity of the operation," said Kirkpatrick. "If I myself had known in the beginning what I would have to do, I probably wouldn't have started," he added.

11.10 Citron Germplasm in California

A major conundrum for new etrog growers in California is how to obtain the initial propagating material. State and federal phytosanitary regulations prohibit the importation of whole citrus trees, or of cuttings that would be used directly for propagation. When Kirkpatrick planted his imported seeds this was allowed, but since 2008 the importation of citrus seeds for propagation has required a special permit from the U.S. Department of Agriculture, because of concern that the bacterial disease huanglongbing, which has devastated citrus orchards around the world, might be introduced by seed transmission (W.D. Aley, USDA-APHIS, pers. comm 2008).

For other citrus such as mandarins and lemons, budwood usually is brought into the United States with a USDA permit, inspected at Beltsville, MD, and shoot-tip-grafted to remove pathogens. Since any propagating material derived from shoot-tip-grafting would be disqualified halachically, this standard phytosanitary procedure does not work for etrog growers. It is possible that a plan for importation of etrog propagating material could be devised that would satisfy both halachic and phytosanitary regulatory requirements, but so far this has not happened.

The author obtained seeds of two etrog cultivars, 'Assads' from Morocco (Fig. 11.12), and the Morningsong selection of 'Temoni' (Fig. 11.13), originally from Yemen, for the Givaudan Citrus Variety Collection and U.S. Clonal Germplasm Repository for Citrus and Dates, in Riverside, CA. In both cases the seeds came from fruits grown on trees believed to be from a never-grafted lineage, and no grafting was used at any point in their propagation; but the author made no attempt to obtain a rabbinical hechsher. Trees of 'Assads', which are available from Four Winds Growers, are therefore likely to appeal to Jews less stringent than the ultra-Orthodox in their halachic standards.

An etrog-type citron, called simply 'Ethrog' or 'Etrog' (CRC 3891; PI 508265), is in the Citrus Variety Collection, and its budwood is available from the California Citrus Clonal Protection Program (VI 526). Visitors knowledgeable about etrog cultivars have suggested that CRC 3891 is likely to be the 'Ordang' cultivar of etrog, originally from Greece, but this has not yet been confirmed by genetic analysis. This accession, which came from an airport interception in 1970, received shoot-tip-grafting during processing as a foreign import, so trees derived from it are not suited for strict Jewish ritual use. There is another, similar accession (CRC 3526; PI 539425) named 'Etrog' in the CVC at the UC South Coast Research and Extension Center in Irvine, CA.

The two other citron accessions for which budwood is available in California are 'S-1' and 'Buddha's Hand'. 'S-1' (CRC 3878; PI 539441), a selection of 'Arizona 861' that looks like a standard acid-fleshed Mediterranean citron, is used

Fig. 11.12 'Assads' etrog grown on its own roots at the University of California at Riverside Givaudan Citrus Variety Collection, 2013

Fig. 11.13 'Temoni' etrog that remained when a grower uprooted his trees in Rainbow, CA, 2008

for phytosanitary tests because it is especially sensitive as an indicator for certain viroids such as exocortis (Garnsey and Cohen 1965).

Curiously, budwood of ‘Corsican’, ‘Diamante’, and other citron cultivars originally grown for culinary use is not currently available in California, so farmers who want to grow culinary citron now plant ‘Ethrog’ (CRC 3891). These plantings account for just a hectare or so throughout the state.

11.11 Fingered Citron: From Asia to California

The fingered citron, or Buddha’s Hand, is the type of citron most commonly grown today in the United States. The fruit splits at the stylar end (opposite the stem) into distinct carpels that look somewhat like human fingers, which are solid albedo (the white part beneath the flavedo, the rind surface), with no juicy pulp or seeds. (Very rarely, fruits can have small sectors of pulp.) The fruit is powerfully aromatic, with a characteristic aroma of violets or osmanthus. Its primary use in the United States is ornamental, like a flower, and as a novelty, but the rind is also used to make jam and to flavor spirits (Karp 1998, 2009b).

The fingered citron took a surprisingly long time to become established in the United States, considering how long it has been known and grown in Europe. Probably the first European to describe it was the Jesuit priest Martino Martini (1655) who wrote in his Novus atlas Sinensis, in a section on Changde, in what is today Hunan Province, China (translated from Latin by D. Karp):

> They also have citrons which they call the idol’s hand, for their extremities terminate in fingers. They are not suited for food, but at home, hanging inside a room, they exhale a very sweet aroma, suspended in artfully woven netted bags of made of silk.

Gaertner (1788) was the first Western botanist to provide a partial description and drawing of a fingered citron. The great plant explorer Fortune (1846) sent fingered citron plants to England in 1845, but they don’t appear to have made the journey to America afterwards. Working in the Dutch East Indies, van Nooten (1863) wrote the standard botanical description of fingered citron. As of 1890, fingered citron trees were growing in England and France (Gardeners’ Chronicle 1890).

In one of the earliest books on citrus in California, Lelong (1888) knew the fingered citron only from a Japanese description. In the 1900 edition he reported that it had been introduced to California, but “after being thoroughly tested [it was] found to lack the essential qualities for culture on a large scale” (Lelong 1900). He did include a photo.

Budd and Hansen (1903) wrote that they had seen fingered citron trees growing in South Carolina. But when Bailey (1914) described it he noted, “It should be introd. into this country.” The USDA did import scions of a ‘Bushukan’ (PI 39940), from Yokohama in 1915 (USDA 1918); and a decade later Webber received budwood from a Javanese garden for the USDA (McKeee 1927; PI 64605). Evidently neither accession survived, since Webber (1943) wrote that he had never seen a plant or fruit of fingered citron, and that apparently "it is not grown in the United States."

Yet another USDA importation of fingered citron budwood from Taiwan in 1954 left no trace (Russell and Leese 1960; PI 220239). Bill Bitters, longtime curator of the Citrus Variety Collection, wrote in 1957 that the fingered citron had "been introduced by the University's new citrus importation program, as a result of numerous requests by garden clubs" (Bitters 1957). Nevertheless, in 1966 he resorted to bringing in seeds supposedly of fingered citron from a Manilla gift shop, although seeds are very rarely if ever present in fingered citrons (Hyland 1966). Hodgson, who passed away that year, did not mention fingered citron as being present in California in Horticultural Varieties of Citrus (Hodgson 1967).

After all those attempts and opportunities, apparently no fingered citron germplasm was available in California in the early 1970s. The standard fingered citron grown in California today, named simply 'Buddha's Hand' (CRC 3768; PI 539445; VI 369), derives from budwood imported from Hawaii in 1975. It most resembles the 'Guang' cultivar of fingered citron grown in Southern China (X. Hu, pers. comm. 2013).

Only since the 1990s have growers planted commercial orchards of 'Buddha's Hand' citron, which now account for about 10 to 12 ha across the state (Fig. 11.14). The main season is fall and early winter, but in coastal districts the trees produce at least some fruit continuously.

Fruition Sales of Orange Cove, CA, in the citrus belt southeast of Fresno and north of Visalia, is the largest packer of 'Buddha's Hand' citron. Eric Christensen, who owns the company with his wife, Kim, packs 5 ha of 'Buddha's Hand' citron

Fig. 11.14 'Buddha's Hand' (fingered) citron grove grown by Phillips Farms at the Rattlesnake Ranch between Seville and Elderwood, CA, 2006

grown by four farmers, including his own trees, which he started planting on a very small scale in 1992. He, along with Mike Foskett and Lance Walheim of California Citrus Specialties (CCS) started putting in larger plantings in the late 1990s and early 2000s; Fruition Sales now packs for the crop from the former CCS trees.

Christensen and his growers start harvest in early October when the fruit is green. Many of the fruits, which are sold in a special box under the registered trademark Goblin Fingers®, cross over from the produce to the floral sales category, and do especially well for Halloween. Christensen finishes in January, when the fruit is bright yellow. There's no way the fruits could go over a conventional citrus packing line, on which the belts and rollers would damage the delicate fingers. So the whole harvest and packing process is done by hand, during which it is sanitized, dipped in a fungicide, and goes through strict food safety procedures. The fruit keeps better early in the season, when the young fruit is stronger and is less likely to have been affected by rain, which can pool in the "palm" of some of the 'Buddha's Hand' fruit and cause rot.

"Demand is stable, but it's a niche market that could easily be overrun," he noted (E. Christensen, pers. comm. 2022).

Lisle Babcock of Deer Creeks Height Ranch, in Porterville and Terra Bella, CA, was the other large 'Buddha's Hand' grower when he started planting in the late 1990s. He had about 2 ha of 'Buddha's Hand' citron, on Carrizo rootstock, before selling his farm in 2018 to Setton Farms, which continues to produce them. The planting is certified organic. To protect the fruits from rain Babcock would cover them with white foam sleeves. They'd be picked into small boxes, then cleaned with a brush to get rid of the spiders and webs that would accumulate between the fingers. His planting is on a thermal slope where freezes are less common then elsewhere in the citrus belt, but "if you got a frost you'd kiss the fruit goodbye," he remembered (L. Babcock, pers. comm. 2022).

Many California growers have small plantings of 'Buddha's Hand' citron and sell the fruit at the state's certified farmers' markets. The trees are also fairly common in home orchards.

11.12 Citron Cultivation in Florida

Since the development of commercial citrus cultivation in the United States, in the second half of the nineteenth century, Florida has been the largest producer by acreage, and particularly dominant in citrus grown for processing, so it might seem that it should have taken the lead role in citron cultivation. Such was not the case, however. Much as in California, there were boosters touting overblown expectations, challenges in finding the right varieties and surviving freezes, and some serious attempts to grow citron—but in Florida such experiments were fewer, and left less of a trace.

Adams (1871) encouraged settlers to plant citron, which he claimed would yield 4,500 kg of fruit per hectare, which could be sold for 25–40 cents a pound. (He was writing from Jacksonville, but did not mention that the intermittent hard freezes common that far north would kill any citron plantings.) Similarly, Sutherland (1883) boasted of "fortunes easily made" in Florida, "where the orange and the citron trees grow is the gold mine of the present." And Harcourt (1886) claimed that Florida-grown citron was "a better and finer article than the imported candied citron, bringing the highest price whenever placed on the market. The sooner our people realize that there is money in the citron, the better it will be for them." At Belair, the first botanical experiment station in Florida, located northeast of Orlando, General Henry Sanford had a tree of the "Citron of Commerce," which produced fruits "often weighing five pounds [2.3 kg]" (Houston 1889).

In 1886, Capt. Thomas T. Eyre was encouraged by seeing "large, bitter citron growing wild in and near the town" of Fort Myers (Florida Agriculturist 1894). Located on Florida's southwestern coast, this area "had the soil and climate to raise all of the citron of commerce needed in the United States", he wrote (Eyre 1891). He trialed 16 cultivars, "found all to be worthless to the trade, and threw away 3,000 young trees," but vowed, "I must and will make it a success" (Florida Agriculturist 1890; Eyre 1891). He was one of the initial recipients of 'Corsican' citron cuttings procured by the USDA (Van Deman 1892). Within a few years a local observer wrote that "the sample of cured citron exhibited in Ft. Myers some days ago by Mr. Eyre was an agreeable surprise to his friends, some of whom had begun to think him a little cranky" (Florida Agriculturist 1894). He claimed to have shown that citron could be produced economically in Florida, but nothing further was heard of his venture. As the old saying goes, success has many fathers, but failure is an orphan.

In 1902 the Florida State Horticultural Society listed 'Lyman', 'Lemon', and 'Orange' as the three citron main cultivars suited for central and southern Florida (Powers 1902). Reasoner (1900) noted that in Florida citron was grafted on rough lemon and sour orange.

The number of bearing citron trees grown in Florida increased from 2,480 in 1890 to 23,234 in 1910 (California State Board of Agriculture 1915). But almost all of these must have been dooryard trees, whose fruit was used in home recipes for confection, sweet pickle (with vinegar and sugar), and marmalade (Rolfs 1911). Perhaps even those were not much esteemed, since a fertilizer company's booklet noted:

> … though this industry never has received much attention, even the little interest that has been shown it has died out and it is only occasionally one sees a tree left, and then rather on sufferance than because its owner cares for it (Wilson & Toomer Fertilizer Co 1911).

Hume (1913) and Cook (1913) said basically the same thing, the latter adding that citron "is not likely to become of any commercial importance for long years, for the cheaper labor of Europe would make it an unprofitable crop in our country."

There were, however, a few attempts to cultivate citron commercially in Florida in the interwar years. The leading force was the Hills Brothers Company of New York (different than the Hills Bros. coffee company based in San Francisco), which was founded as a store on Fulton Street in 1871, and sold imported dried fruits and nuts, and domestic citrus. In 1893 the company started building a factory in Brooklyn to process at least some of its own candied citron, which was sold under the Dromedary brand. It then moved into canning grapefruit and established The Hills Brothers Company of Florida (Butterick 1925).

According to Morton (1987), "From 1926 to 1936, there were scattered small plantings of citron in Florida, and particularly one on Terra Ceia Island [south of Tampa], supplying fruits to the Hills Brothers Canning Company. The groves eventually succumbed to cold and today the citron is grown in southern Florida only occasionally as a curiosity."

Fingered citron trees are occasionally grown in Florida yards (Qiu et al. 2022).

There are many Jews in Southern Florida, and in about 1993 Allen Schloss of Surfside, FL, started planting 400 'Yanover' ('Diamante') etrog trees grown from seed in Homestead, south of Miami. He grew them freestanding, without trellises, and gave the fruits to schools and synagogues, as his son's school hobby. "Some of the fruits were worth $500 or $1,000, others zippo," he recalled. In 2003, however, officers of the state citrus canker eradication program, which attempted to stop the spread of canker (*Xanthomonas citri* subsp. *citri*) and protect the Florida citrus industry, ripped out all the trees, much to his dismay (A. Schloss, pers. comm. 2005).

Citron is quite susceptible to citrus canker (Peltier and Frederich 1924), but in 2006, after the disease became widespread, the state ended its eradication program. However, since 2005 huanglongbing, a devastating disease of citrus believed to be caused by the bacterium *Candidatus Liberibacter asiaticus*, has devastated Florida citrus production. Citron does become infected, although it is not as badly affected as sweet orange and grapefruit, the prevalent citrus in Florida (Miles et al. 2017).

It is challenging to grow etrogs successfully for Jewish religious use in Southern Florida, where the hot humid climate fosters pests and diseases that blemish the fruit and kill the trees. About 2011 Steven Silvers and Naftali Mannosse planted seeds of 'Temoni' imported from Yemen to grow more than 200 trees for a nursery that they called Esrog Delights, in Loxahatchee Groves, FL, in Palm Beach County (Miller et al. 2015). They sold some fruits and donated others, and developed a line of cosmetics, nutritional foods, organic soap, lotions, drinks, and jellies. Unfortunately the trees became infected with huanglongbing, and they had to cut them down in 2019 (S. Silvers, pers. comm. 2022).

11.13 Effects of Tariff Rates on Citron Cultivation and Processing in the United States

Changes in the tariff rates on imported citron significantly affected the incentive to grow, brine, and candy citron in the United States, and the form in which it was imported. Citrus in brine entered the United States free of duty for manufacturing purposes before 1922, when the Fordney-McCumber Tariff Act imposed a duty of 2 cents per pound on brined citron, and raised the duty on candied citron from 2 to 4.5 cents per pound. As a result, imports of citron in brine declined and imports of candied citron increased. Domestic candying of citron declined from 1,225 mt annually in the previous decade to 635 mt in 1923–1929 (United States Tariff Commission 1948).

In hearings before the House of Representatives Ways and Means Committee in 1929, R.U. Delapenha, representing the American manufacturers of 90% of the citrons, lemons, and oranges imported in brine, testified that when rates were revised in 1922, imports of brined citron dropped precipitously, while imports of candied citron increased. Because "these rates were not properly proportioned," Delapenha said, "the domestic manufacturers cannot compete with the foreign (Italian) shippers and manufacturers," and "the industry has been practically completely ruined" (Congressional hearings 1929).

After 1930, when brined citron reverted to the free list and the duty on candied citron increased to 6 cents per pound, these trends reversed. In 1937–39, imports of candied peel averaged 272 mt annually compared with 1,134 mt of citron in brine. From the 1910s to the early 1930s, the principal source for imports of both brined and candied citron was Italy, where most of the fruit was grown in Calabria and processed in Livorno. In the 1930s, however, Puerto Rico emerged as a major supplier (United States Tariff Commission 1948).

11.14 Rise of Citron Cultivation in Puerto Rico

Although citron cultivation never became commercially important on the United States mainland, it was a major crop on Puerto Rico from the 1920s through the 1990s. Previously citron had not been grown for world markets in a tropical growing area, and it was unclear whether such a climate would be well-suited for that purpose. But Puerto Rico had several advantages: it was home to hundreds of families of Corsican emigrants, and it was close to the major market of the mainland United States, which it was able to continue supplying during the Second World War, when shipments from Europe were interrupted.

Corsican immigration to Puerto Rico began in the 1760s, when France took control of the island, and accelerated in the nineteenth century as a result of economic difficulties in Corsica (Farage 2002). In Puerto Rico Corsican immigrants played an important role in the development of coffee in the highlands and sugarcane in the lowlands. Many settled in a foggy mountain town, Adjuntas, located at elevation 700 m in the Cordillera Centra, in the central midwestern part of the island (Orengo Serra 1993, 2002).

The Spanish had introduced citron to Puerto Rico by the seventeenth century, and it was common throughout the island when it came under American control in 1898, after the Spanish-American War (Hill 1899). Cook and Collins (1903) noted that "considerable quantities" were grown near San Juan for local sale, and suggested that commercial cultivation for candied peel should be investigated. At the time, however, they observed only thin-skinned varieties unsuited to candying.

In the early twentieth century, French tariffs on the export of citron from Corsica to the mainland exacerbated the decline in the local citron industry, while on Puerto

Rico foreign competition caused a crisis for coffee growers. So both European and Puerto Rican Corsicans were keen to explore new crops and growing areas.

Orengo Serra (1993, 2002) gives four accounts of how Corsicans imported their island's namesake cultivar, 'Corsican', to Puerto Rico: (1) Francisco Mattei Delucca (1874–1953) emigrated from Barrettali, on Cap Corse, to Puerto Rico in 1891, and brought 'Corsican' citron seeds in a sausage; (2) The Orlandi family introduced citron from Cap Corse to Puerto Rico in the late nineteenth century; (3) Jean Mattei, who had grown citron on Cap Corse, brought citron plants in his luggage to Puerto Rico at the beginning of the twentieth century; (4) Joseph Antoine "Tono" Salicetti brought Corsican citron seeds in his jacket when returning from Corsica in the 1920s. Some of these importers took care to hide their seeds so that that they would not be confiscated by inspectors enforcing quarantine regulations.

It is also worth noting that because citron is cleistogamic, it can fertilize itself before the flower opens, and so generally reproduces true-to-type by seed.

In 1924 the Hills Brothers Company, which was also actively encouraging citron cultivation in Florida, started looking into sourcing citron from Puerto Rico. At first the learning curve was steep. For example, Salicetti shipped fresh, fully ripe yellow citrons, which arrived in poor condition, and small fruits that were incompatible with Hills Brothers' processing machines.

But with their connections in their homeland's citron industry, Puerto Rican Corsicans were able to obtain the technical know-how to compete on international markets. For example, Jerónimo Malatesta sent documents from Nonza on Cap Corse to Jacques Pietri on Puerto Rico explaining the techniques of citron brining and candying; Pietri thanked him, in a letter dated June 1928, for enabling him to sell brined citron at a good price. The Report of the Commissioner of Agriculture and Labor boasted that "this island can surpass the Mediterranean countries in the production of high quality citron peel." Adjuntas, with its relatively moderate, frost-free climate and abundant water, proved well suited to citron cultivation, and for a while, at least, citron produced more profits than coffee (Orengo Serra 1993, 2002).

Whereas in Corsica citron was brined in sea water, Puerto Rican processors brined their fruit in fresh water with salt added. The spontaneous fermentation that developed imparted to the rind the desired degree of translucency. The barrels used in the storage and transportation of cured citron were typically bought from rum producers (Benero et al. 1970). Otherwise they used the same methods as in Corsica. After a month of brining, the citron was trucked to the Ponce dock for export to the United States (New York), Europe (France, Italy, Belgium, Holland and Germany) and even Corsica, where the Mattei family had contacts with citron manufacturers (Orengo Serra 1993, 2002).

Shipments of brined citron from Puerto Rico to the United States mainland increased from 244 mt in 1931 to an average of 625 mt annually during 1937–39 (Schoonover et al. 1939). To diversify the production of citron and finance the harvest for small and medium-sized citron growers, the Cooperativa de Cosecheros de Cidra de Adjuntas was established in 1943, and became active in the production, manufacture, and export of citron (Orengo Serra 1993, 2002). Sales increased further during the Second World War, and in 1946 and 1947 amounted to 1,134 mt and 1,406

Table 11.1 Puerto Rican citron statistics, 1950–2012

Year	Number of farms	Number of nonbearing trees	Number of bearing trees	Area (ha)	Production (mt)
1950	580		132,212	590	4,025
1959	369		78,989	441	2,760
1964	514			473	3,156
1974	214			546	1,279
1978	312	26,815	203,794		1,719
1982	273	60,082	1,033,793		3,444
1987	206	45,523	242,000		2,654
1992	235	21,429	166,569	412	1,374
1998	101	45,167	298,086	319	1,486
2002	118	34,702	265,063	226	1,560
2007	18	1,634	12,554	24	111
2012	9	2,944	2,482	7	21

Source United States Census of Agriculture

mt, respectively. After the war, Puerto Rico also sent even more substantial quantities of brined citron to Europe (United States Tariff Commission 1948). According to Agricultural Census data, overall citron production in Puerto Rico peaked in 1950 at 4,025 mt, grown on 590 ha (Table 11.1). Adjuntas produced more than 98% of the island's crop, and citron was one of the few major industries in the highlands (USDA 1950–2018).

11.15 Decline of Citron Cultivation in Puerto Rico

However, from the second half of the 1940s onwards, competition in the North American market from European producers caused a crisis for the Puerto Rican citron industry. By the 1950s, Puerto Rico and Italy both offered large quantities of the leading Italian citron cultivar, 'Diamante', and competed on price. Sometimes the price of the Puerto Rican product was so low that the Italians bought from them. The citron market experienced its usual ups and downs, caused by natural disasters (Hurricane Santa Clara in 1956), natural fluctuations in the citron crop, European attempts at price control, and the effects of the United States federal minimum wage on the Puerto Rican workforce (Department of Labor 1971; Orengo Serra 1993, 2002).

As of 1971 there were hundreds of smaller citron growers, and four major companies involved in processing and export:

- Cooperativa Cosecheros de Cidra, which sold citron in brine to Europe, the mainland United States, and Canada;

- Joaquin Mattei of Adjuntas, son of François, who had brought citron to Puerto Rico from Corsica. He sold citron in brine to Europe, the mainland United States, and Canada;
- Alberto Rullan Mayol of Adjuntas, who began operations in 1954, and sold citron in brine to Europe, the mainland United States, and Canada;
- Citron Export Inc., which began operations in 1964. Its parent was R.A. De Jong of Holland; 90% of its finished product was shipped to Europe (Holland), and 10% was sold locally (Department of Labor 1971).

The fermented fruit was washed, halved, cored, and diced. The diced citron was stored in drums with fresh brine, or candied (Fig. 11.15). In the postwar era the great majority of Puerto Rico's crop was shipped brined. In the early 1970s just one processing firm, Candied Citrus Fruit Corp., a subsidiary of Citron Export., candied citron that was produced in Puerto Rico (Department of Labor 1971). Most of the local consumption of citron was of *dulce de cidra*—canned citrons in a syrup of sugar, caramel and vitamin C (Luxner 1995). Cancel et al. (1972) observed "Market outlets have not increased; on the contrary, they are becoming rather uncertain." Puerto Rican citron production declined to 1,279 mt in 1974 and 1,719 mt in 1978, before rebounding to 3,444 mt in 1982 (Table 11.1).

In 1977 a fungal disease that caused branches to break and die back, Sphaeropsis knot (*Sphaeropsis tumefaciens*), was detected in an Adjuntas citron orchard (Rodriguez and Melendez 1984). The problem got worse over the next two decades, but as late as 1995 Puerto Rico produced 65% of the world's citron supply; the remainder came from Italy and Greece (Luxner 1995). Hurricane Georges, in 1998, reduced Puerto Rico's crop that year and uprooted many of the island's citron trees (Rivera Vargas 2003). Around 1990, citrus growers in São Paulo state, Brazil, at that time the world's largest citrus producer, started growing citron in quantity. In the 1990s and early 2000s Brazilian growers took advantage of their lower costs and the interruption in supply from Puerto Rico to become the world's largest producers of culinary citron.

By 2003, the wholesale price for 100 kg of citron had declined to $6, from $25 a few years earlier, and just three companies remained in the citron business in Puerto Rico: Cooperativa Cosecheros, Citron Exports, and Mattei. "Now we are in crisis," said William Mattei, son of Joaquin, and grandson of François Mattei de Luca. "If the competition from Brazil is strong, we will not be able to continue selling" (Rivera Vargas 2003).

By 2006 only Mattei remained processing citron on Puerto Rico; the others had dropped out, undercut by low-priced competition from Brazil. Citron Export shifted to growing coffee in Adjuntas, and tried growing citron in the Dominican Republic. The citron processing equipment at the Cooperative was derelict and rusting, amid barrels of abandoned citron (Fig. 11.16). His customers in Europe consolidated, and some of them stopped buying. Mattei estimated that there were 10 ha of citron left in Puerto Rico at the time [mostly 'Corsican', and 'Italian', similar to 'Diamante' (Fig. 11.17)], but many of them were neglected and overgrown. He was hopeful that the citron industry could be revived, and had started clearing some of his orchards

Fig. 11.15 Citron processing at William Mattei Co., Adjuntas, PR, 2006. Upper left: Recently harvested citrons are placed in concrete tanks and then covered with brine, in the first step of processing. Upper right: Brined citron half with its pulp scooped out, sitting on diced citron in a barrel. Bottom: William Mattei, then the last remaining commercial citron processor in Puerto Rico, holding a handful of diced, brined citron

that had been overrun by jungle (Fig. 11.18). He had stopped selling to Europe, but still shipped brined citron to North American buyers, including Gray and Company, Portland OR; Paradise Fruit Company, Plant City, FL; and Dawn Foods, Ontario, CA (interview with W. Mattei, 2006).

For another decade Mattei struggled to keep his citron growing, but he found it difficult. It was not ideal to be the only citron processor left on Puerto Rico, because other farmers from whom he used to buy fruit were leery of growing a crop for which

Fig. 11.16 Ruins of the Cooperativa de Cosecheros de Cidra in Adjuntas, which was established in 1943, and had been abandoned for several years by the time the photo was taken in 2006

Fig. 11.17 Left: 'Italian' (similar to or the same as 'Diamante') citron on the tree. Right: Brined citron halves ('Italian' left, 'Corsican' right) at the farm of William Mattei, Adjuntas, 2006

there was only one customer. Sphaeropsis knot continued to be a major problem. Huanglongbing was detected on Puerto Rico in 2009 and spread through the island (Marroquin-Guzman and Estévez de Jensen 2013), although it was less severe in the highlands of Adjuntas. His production declined, so that even when there was demand he didn't always have enough fruit to sell. The final blow was Hurricane Maria, a devastating Category 5 storm that struck Puerto Rico in 2017, which destroyed his shed and flooded his field. Mattei was forced to shut his citron business, and the long saga of citron cultivation on Puerto Rico came to a close (interview with W. Mattei, 2022).

> "Maybe someone could revive the industry if they had enough money and there was demand for the fruit," he said. "I always hoped that this would be the case, but it never happened."

Fig. 11.18 William Mattei abandoned most of his citron planting to the jungle when prices dropped c. 2001, but in 2006 was gradually reclaiming the trees in order to supply his brining operation, the last remaining commercial citron processor in Puerto Rico

11.16 Perspectives

Writing in 1938, Webber (1943) analyzed the reasons for the limited success of culinary citron plantings in the United States:

> … with the unrestricted duty-free entrance of the foreign product, it is doubtful if a successful industry can be developed. The factors that have heretofore prevented the establishment of a citron industry in the United States were primarily: (1) the inability of growers, in view of the necessity of processing the fruit, to dispose of the crop because of the lack of processing plants; (2) the restricted scale of production due to limited demand; (3) inadequate knowledge with reference to varieties, culture, and markets; and (4) the lack of varieties known to be satisfactory from both the growing and the processing standpoint.

From the current perspective, most of his observations still apply. In today's highly globalized trade system, low-cost producers typically dominate markets, particularly for crops such as processed citron that store well and can be transported by ship. It would be difficult for new citron producers to operate profitably without close links to existing processors or building their own facilities, mastering processing methods, and developing sales contacts. The world demand for candied citron has been slowly shrinking, and since the mention of "fruitcake" mostly evokes derisive smirks these days, that doesn't seem likely to change soon. In the interwar years Schoonover et al. (1939) estimated that 90–137 ha of citron orchards could supply the entire crop for the United States market, and that number would be smaller now. Knowledge of the cultivars, horticultural practices, and markets for citron is less common than for other citrus crops, but should be sufficiently available if someone wanted to try growing culinary citron. Growers in the United States (including Puerto Rico) do have access to the culinary citron cultivars best suited for commercial production, although some might require renewed phytosanitary cleanup and certification.

In the author's opinion, the potential exists for three niche markets for citron cultivation in the United States today: (1) there is a growing market for high-end etrogs for Jewish ritual use, but putting together all the pieces of the puzzle—sourcing propagating material for traditional cultivars, choosing a suitable growing area, mastering the esoteric horticultural practices, and establishing links to markets—would be exceedingly difficult; (2) for the culinary citron market, there is an opportunity, albeit on a small scale (a few hectares at most, at least to start) to produce artisanal, premium-priced candied citron, emphasizing the domestic provenance and citron's colorful history for marketing, much as the Corsicans have done (see Chap. 10, "The Citron in Corsica" in this volume); (3) bonsai cultivation of fingered citron in pots for the ornamental trade—a significant industry in Jinhua, China—could be profitable in the United States if the dwarfed cultivars could be obtained, along with the necessary horticultural knowledge (see Chap. 8, "The Citron and its Uses in China" in this volume).

Suggestions for citron cultivation in the United States may seem futile, since the efforts and hopes of virtually all previous citron farmers have been dashed. But for those growers nimble enough to profit from these niche opportunities, the day of the citron may yet return.

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Chapter 12
The Citron in Mediterranean Food and Beverages

Elisabetta Nicolosi and Haim Aviv

Abstract Etrog citron fruits have been traditionally used for a variety of culinary purposes, as fresh salad, jam, liqueurs and syrups, and in other specialty dishes. Most of the citrons grown in the world currently are used to produce candied fruits, widely used in the confectionery industry. The candying procedure of etrog citrons involves a particular procedure that is different from that used for candying other fruits. Another delicacy is citron jam, appreciated for its taste and aroma and widely used also for its energetic and restorative action. An old Jewish culinary tradition is the preparation of etrog jam at the conclusion of the Sukkot festival. Delicious sweets, mainly in Italy, are prepared with candied citrons, citron flavored custard and jams. Traditional Italian recipes are still very popular today in which candied citrons are one of the main ingredients. Moreover, numerous recipes for savory dishes based on etrog citron fruits are very well established. A wonderful, uniquely flavored liquor can be prepared from the peels of etrog citron fruits by adding an extract prepared from the outer yellowish skin to a mixture of alcohol and sugar. This part of the fruit, named the flavedo, is rich in the typically fragrant etrog oil along with numerous secondary metabolites. Detailed recipes for preparing the delicate foods and drinks from the etrog citron are included in this chapter.

12.1 Introduction

The citron (*Citrus medica* L.) is one of the forefathers of the *Citrus* tribe and was probably the first to have reached the Mediterranean (Nicolosi et al. 2005). The citron is unique among citrus fruits with its diversified uses: from culinary purposes to perfume production and its wide-ranging role in medicine, especially Chinese medicine (see also Chap. 8 "The Citron (*Citrus medica* L.) in China" in this volume).

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The etrog citron has acquired major significance due to its use for worship during the Jewish feast of Tabernacles (Galiano 1994; see also Chap. 18 “History of Citron: Botanical Remains and Ancient Art and Texts” in this volume), a role played in Jewish tradition up to the present time. Within the Mediterranean, the Calabria Region in Italy has been known since antiquity as a center for etrog citron cultivation and commerce (Fersini et al. 1973; Monaco 2019; see also Chap. 9 “The Citron in Italy and its Cultivation in Calabria” in this volume).

The citron is unique also in its internal structure. Whereas all other citrus fruits have a juicy pulp, the citron has a very thick white inner peel (albedo) and almost no juice, a feature which affects its culinary uses. The present chapter presents some recipes, used both in the past and today, for preparing delicate foods and drinks from the etrog citron.

The use of etrog citron fruit in the preparation of culinary dishes is relatively recent, in fact, even though citron fruits were already known two thousand years ago, to taste candied fruit, liqueurs, and dishes with citron fruits it will be necessary to wait a few years. The use of citron in medicine is well documented (see other chapters in this Compendium).

Most of the citrons grown in the world currently are used to produce candied fruits, widely used in the confectionery industry. The main consumers of candied citron fruits are the United States and the countries of Central and Northern Europe which consume almost 80% of the Italian production which comes almost exclusively from Calabria.

The candying technique, widely used and established today in Italy, almost certainly comes from the Arabs who spread the candying process among the Sicilian people between the ninth and twelfth centuries, after which it spread to Europe in the sixteenth century. In his *Trattato di cucina* Bartolomeo Scappi di Dumenza reports dozens of recipes made with candied flowers and citron fruits. The culinary art of this gastronome, who lived between 1500 and 1577, at the service of the Roman Church, was inspired by the Arabs.

In Italy, an important confirmation of the use of candied citron dates back to the Bourbon period: in Naples, in Sicily, in all of Italy, the citron becomes the great protagonist of desserts, and recipes bloom. Some of them, even today, are part of the tradition that flourishes thanks to contemporary chefs. The rich range of dishes include *Mostaccioli* with citron jam (in Sicily called *Pasticciotti*), Wheat cake (today *Pastiera napoletana*) with citron pesto, and *Cassata Siciliana* with candied citron fruits cut into pieces mixed with *ricotta cheese* and used in thin slices for garnish.

From 1800, citron fruit and flowers have been constantly present in various sweet dishes, jams, icings, syrups, jellies, and sorbets and they are also candied naturally. Candied fruits have since taken hold in Europe, meeting the taste of consumers: in Italy they have become important ingredients in the preparation of the most famous desserts, the *Pastiera napoletana* and the *Cassata Siciliana*, already mentioned, and the *Panettone Milanese*, today increasingly widespread and a symbol of the Italian pastry tradition.

12.2 Etrog Citron Candying Procedure

The candying procedure of etrog citrons is a unique process, different from the one used for candying other fruits. It consists of two distinct and separate stages: the *brining* (*salamoiatura*) and the *candying*. Brining is the basic process which determines the goodness of the final product: the fruits are harvested, after eliminating damaged or yellowed ones, and are then placed in plastic barrels (chestnut wood barrels were once used), in which sea water is added with the addition of table salt up to a salinity of 4–5% (Fig. 12.1). The fruits remain inside the barrels for about 40–60 days, and during this period it is necessary to frequently check the water level and provide for absorption and any losses. In the brining process, the outer peel of the fruit releases part of the water and essential aromas from the tissues and absorbs sodium chloride and other salts present in the solution, resulting in a 2% weight loss. Once this phase is completed, the citrons are taken from the barrels, cut in half, the internal pulp is removed, and the resultant pieces are arranged in a *crown* again in the barrels and covered with water and salt; this phase is called *sbuzzatura.*

At the end of these phases, the *candying phase* starts with a very important preliminary procedure which provides for the elimination of all traces of salt. The pieces of fruit are boiled for a few minutes, then cooled and dried. A subsequent series of boiling in gradually increased sugar solutions, prepared with equal amounts of sucrose and glucose then takes place. This process continues until a concentration of 70 g of sucrose per 100 g of solution is reached. These repeated treatments allow the fruits to absorb a high quantity of sugar which forms a crystalline coating around the citron. The fruits remain in their syrup for about three weeks after which they are drained and left to dry when, finally, they are ready for the market (Fig. 12.2). Overall, the *brining* and *candying* process takes about four months. The candied citron fruits are cut in half and are ready to use (Fig. 12.3).

Candied citrons can be prepared at home with a very simplified procedure. The following ingredients are needed for the preparation: 1 large citron fruit, 200 g of sugar, 200 mL of water. After having carefully washed the fruit, cut it into slices,

Fig. 12.1 Brining phase: citrons stored in plastic barrels containing sea water

Fig. 12.2 Citrons removed from the barrels and ready for the *Sbuzzatura*

Fig. 12.3 Candied citron fruits at the end of the candying process

leaving the flavedo and albedo and eliminating the pulp with the seeds. Cover the slices with water for 24 h, then drain and pour into a pot, cover again with water and bring to the boil for about 10 min. Allow the slices to cool down and again boil the slices in water. Drain the citron slices and put them in a pot with 200 g of sugar and 200 mL of water, bring to the boil and continue cooking until the water and sugar are completely absorbed by the slices. The slices are then placed and rolled in sugar to allow the sugar to be distributed all around the slices. At this point, the candied citrus slices are ready to be eaten or stored in airtight glass jars.

12.3 Citron Jam

Another delicacy is citron jam, which is highly appreciated for its taste and aroma. It is also widely used for its energetic and restorative action, to fight depressive states and to enhance post-illness convalescence. The British traditionally use it especially for breakfast.

The preparation of the jam is laborious: the fruits must be washed, pierced with a sharp stick and placed in a container with water that must be changed daily for at least three days. On the fourth day, the fruit are cut into large slices and, once the seeds have been removed, the slices are boiled until soft. The slices are then dried and cut into small pieces. Meanwhile, a solution with water and sugar (500 g of water and 500 g of sugar per 1 kg of citron pieces) must be prepared and poured above the previously cut pieces. The mixture is then brought to the boil and reduced to a simmer while being stirred constantly until the desired consistency is reached.

A good citron jam can be recognized by the presence of the peel cut into small pieces and by the intense aroma. The jam should be stored in sterilized and airtight glass jars (Fig. 12.4).

Fig. 12.4 Citron jam produced in Calabria, Italy

12.4 Sweet and Savory Food: From Tradition to Gastronomic Innovation

Typical, special sweets, handed down from very ancient traditions of the *Riviera dei Cedri* in Calabria, Italy, are the so-called *Panicilli*: where citron leaves are utilized. The leaves become an indispensable element to wrap a filling composed exclusively of raisins and candied citron peel. The bundles are formed by overlapping alternately about 6–8 leaves, the filling of raisins and candied fruit is placed in the center, the bundles are then tied with broom strands and are cooked in the oven until the leaves turn gold (Fig. 12.5). The leaves, in addition to protecting the internal product and allowing the sugar contained in the raisins to dissolve, transmit an unmistakable scent and a delicious aroma. Today, more modern variants are inspired by the ancient *Panicilli*, enclosing in citron leaves, for example, citron mousse and raisin ice cream with figs and candied citron, or other delicacies incorporating Calabrian pastry.

There are many others that are traditional desserts, but some are derived from the chefs' fantasies when they reinterpret old recipes, being able to satisfy the most refined palates. Much appreciated, even by the youngest, are the *Slices of candied citron* coated with dark chocolate or the *Cannoli with citron custard* (Figs. 12.6 and 12.7).

In addition, traditional preparations are typical in the making of various shapes and sizes of cakes, pastries and biscuits, based on citron flavored almond paste. The ingredients, expertly blended by the hands of master pastry chefs, are simply peeled almonds, granulated sugar, egg whites, candied citrons and green citron fruits. For the fillings of cakes and pastries, citron flavored custard is used, sometimes in combination with citron jams (Figs. 12.8, 12.9 and 12.10).

For the preparation of *Pasticciotti with citron jam,* it is necessary to obtain short-crust pastry by mixing flour, sugar, eggs, butter, the grated rind of a lemon and half a glass of Marsala; for the filling, only citron jam that has previously been prepared is used (Fig. 12.11).

A traditional Italian recipe, known and appreciated all over the world, is that of *Panettone*; it is a Christmas cake originally created in Milan and present on festive

Fig. 12.5 Ancient *Pannicilli* before and after cooking in the oven

Fig. 12.6 Slices of candied citron coated with dark chocolate

Fig. 12.7 Cannoli filled with citron custard

tables throughout Italy and in all cultures that associate with the Christian religion. In addition to its soft and rich dough, the peculiarity of *Panettone* is the dome shape that makes it unique. As it is known today it has evolved from breads, enriched with precious ingredients, that were prepared on religious holidays. In the classic recipe, the inside of the dough is enriched with pieces of candied citron and oranges, as well as raisins. The version, revisited by the best Calabrian pastry chefs who exploit all the potential of citron, provides a filling with citron custard and candied fruit are

Fig. 12.8 Typical cake prepared with almond paste and a filling of candied citron pumpkin

Fig. 12.9 Small desserts prepared with almond paste and candied citron

used to garnish the dome which is covered with white chocolate flavored with citron (Fig. 12.12).

Another traditional Italian dessert, *Colomba pasquale*, is very similar in external decoration: the *Colomba* is a soft baked cake made from the leavened dough of classic

Fig. 12.10 An assortment of delicious sweets made with candied citrons, citron flavored custard and jams

Fig. 12.11 Typical *Pasticciotti* containing citron custard and citron jam

ingredients expertly mixed by the hands of Italian pastry chefs with a characteristic shape that recalls the symbol of Christian peace (Fig. 12.13).

Fig. 12.12 Panettone, an Italian Christmas speciality prepared by Calabrian pastry chefs, filled with citron custard. The dome is garnished with white chocolate flavored with citron and candied fruit

Fig. 12.13 Colomba, traditional Italian Easter cake

12.5 Savory Dishes

Citron is well established in the preparation of many savory dishes. Of very common use, especially in Sicily, is the preparation of fresh salads. Here are some simple recipes that are easy to prepare.

Citron and Blood Orange Salad: the citron must be peeled and cut into very thin slices; slices of blood orange are added together with fresh onion that is sliced very thinly. Season with chilli, olive oil, salt, and a few sprigs of parsley (Fig. 12.14).

Citron and fennel salad: the combination of citrons with fennel, both thinly sliced, is complemented with pitted green olives and red onion that is also cut very thinly. Season with olive oil, salt, and black pepper (Fig. 12.14).

Citron and tuna salad: this is a Mediterranean salad with slices of yellow citron, tuna fish fillets in oil, pitted green olives, capers and aromatic herbs. It is considered a complete dish for its high nutritional value (Fig. 12.14).

The passion for *Pasta* in the Mediterranean diet has led chefs to develop complex and refined dishes but also to prepare very simple dishes based on fresh pasta with the unmistakable scent of citron. An example is *Trofie* or *Linguine with citron*: the procedure is very simple and fast; just heat olive oil in a pan with a few cloves of minced garlic, add abundant julienne-cut citron peel, parsley and salt, and let it blend for a few minutes with dry white wine. Meanwhile, cook the pasta and drain it, then whip it with the sauce already prepared; finally, the dish is completed with chopped parsley and plenty of fresh, grated citron peel. Success is assured! (Fig. 12.15).

Fig. 12.14 Citron and blood orange salad (left), citron and fennel salad (center) and citron and tuna salad (right)

Fig. 12.15 Trofie pasta with citron peel cut into julienne strips garlic, parsley and olive oil

12.6 Liqueurs and Syrups

Really fragrant liqueurs with digestive properties, particularly appreciated after a meal, are obtained from fresh citron peels infused in alcohol with the addition of water and sugar. The procedure for preparing etrog citron liqueur is simple.

The citron's outer fruit peel (flavedo), which is yellow or yellowish green in certain ripe 'Yemenite' etrogs, is rich in aroma. The flavedo is where most of the citron's health-benefitting ingredients are concentrated. In recent years, extensive scientific work has been carried out to distinguish and characterize these substances called flavonoids, and tests have shown that they have a variety of important biological activities. For example, flavonoids have cholesterol-lowering elements which balance the level of lipids in the blood and, therefore, could help improve heart function. Other flavonoids help weight loss, improve the functions of the digestive system (pectin), have positive effects on the nervous system, and more.

The first stage in preparing etrog citron liqueur is choosing the etrogs: they must be ripe and juicy, and the external peel must be rich in odor. It is also important to make sure that the fruit is not coated with wax or chemicals. Prepare a glass jar with a sealed lid and fill it two-thirds (500 mL) with 99% alcohol—preferably from grape fermentation, but alcohol produced from wheat or potatoes can also be used. Take 3–4 large etrog citron fruits (or 7–8 small ones), rinse them and leave them to dry. Using a peeler or fruit knife, peel the yellow external peel (flavedo) straight into the alcohol-filled jar. Note: the thinner the peel, the less bitter the liqueur will be. The alcohol must totally cover the peels and at least 1–2 cm above them for the process to be effective and rich. The etrog citron peel remaining after the flavedo has been removed can be used to make candied peel or jam.

The peels are kept in the closed jar for at least ten days, with the mixture being occasionally stirred. The yellow or green mixture is then transferred into a bottle with the jar being carefully tilted to capture the concentrated liquid without the sediment.

Fig. 12.16 Citron liqueurs

The bottle can be kept for a long time in a cool and dark room (Fig. 12.16). Some lemon peel (up to a quarter of the fruit) can be added for a more lemony taste.

Preparing the syrup (sugar water): for every half liter of alcohol, prepare a syrup by dissolving two cups of sugar in four cups of water. Heat the mixture and stir it until the sugar dissolves, and then refrigerate. Different ratios of sugar concentrations can be used, depending on taste. It is important to use quality water, either mineral water, filtered water or even distilled water (in reverse osmosis).

Preparing the liqueur: mix one cup of the alcoholic extract in two cups of syrup, achieving an alcohol concentration of 33%, and the liqueur is ready. The alcohol concentration in the liqueur can be diluted up to 25%, depending on taste. The liqueur is usually stored in the freezer (Fig. 12.17).

A process like the one described, but without the use of alcohol, is carried out to produce *Citron syrups*: the green etrog citron peels, without albedo, are left to infuse in a sugar solution. The resulting syrup is widely used for the preparation of refreshing beverages and for the preparation of ice creams and sorbets.

The foregoing paragraphs present a range of gastronomical uses of the citron in the Mediterranean, in particular Italy. There are however many more attractive citron

Fig. 12.17 A range of citron liqueurs and syrups

recipes in other citron growing areas, such as China. There is undoubtedly room for a broader discussion of the citron's culinary qualities, within an appropriate text.

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Part III
Tradition

Chapter 13
'Fruit of the Goodly Trees': The Talmudic Discourse on the Etrog Citron

Eliezer E. Goldschmidt

Abstract The third chapter of *Sukkah* in the Talmud is dedicated to the "Four Species," amongst which is the etrog citron. The traditional identification of the etrog (pl. etrogim) as the "*fruit of the goodly tree*" (Lev. 23:40) is further supported by clues from the biblical text. In order to be qualified for its ritual use, the etrog must have a typical, elongated shape, with a peduncle, and preferably a "*pitam.*" A whole fruit, intact, mature, green-yellow in color, without any blemishes is required. The detailed Talmudic discussion is reviewed and illustrated from an agricultural botanist's viewpoint.

13.1 Introduction

This book, which is entirely devoted to the etrog citron, must also relate to the Talmudic discussion surrounding it. This discourse is the link between the biblical "*pri etz hadar*" (Lev. 23:40), "fruit of a *hadar* tree," or, as it is more commonly translated, "fruit of the goodly tree," and the practical laws summarized in the *Shulkhan Arukh* (*The Code of Jewish Law*). In the present chapter, we briefly address the botanical and agricultural aspects of this discourse, not all of which received attention in the rabbinic literature.

13.2 Structure of the Etrog Citron

Prior to approaching the halakhic issues, we need to say something about the structure of the etrog citron (hereafter: etrog). The etrog, which belongs to the *Citrus* genus,

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has an elongated, often pointed shape, by which it can easily be distinguished from other citrus fruits such as lemon, orange, grapefruit, and mandarin.

Figure 1a shows a "Calabria" etrog, with a pedicel (stem end) at the bottom and a persistent style (*pitam*) on the top. Figure 1b contains a cross-section of the same fruit, showing some of its typical characteristics: an external, colored rind (flavedo), an internal thick white peel (albedo), and a relatively thin pulp containing seeds and juice sacs. Figure 1c depicts a cross-section of a "Yemenite" etrog with a very thick albedo, and a thin pulp with thick-walled segments containing seeds, but no juice sacs.

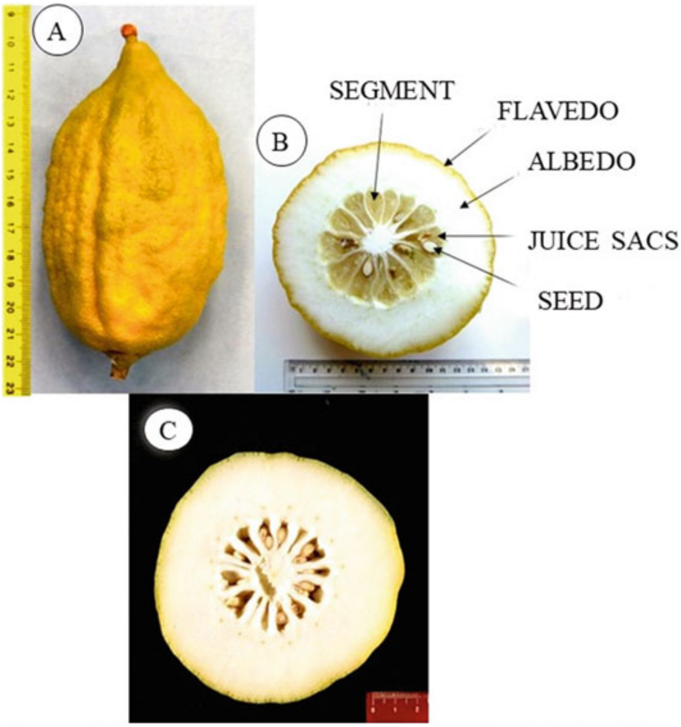

Fig. 13.1 Anatomical structure of the etrog citron. **a** A "Calabrian" etrog; the *pitam* is persistent and viable due to a hormonal spray that prevents it from dropping. **b** A cross-section of a "Calabrian" etrog revealing the fruit's structure: the external green/yellow peel (= flavedo), the internal thick white peel (= albedo), and the inner pulp section divided into segments containing juice sacs and seeds. **c** A cross-section of a "Yemenite" etrog: the albedo takes up most of the area. The segments, divided by thick partitions, contain seeds but no juice sacs

13.3 Identifying the 'Fruit of a *Hadar* Tree'

The biblical verse that commands the taking of four species (Lev. 23:40) mentions four plant species, three of which appear by their names, while the fourth is indicated by a vague term—"fruit of the *hadar* tree." As already noted by the Rosh[1]: "[the] Lulav's four species are clearly defined in the biblical text, with the exception of the etrog, which is not clearly defined." This is probably the background to the Talmudic instruction (BT *Sukkah* 31a): "A person who does not have an etrog, must not take a quince, a pomegranate or any other fruit"; as further explained by the Rosh (see footnote 1): "With regard to palm frond, myrtle and willow there is no fear of erring or confusion, but regarding the etrog one might assume by mistake that a quince or pomegranate may also defined as "fruit of a *hadar* tree." Therefore, notwithstanding our tradition that the biblical "fruit of a *hadar* tree" is the etrog, and as declared by Maimonides that "This identification has never been questioned,"[2] the Talmud brings forth several homoletic interpretations that strengthen and anchor the identification of "fruit of a *hadar* tree" as the etrog,[3] as follows (BT *Sukkah* 35a):

> The Rabbis taught, "*pri etz hadar*" implies a tree whose "fruit" and "tree" (= stem and leaves) taste alike; say therefore: this is the etrog. Rabbi [Rabbi Yehuda the Prince] said, read not "*hadar*" but "*ha-dir*" [= a deir sheep], just like a deir sheep, where large and small sheep, perfect ones and blemished ones dwell together, this tree bears large and small, perfect and blemished fruit together, meaning that while the new, young fruit develop, the large, older fruit still exist. Rabbi Abbahu said, read not "*hadar*" but "*ha-dar*" (= dwells, remains), a fruit which remains on the tree from this year to the next one. Ben Azzai says, read not "*hadar*" but "*hydor*," since the Greek word for water is "*hydor*" [hydro]; what fruit depends upon frequent supply of water? Say therefore: this is the etrog.

These homilies relate to the etrog's unique botanical and agricultural features.

An additional view appearing in the Jerusalem Talmud (JT) (*Sukkah* 3:5) interprets "*hadar*"—glorious beauty: "The script mentions "*pri etz hadar*"—a tree whose fruit

[1] Rosh, BT *Sukkah* 3:14.

[2] Rambam, *Introduction to the Mishnah*, Kapach ed. (Jerusalem: Mossad Harav Kook, 1963), 9: "… there is no argument regarding the command to take 'a fruit of a *hadar* tree' that the Torah is referring to an etrog, and nobody argues it is a quince, pomegranate, or any other fruit… When the Talmud discusses and argues, bringing proofs to any one side, like the *verse* 'the fruit of a *hadar* tree' which the Talmud asks if it means a quince, pomegranate or any other fruit, until it proves from the words "*pri etz*" (fruit of the tree) as referring to a tree whose taste of its woody organs and fruit are alike; or because it is a fruit that remains on the tree from year to year; or a fruit that needs irrigation; this does not mean there is any doubt regarding the identity of the etrog so that proofs were necessary, as we know without any doubt, from the days of Yehoshua until the present day, that we take an etrog and palm frond every year and nobody disagrees. However, the Talmud is examining how the Torah's words fit this definition".

[3] See also Menahem Me'iri, *Menahem ha-Meiri, Beit ha-Bekhira* (Zichron Ya'akov: Torah Educational Center, 1977), M *Sukkah* 36a: "Although the Torah does not explicitly mention etrog, the tradition is that "the fruit of the *hadar* tree" refers to the etrog. And although it is a tradition and there is therefore no need to seek other reasons why the Torah means an etrog, the Talmud explains that it is hinted in the words 'the fruit of the tree,' meaning the woody organs of the tree taste is the same as its fruit".

is glorious and the tree itself is glorious; what is it? The etrog. Would you say, "a pomegranate?" Its fruit is glorious, but its tree is not. Would you say, "a carob?" Its tree is glorious, but its fruit is not. What is it then? The etrog."[4] These homilies require further explanation. The characteristic that "tree and fruit taste the same" is not unique to the etrog. The Talmud mentions other plant species that have this feature, such as pepper, but rejects the option that the commandment "take a fruit" refers to a tiny fruit such as pepper, since a single pepper fruit is barely noticeable.[5] However, myrtle is also mentioned as having "tree and fruit that taste alike,"[6] and even fenugreek seems to have this property.[7]

What then is the meaning of "tree and fruit taste the same?" Another homily has a different angle: "Go out and check: Is there a tree whose stem is eaten just like its fruit? You will not find any except the etrog."[8] Some commentators related this feature to the ancient sin of the earth, that instead of producing "a fruit tree"—implying that "fruit" and "tree" taste the same—produced "a fruit-giving tree."[9]

The most feasible explanation[10] is that "*etz*" refers to the soft edible leaves and stalks (*timorot*). Indeed, the JT[11] states that while one recites the blessing "*borei pri ha'etz*" on the etrog, on its *timorot* one recites "*borei minei deshaim*." Ramban[12] cites this JT, adding: "The same applies to the etrog's leaves, since its fruit and tree have the same taste."

But there is also room for other interpretations: the "*etz*" could be referring to the inedible colored rind of the etrog, and "*pri*–fruit" to the inner, edible part. This explanation of "*etz*" can be supported from a proverb of the walnut, i.e., that "its tree (*etzo*) protects its fruit,"[13] which probably refers to the hard shell that protects its inner, edible part. The *Kapot Temarim*[14] suggests an original interpretation of "tree

4 See the JT for other teachings, similar to those cited in the Babylonian Talmud (BT). For further interpretations of "*pri etz hadar*," see David Z. Moster, *How a Chinese Fruit Became a Jewish Symbol* (New York: Palgrave-Macmillan, 2018), 49–88.

5 See Adin Steinsaltz, *Tractate Sukkah* (Jerusalem: Israel Institute for Talmudic Publications, 1984), 35a, which defines the pepper mentioned in this discourse.

6 Ibid. 32b. Chatam Sofer, *Moshe Sofer (responsa)* (Jerusalem: Hod, 1972), *Orach Chaim* 207 writes that the same reason given to reject the use of pepper since its fruits are small, applies to the myrtle fruits which are small and unrecognizable.

7 The commentary of Rabbi Ovadia Bartenura, *Terumot* 10:5; Rambam, *Commentary to the Mishnah*: "The taste of the fenugreek's stem is similar to the taste of its fruit".

8 *Bereishit Rabba* 15:8.

9 Rashi, *Ber.* 11:1 s.v. *etz pri*, and other commentators who follow Rashi.

10 This is also the explanation of Judah Feliks, *Plant World of the Bible* (Ramat Gan: Massada, 1968), 66.

11 JT *Kil.* 5:8.

12 Ramban, *Berachot* 36a s.v. *vekatav*.

13 *Shir Hashirim Rabba* 6:11.

14 Moshe ben Khaviv (1614–1657), *Kapot Temarim Sukkah* 35a s.v. *begmara tanu rabannan*: "If one asks, perhaps the Torah is referring to a lemon or orange whose woody organs have the same sour taste as their fruit? We could answer that the main fruit part of the lemon or orange is the sour internal section, which is more prominent than its peel, unlike the woody organs which are not sour but bitter, just like the peel. But the etrog's inner sour part is minimal and is not regarded as "fruit,"

and fruit taste the same": in all other citrus fruits the edible part is the sour inner part of the fruit, which doesn't taste like the tree, unlike the etrog whose inner part is minimal, and its main edible part is the bitter, spicy white peel, which has the same taste as its tree. According to Rabbi Samson Raphael Hirsch,[15] the phrase "tree and fruit taste the same" refers to the essential oil of the citron peel, which is present in all its organs—fruit, leaves, and stems, and which gives the etrog its distinctive fragrance and aroma.

The Talmudic homilies of Rabbi, "*hadir*," the sheep pen—and Rabbi Abbahu, "*hadar*" as "dwells, remains"—are similar[16] and are based on the etrog's reproductive behavior; the tree has several waves of flowering and actually blossoms and produces fruit throughout the year. Then, unlike other fruits, etrog fruits do not fall off the tree upon ripening, but remain intact on the tree up to two or three years and continue growing. Thus, large and small fruits are present on the same tree simultaneously. The terms "perfect and blemished fruits" in Rabbi's homily probably refer to the variability in fruit shape and symmetry, which is typical of the etrog.[17]

Ben Azzai's homily (*hadar–hydor*) takes us to the agricultural domain. The etrog was the only fruit tree known to our Sages that could not be grown without irrigation. According to Ben Azzai, this feature, as hinted in the Greek translation of *hadar*, supports the identification of "fruit of the *hadar* tree" as etrog. The etrog tree needs irrigation, like vegetables whose cultivation also depends upon irrigation. This similarity is the source of certain halakhic comparisons between the etrog and vegetables regarding the laws of Tithing and *shmitta*, the Seventh Year.[18]

13.4 Etrog Paragraphs in the Mishnah

Tractate *Sukkah* of the Mishnah (= the basic sections of the Talmudic text) deals with all aspects of the feast of Sukkot (Tabernacles). In its third chapter, a separate paragraph is devoted to each of the four species—palm frond, myrtle, willow, and

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and its main "fruit" is instead the thick peel, which is bitter, just like the woody organs. Therefore, the woody organs and fruit have the same taste." The Chatam Sofer in his *teshuvah* (n. 6 above) applauds this explanation. But it should be noted that this explanation was written when other citrus fruits, like lemons and oranges, were already grown in the area, and therefore this feature of thick rind is what differentiates the etrog from the other citrus fruits. However, as far as we know, in the times of our Sages there were no other citrus fruits in the Land of Israel, and therefore it would have been irrelevant to mention the difference between the etrog and other citrus fruits.

[15] Samson Raphael Hirsch, *Commentary on the Torah* (Jerusalem: Mossad Harav Yitzhak Breuer, Jerusalem, 1976), *Vayikra* 23:40.

[16] See Rashi, *Sukkah* 35a s.v. *hadar*. Rabbi Abbahu is of the same opinion as Rabbi, and their only disagreement regards the term "*hadar*," whether its root is from the word *dir* or from *dirah.*

[17] Eliezer E. Goldschmidt, "Factors Determining the Shape of Citrons," *Israel Journal of Botany* 25 (1976): 34–40.

[18] M *Bik* 2:6; BT *Roš Haš* 14a, 15b.

etrog, discussing the laws common to all four species, as well as specific features of each.

Three paragraphs of the Mishnah are dedicated to detailed instructions concerning the etrog (*Sukkah* 3:5–7). The first of these paragraphs relates mainly to the general aspects of the etrog as an edible fruit, while the second and third paragraphs relate to the etrog's specific botanical features.

13.5 Dryness

One of the disqualifications common to all four species is that of dryness, with the Talmud explaining that a "dry" plant organ does not comply with the requirement of "*hadar*"—glorious.[19] According to Rashi, the four species must be glorious just like all other worship artefacts that must be "glorious." But according to other commentaries, this is a unique ruling regarding the four species, i.e., that they must be "glorious."

What is then the kind of dryness which disqualifies an etrog? It is obvious that the dryness of a thick, juicy fruit differs from that of the leafy palm frond, myrtle, and willows, and the symptoms of dryness must also be different. The Me'iri writes: "Dry, this seems to be a shrunken etrog, without any moisture remaining in it."[20] The Rosh, in the name of the Raavad, goes a step further:

> The dryness of a fruit is comparable to that of a live being since the fruit's moisture is compared to a living flesh's blood. So, as long as the etrog emits liquid when squeezed or cut, it is considered moist; but once it no longer has any moisture it is like dead flesh that does not emit even a drop of blood.

Although it is difficult to test the etrog's moisture because it cannot be squeezed or cut, but since "a hole that does not remove any part of the etrog does not disqualify it," it would be permissible to pierce the etrog with a needle and thread to check if there is any moisture on the thread. "Unlike the palm frond, which is disqualified when dryness turns it white, the etrog does not turn white when dried out, it rather turns red and darker. Thus, the right way to test its dryness is by determining its moisture [level]."[21]

[19] BT *Sukkah* 29b and Rashi; and see *Tosafot* s.v. *lulav*; Rambam, *Commentary to the Mishnah*, *Sukkah* 3:1.

[20] Me'iri, *Sukkah* 34b s.v. *amar haMe'iri*; similar to Rabeinu Nissim, *Commentary of the Rif*, Ran 17a, s.v. *matnitin* etrog.

[21] Rosh, BT *Sukkah* 3:20.

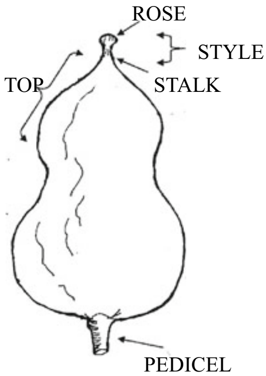

Fig. 13.2 A schematic depiction of the etrog in halakhic terms. The ridge around the center of the etrog is called a "*gartel*"[22] (a belt, in Yiddish)

13.6 Defects and Blemishes

Figure 2 illustrates the etrog's overall structure in halakhic terms, will help in understanding the details. The second etrog paragraph (*Sukkah* 3:6) deals with fruit defects and blemishes, those that disqualify it and those that do not, opposite each other:

Scab covered most of its surface.

Its "pitma" has been removed.

Peeled, split, and any of portion of the fruit missing—invalid.

Scab covered a minor part of its surface.

Its pedicel has been removed.

Punctured, but no portion of the fruit missing—valid.

The two parts of this paragraph are arranged in parallel, and this has implications with regard to their interpretation, as will be clarified further on.

13.7 *Chazazit*—Scab

What is a *chazazit*? It can be translated as "scab"; Rashi explains it as "some kind of small blisters,"[23] and the Rosh adds: "It must be tangible and can be felt when touching it, as it is higher than the rest of the fruit's surface."[24]

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[22] The *gartel* phenomenon is already found in etrogim in archaeological finds. According to Bar-Yosef, it is the result of viroids (see chapter "Diseases of the Etrog Citron and Other Citrus Trees"). For a halakhic reference to *gartel*, see Yitzhak M. Lieberman, *Pri Etz Hadar: The* Etrog *in Halacha and in Practice* (Bnei Brak: Author's ed., 2015), 97–98.

[23] Rashi, BT *Sukkah* 34b s.v. *chazazit*.

[24] Rosh, BT *Sukkah* 3:15.

The Ria'z writes: "*Chazazit* is some kind of small blisters that grow on fruits while they are still attached to the tree, but a *chazazit* that develops after the fruit has been detached is a result of dryness and dehydration, and does not disqualify it."[25] Raavad terms them *chavarburot*, indicating a certain change in the texture of fruit surface.[26]

From these commentators it is evident that they recognized the *chazazit* and could identify it. On the other hand, Rabbi Yisrael Isserlin (Austria, 1390–1460), author of *Terumat Hadeshen*,[27] expresses doubts regarding "…those common blemishes termed *plat mohl* (*blettel*[28])," whether they should be regarded as the Talmudic *chazazit*. Perhaps he was of the opinion that *chazazit* is a general term for fruit blemishes.

Various suggestions have recently been made to identify *chazazit* with recognized citrus fruit diseases, especially various fungi,[29] but having carefully examined the phenomenon, and in consultation with experts in the pathology of citrus fruits, we have not been able to identify a particular phenomenon matching the above descriptions that would be reminiscent of a cancerous growth on the fruit's surface.

From the way it is discussed in the Talmudic sources, it appears the *chazazit* scab was a common, familiar, and well-known phenomenon. Therefore, in our opinion it is reasonable to assume that the Talmudic *chazazit* is the blemish known nowadays as "*blettel*," a rough, light grayish cork tissue on the fruit surface (Fig. 13.3). Although this identification does not exactly match earlier descriptions, in our humble opinion this is the closest identification of the *chazazit* scab mentioned in our sources.

Our source paragraph distinguishes between the case of a "scab covered most of its surface," which renders the etrog invalid, and that of a "scab covered a minor part of its surface" in which the etrog is still valid. But the Talmud restricts this latter case—"This is only when the scab appears as a single spot, but when it appears as

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25 *Piskei Haria'z, Rav Yeshayahu Ditrani Akharon* (Jerusalem: Hotzaat Machon Hatalmud Hayisraeli Hashalem, 1966), *Sukkah*, ch. 3, *halackah* 5:3, 264. Cited in Yehoshua Boaz, *Shiltei Hagiborim*, in Rif, *Sukkah* 17b.

26 Cited in Rosh, BT *Sukkah* 3:19.

27 Yisrael Isserlin, *Terumat Hadeshen*, ed. Natan Steiner (Tel Aviv: Nathan Steiner, 1950), 99. He may not have had the opportunity to see etrog trees, unlike the commentators mentioned above who lived in southern France, Spain, and Italy. But see Aharon HaCohen, *Orkhot Hayim* (Florence, 1750), Part I, *Hilchot Lulav*, 16 (from Lunel: southern France and Spain, end of the thirteenth century, early fourteenth century), who is also indecisive in identifying the *chazazit*.

28 "*Blettel*" is the Yiddish word for a small leaf; according to common belief, this blemish is caused by the leaves rubbing against the etrog, hence the name "*blettel*–leaf." In fact, however, any scratch or injury inflicted by an insect or mite on the young fruit peel results in the formation of a white/gray/silver cork tissue. Small or large *blettel* spots are very common, and sometimes cover most of the area of the fruit (as in the case of an injury caused by mites). Citrus growers call this phenomenon "silver scurf." The *blettel* is prominent on the fruit while it is still green, but when the fruit turns yellow it are almost imperceptible.

29 Yaakov T. Meir, *Chazazit*, Steinsaltz-Portal Hadaf Hayomi (Jerusalem: Israel Institute for Talmudic Publications, 2004), *Bechorot* 41a. Lieberman, *Pri Etz Hadar* assumes that the *chazazit* in the form of a *blettel* develops when the fruit is in moist conditions, when a kind of light brown wart grows, with a peel on top. When this peel is removed, a cream-white moist spongy substance is revealed.

Fig. 13.3 A *chazazit* covering a considerable part of the fruit surface, including part of its tip

two or three spots the etrog is considered 'speckled' and is therefore invalid." And another reservation: "If a scab appears close to the top of the etrog: "Close to the top; the upper part of the etrog from where it inclines towards the tip," see Fig. 13.2) even the smallest size scab disqualifies it (ibid.: "…since it is more visible there than in other places, being the part that a person readily inspects.").[30]

Over the generations, the case of the *chazazit* scab became a leading example for other fruit defects, which are also taken more seriously when occurring on the top of the etrog than on other parts of the fruit's surface.[31]

13.8 *Pitma* and *Okets*

Pitma and *oketz* are mentioned in our paragraph (*Sukkah* 3:6) in contradistinction; removal of the *pitma* disqualifies the etrog, but removal of the *oketz* does not. The Talmud (*Sukkah* 35b), in the name of R. Yitzchak ben Elazar, interprets thus: The *pitma* has been removed—the *pestle* has been removed. These few words intrigued all commentators.[32] *Oketz* is unquestionably defined as the pedicel, the stalk that

[30] The commentaries disagree as to whether the "tip" includes the whole upper part of the etrog from where it starts to incline towards the *pitam*, or if it is limited to the area of the *pitam*. Rabeinu Nissim, in Rif, *Sukkah* 17b, s.v. *amar Rava.*

[31] Ibid.; *Shulkhan Arukh* 648:12.

[32] This is similar to the JT (3:6) "The *pitma* is removed: in Babylon they explain this to mean the *shoshanta*, R. Yitzchak bar Chakula says it means the *pika*"; the commentaries differ on the meaning of this JT paragraph.

Fig. 13.4 A longitudinal section of a two-month-old "Ordang" etrog, showing the structure of the pedicel, the *pitam*, the albedo, the juice sacs, and the seeds (*Photo* Dr. Ilana Stein)

connects the fruit to the stem, through which the fruit receives its nutrition from the tree (see Fig. 13.4). In contrast, there is much controversy over the identification of the *pitma*. Rashi explains:

> *Pitma*… The top of the etrog, as heard from R. Yaakov, similar to the *pitma* of the pomegranate (*Uktzin* 2:3).[33] R. Yitzchak ben Elazar called it 'the pestle,' since the *pitma* is pointed and has the same shape as a pestle. This is how my elderly master, R. Yaakov taught. But R. Yitzhak Halevi used to explain that both pedicel and *pitma* are at the etrog's bottom side, *oketz* being the part of the pedicel outside the bottom hole, and if removed the etrog is valid, whereas *pitma* is the part of the pedicel concealed at the bottom of the etrog, and when this part is pulled out it takes with it some of the etrog*'s* flesh; thus a portion of the etrog is missing and the etrog is disqualified. According to this explanation the words 'the pestle is removed,' refer to the part pedicel that enters the etrog*'s* flesh like a pestle that grinds in the mortar.[34]

Rashi concludes: "R. Yaakov's explanation appeals to me, since we haven't found the term *pitma* referring to the pedicel."[35,36]

Clearly, both interpretations agree that the term "pestle" refers to the rounded top of a pestle used for grinding. However, according to Rashi's first explanation the

[33] Rashi, *Sukkah* 34b s.v. *nitla pitmato.*

[34] Ibid., 35b s.v. *tani.*

[35] See *Tosafot* 35b s.v. *nitla* which rejects Rashi's proof.

[36] See Rabeinu Chananel's explanation of "if the pestle is removed" (36a s.v. *nitla pitmato*).

"pestle" resembles the top of the etrog, nowadays called the *pitam* (Figs. 1 and 2),[37] but according to the second explanation it is the inner part of the pedicel which, when detached from the etrog, has a round top resembling a pestle.

Beyond identifying the fruit organs in question,[38] we must understand why their absence disqualifies the etrog. The pedicel is certainly not part of the fruit itself, and the only reason to disqualify an etrog without its inner pedicel is that "when the pedicel was removed, part of the etrog's flesh was also removed, and therefore it is invalid" (Rashi, in his second explanation[39]). But even if *pitma* refers to the *pitam*, it is still not an inherent organ of the fruit, so why should the etrog be disqualified if the *pitam* is missing? The Ritva answers: "Although the etrog is not lacking any part of its body, nevertheless, an etrog without its *pitam* is not glorious."[40]

The medieval commentators also note that many etrogim do not actually retain their *pitam* up to the later stages of fruit development: "Most of the etrogim do not have that "rose with its stalk" (= a complete *pitam*, see Fig. 13.2), yet the etrog is glorious without them."[41] Therefore, says the Ramban,[41] even if the *pitam* has dropped, the etrog is valid, since this is its natural behavior, as the *pitam* is not part of the body of the etrog whose absence would disqualify it. Nevertheless, according to the Rosh, "one should disqualify an etrog that had a *pitam*, and the *pitam* has been removed."[42]

This circumstance, i.e., that most adult etrogim do not have a *pitam* (although all had a *pitam* when flowering) is the situation even today; furthermore, in certain varieties (e.g., "Yemenite" and "Calabrian") *pitams* are rare. However, today it is possible to obtain beautiful etrogim with a viable persistent *pitam* from every variety thanks to the spraying of the synthetic hormonal auxin, Picloram.[43]

It is very difficult to find the original meaning of *pitma*, in order to decide among the various options. The contrasting parallels between the two parts of the paragraph—its "pitma" has been removed—valid; its pedicel has been removed—invalid—hints towards the identification of the *pitma* with what we call *pitam*.[44] Furthermore, according to Rashi's second explanation (that *pitma* refers to the inner part of the

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[37] The comparison of the *pitam* to the pestle is also reflected in the botanical, Hebrew, and English terminology of the flower's parts. In Hebrew, the female flower organ is called *aeli*, and in English pistil. "Pistil" is similar to "pestle," and the Hebrew word *aeli* can also translated as the pestle's mortar! This seems to support Rashi's first explanation, which identifies his "pestle" with the top nipple.

[38] See Me'iri (*Sukkah* 34b s.v. *hamishnah harevi'it*), who elaborates in defining the *pitam* and *shoshanta*, and distinguishes between different varieties of etrog. He is inclined to explain its "*shoshanta*" as something totally outside of the etrog, which may be referring to the stamens that sometimes remain attached to the young fruit at the beginning of its development.

[39] Ritva, *Sukkah* 35b, s.v. *nitla pitmato.*

[40] Ibid.

[41] Ramban, "*Lulav hagadol*," 57 s.v. *me'atta.*

[42] Rosh, BT *Sukkah* 3:16.

[43] Eliezer E. Goldschmidt "On Prospects of Preventing Citron (*Citrus medica L.*)-style Abscission by Spraying Picloram," *Hasadeh* 50 (1970): 740–42.

[44] But see Ramban ("*Lulav Hagadol*," 50, s.v. *inyan*) who writes to the contrary: "…The second part of the Mishnah verifies the ruling of the first part," and he is therefore of the opinion that they are

pedicel) there is no reference in the Talmudic discourse to the presence or absence of the *pitam*, which deserves a mention since it is the prominent part of the etrog's tip and which everyone looks at. On the other hand, examining archaeological and artistic evidence, the pedicel is usually highlighted with a large T-shape, whereas the *pitam* is not always prominent, which apparently designates more significance to the pedicel.[45]

13.9 Peeled

For an etrog to be competent, it must be intact. This is the basis for the last part of our Mishnah paragraph (*Sukkah* 3:6), which is also arranged in parallel: peeled, split, and any of portion of the fruit missing—invalid; punctured, but no portion of the fruit missing—valid.

A peeled etrog is disqualified since removal of the peel nullifies its intactness.[46] The Talmudic discourse states, nevertheless, that if the etrog has been "peeled like a red date" it is still valid. This triggers two questions: (1) which part of the peel can be removed, allowing the fruit to still be considered intact? (2) what does the similarity to a red date teach us? These questions are intertwined.

There are two main explanations for the term "peeled":

1. Only a thin membrane covering the fruit has been removed without damaging the actual fruit. This is how the Rambam explains it: "Peeled does not mean that the yellow rind was peeled away until the white was exposed, since that would disqualify the etrog because part of it is missing. Rather, it means that the very thin membrane covering the yellow peel has been scratched away…"[47] This thin, waxy lipid membrane is scientifically called "cuticle," and is visible under a microscope (Fig. 13.5).
2. An alternative explanation: the fruit's flavedo (Fig. 13.1) was removed without damaging the albedo (Fig. 13.1), which is the edible part of the etrog. The Rosh adopted this view: "The law permitting a peeled etrog pertains to a circumstance where only the red (= yellow) peel has been removed without any of the white layer, otherwise part of the etrog would be missing and it would be disqualified" (see footnote 48). The Rashba also writes in one of his *responsa*: "It is only considered missing when part of the etrog's flesh, which is the white part, is

both referring to the same part of the etrog, supporting Rashi's second explanation. Ritva (*Sukkah* 35b) is of the same opinion.

45 See more concerning the *pitam*: Goldschmidt, "New Insights in Citron (*Citrus medica* L.) Genomics and Fruit Development," *HortScience* 52 (2017): 823–26.

46 The commentaries disagree as to whether partially peeled disqualifies the etrog or whether totally peeled is kosher (Rashi), or the opposite, that partially peeled is kosher and totally peeled is invalid (*Tosafot* 36a, s.v. *ha*, and other commentaries).

47 Rambam, *Commentary to the Mishnah*, *Sukkah* 3:6; similarly in idem, *Mishneh Torah* (Jerusalem: Rambam La'am, 1958), *hilchot lulav* 8:7.

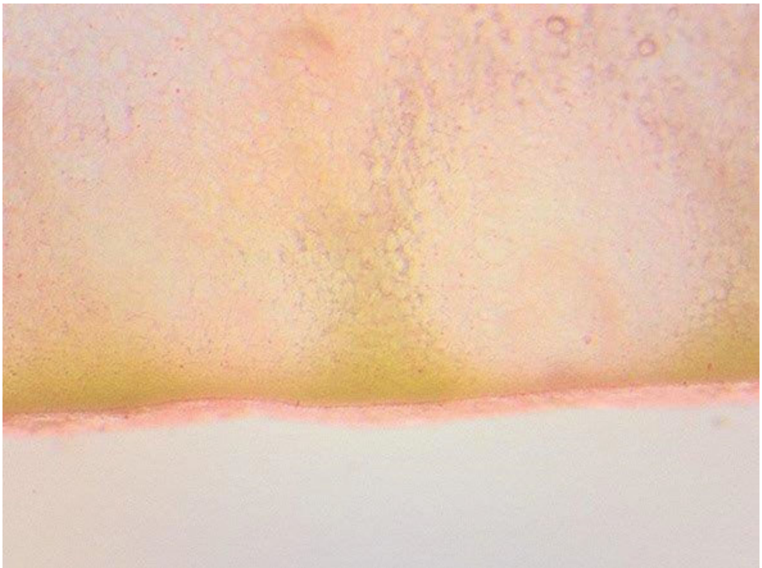

Fig. 13.5 A microscopic image of an etrog peel section after dyeing it with Sudan IV, enabling one to discern the thin external membrane—the cuticle; magnification X25 (Prepared and photographed by Dr. Ilana Stein)

> missing, but the absence of its external layer does not disqualify it; this is how we have been taught.[48,49]

Regarding the similarity to a red date, Rashi comments: "Like a red date, the flesh of the etrog turns red after being peeled, just like all peeled fruits."[50] Rashi understood that the Talmud is referring to a change in color to a reddish brown after the etrog has been peeled, as is the case with peeled apples and other fruits. It is therefore certain that Rashi learned "peeled" according to the second explanation, i.e., that peeling the colored, external layer exposed the inner white layer, since only then does the fruit flesh obtain a reddish, date-like color.

However, looking at the first explanation, i.e., that only the cuticle was removed without touching the fruit's flesh, what does the comparison to a red date teach us? The answer can be found in the words of the Ria'z: "If the etrog's upper membrane has been peeled away like the upper peel of a date, even though none of the etrog is

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48 Rosh, BT *Sukkah* 3:17; see also his words in 3:16: "… similar to peeled, which is not considered missing since the peel is not part of the etrog." Similarly, in Raavad (*hilchot lulav*): "The rule permitting a peeled etrog refers only to the external layer, but if some of the white part of the etrog is also removed the etrog is disqualified".

49 *Teshuvot Harashba* 1058, see his responsa at length. And see Rabeinu Nissim (in Rif, 17a, s.v. *niklaf*), who brings another explanation, but then rejects it.

50 Rashi, *Sukkah* 36a, s.v. *ke'ahina sumka.*

missing, the etrog is disqualified."[51] Thus, according to Ria'z, the similarity to the date does not relate to the color change of the peeled fruit, but to the transparent, upper peel membrane typical of the date fruit (and perhaps especially of the red date), which is reminiscent of the etrog's cuticle.[52]

13.10 Size of the Etrog

The following paragraph of the Mishna (*Sukkah* 3:7) relates to the dimensions of the etrog. "The size of a small etrog; Rabbi Meir says: as a nut. Rabbi Yehudah says: as an egg. The size of a large etrog is such that one can hold two of them in one hand; this is Rabbi Yehudah's opinion, but Rabbi Yose says that "even an etrog that must be held with both hands is valid." The Talmud tells us that Rabbi Akiva once came to the synagogue carrying the etrog on his shoulder, however his fellow scholars argued that such a huge etrog is not "glorious" (*Sukkah* 34b).[53]

13.11 Color Disqualifications

Most fruits, including citrus fruits, change their color as they approach maturation. Thus, attaining the appropriate color is one of etrog's halakhic requirements.

The Mishnah (*Sukkah* 3:6) lists "black (Negro) etrog" among the disqualified, and the Talmudic discourse (*Sukkah* 36a) explains in further detail: "A black, white or speckled etrog is disqualified." The general reason given for these disqualifications is that such fruit are not glorious.[54]

According to Rashi, etrog fruits grown in Africa (Ochosh), where black is their natural color, are competent even for those living in neighboring countries, but are familiar with such fruits, however, black etrog citrons grown outside Africa are disqualified because they are "atypical."[55] While in Rashi's opinion, which seems to have been the common knowledge of his time, in Africa everything is black, even etrog fruits, we are not aware of such a phenomenon.

On the other hand, according to the Rambam: "Places whose etrogim have a slightly black [dark] appearance, these etrogim are competent, but if they are totally

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[51] *Piskei Haria'z*, *Sukkah* 3:5, 264.

[52] Another question raised by the Raavad (*hilchot lulav*, cited by the Rosh, BT *Sukkah* 3:17): "Shouldn't a peeled etrog be disqualified because of its change of color in the peeled parts, deeming it a speckled etrog?" See his comments.

[53] For further discussion of the etrog size preferences, see Yaakov I. Stull, *Nahagu Yisrael: The Sukkot Festival* (Jerusalem: Author's ed., 2020), ch. 2.

[54] *Mishnah Berurah* (Jerusalem: Machon Lehotzaat Sefarim E.L.B., 1986), 648: s.p. 55.

[55] Rashi, *Sukkah* 36a, s.v. *ha*; regarding the disqualification of "*nidmeh*-atypical" in animals, see *Bechorot* 17a.

Fig. 13.6 A young "Kivilevitz" etrog with a reddish-black shade—a "Negro" etrog (*Photo* Assaf Avtabi)

black, like a black person, they are disqualified everywhere."[56] But what then is the black etrog mentioned in the Mishnah? Nowadays, we commonly explain that it refers to young etrog fruits, which are often reddish-black, or totally black, due to the accumulation of the reddish anthocyanin pigment (Fig. 13.6).

During maturation, citrus fruits, including the etrog, gradually change their color from green to yellow. According to the opinion of R. Yehudah (*Sukkah* 3:6), which is the accepted ruling, a "green as leek" etrog is disqualified. This ruling has practical significance, since etrogim are usually harvested while still green and then gradually turn yellow, a process that may take several weeks or even longer.[57]

The term "green as leek," designating a dark green color like that of the leek leaves,[58] is meant to exclude etrogim with a light green shade inclining to yellow, which have already started to change their color, which are competent.[59] From the Talmudic discourse (*Sukkah* 31b), it can be inferred that "green as leek" is disqualified not because it is not glorious, but rather because it has not yet reached maturity. This is the source of the Rosh's ruling, that a "green as leek" etrog, which, within a short

[56] *Hilchot lulav* 8:8.

[57] See chapter "Preserving Etrog Quality after Harvest: Doctrine and Practice".

[58] To identify the leek, see Feliks, *Plant World of the Bible*, 174.

[59] To identify the different colors mentioned in Talmudic sources, see *Tosafot Sukkah* 31b, s.v. *hayarok*; Moshe Raanan, *Bein Tchelet Lekarti*, Steinsaltz-Portal Daf Hayomi (Jerusalem: Israel Institute for Talmudic Publications, 1967), *Berachot* 9b, "*Bein Techelet Le'karti*".

time will attain the typical etrog color, is valid, since it would not change its color after harvest unless it has reached maturity.[60]

Nevertheless, this issue has caused indecision among the halakhic arbiters, an indecision that continues to this present day: Is it permissible to use an etrog that is still dark green if it will certainly turn yellow within a short while? For example, the Maharil (Mahari Segal) used to disqualify, and advised not to buy, etrogim that are totally green lest the color remained as it was, as a dark green etrog is considered invalid. He only permitted it if part of the etrog had started to turn yellow.[61]

13.12 Epilogue

We have devoted this chapter to the botanical and agricultural aspects of the Talmudic discourse of the etrog citron, and have tried to shed light on some of the issues, but have not exhausted all the topics. There is still room to add and expand on these issues, as is also needed in other Talmudic issues related to the four species and plants in general, according to the teachings of our Sages.

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[60] Rosh, BT *Sukkah* 3:21, following *Tosafot Sukkah* 31b, s.v. *hayarok*.

[61] Yaacov Mulin, *Sefer Maharil [minhagim*] (Bnei Brak: Hama'or, 1959), *hilchot* etrog, 16. See more about color requirements in Lieberman, *Pri Etz Hadar*.

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Chapter 14
Theophrastus to the Present: The Citron in Medicine

Zohar Amar

Abstract The uses and medicinal properties of the etrog citron (*Citrus medica* L.) are mentioned frequently in ancient texts. Systematic descriptions appear for the first time in Greek natural history and medical writings. These descriptions were also used in later centuries in traditional Arabic medicine. In Greek sources, for example, the etrog (pl. etrogim) is mentioned as being effective in alleviating nausea in pregnant women, for hygiene, and for sweetening the breath. In the Talmud, the etrog is listed among the foods that increase sperm, although an excess of the fruit is considered bad for digestion. Parts of the etrog were renowned in particular as a remedy against poisoning. Various beliefs and virtues (*segulot*) were also attributed to the etrog, including increasing fertility and contributing to easing the pains of childbirth.

14.1 Introduction

The uses and medicinal properties of the etrog are repeatedly mentioned in ancient historical sources. Systematic descriptions appear for the first time in Greek natural history and medical writings, descriptions that were also used in the later Arabic medical tradition.

In the Greek sources, for example, the etrog is mentioned as being effective in alleviating nausea in pregnant women, for hygiene, and for sweetening the breath. In the Talmud, the etrog is listed among the foods that increase the sperm, although an excess of the fruit is considered to be bad for digestion. Parts of the etrog were renowned in particular as a remedy against poisoning. Various beliefs and *segulot* were also ascribed to the etrog which related to fertility and facilitated easy childbirth.

Early historical sources are studded with frequent references to the uses of the etrog and its beneficial medicinal properties, indications of which have also been

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found in modern-day studies.[1] This essay will survey several of these ancient uses. Methodical descriptions of the etrog and its medicinal properties first appear in the nature and medical literature of ancient Greece and served as the foundation of a medical heritage which dominated the ancient world for approximately 2,000 years, until the latter part of the Middle Ages.

The first such mention of the etrog appears in the work of the Greek botanist Theophrastus (approx. 287–372 BCE), a student of Aristotle, who referred to it as a "Persian" or "Median apple."[2] Further mentions of the etrog appeared in *Naturalis Historia* (*Natural History*) written by Pliny the Elder (23–79 CE),[3] in Galen (second century CE), and others. They described a species of etrog that was generally used for purposes other than eating, primarily medicinal, thereby lending the fruit its scientific name *Citrus medica*. Pliny even mentioned attempts to adapt the etrog to different climates due to its medicinal importance.[4]

Among the uses mentioned are placing the etrog fruit in cloths to prevent them from being eaten by moths and to repel harmful insects. The etrog was also used to maintain oral hygiene by drinking its juice from its sour inner section after cooking, thereby imparting a pleasant fragrance in the mouth. Its efficiency as a means to treat the effects of poison was also often mentioned—drinking etrog juice with wine causes a stomach upset and thereby the purging of the poison.[5]

Galen described the three sections of the etrog: the sour inner section, used with vinegar as a pungent seasoning; the fleshy middle section, difficult to digest and therefore generally dipped in vinegar or fish broth; and the outer peel, a small quantity of which strengthens the digestive system.[6] Dioscorides (a Greek physician, pharmacologist, and botanist) wrote in his treatise *On Medical Material* that the etrog is eaten mainly by pregnant women as a means of suppressing their appetites for certain foods,[7] while Pliny clarified that this referred to the eating of the etrog's seeds to relieve women's nausea during pregnancy.[8]

[1] For example, as an anti-cancer substance, in treating diabetes, and in bolstering the immune system. See Beatriz Álvarez Arias and Luis Ramón-Laca, "Pharmacological Properties of Citrus and Their Ancient and Medieval Uses in the Mediterranean Region," *Journal of Ethnopharmacology* 97 (2005): 89–95; Kalpesh Panara, Krutika Joshi, and K. Nishteswar, "A Review on Phytochemical and Pharmacological Properties of *Citrus medica* Linn," *International Journal of Pharmaceutical & Biological Archives* 3 (2012): 1292–97.

[2] Theophrastus, *Enquiry into Plants*, trans. Arthur Hort (London: Heinemann; Loeb Classical Library, Cambridge, Mass: Harvard University Press, 1990), IV, 4, 2 (311).

[3] Galus Plinius, *Naturalis Historia,* trans. H. Rackham, W. H. S. Jones, and D. E. Eichholz (Loeb Classical Library, Cambridge, Mass: Harvard University Press), XII, 15–16.

[4] Plinius, *Naturalis Historia* XII, 16.

[5] Theophrastus, *Enquiry into Plants,* IV, 4, 2; Plinius, *Naturalis Historia*, XII 15–16.

[6] Claudius Galenus*, Galen on the Properties of Foodstuffs*, trans. and ed. O. Powell and J. Wilkins (Cambridge. Mass.: The Johns Hopkins University Press, 2003), II, 27.

[7] Robert T. Gunther (trans.), *The Greek Herbal of Dioscorides* (New York: Hafner Publishing, 1959), I, 166.

[8] Plinius, *Naturalis Historia*, XXIII, 105.

Rabbinic literature also provides a valuable source of knowledge regarding the etrog's medicinal uses. The Sages were exposed both to Babylonian literature and Greek heritage. For example, the Babylonian Talmud quotes R. Huna bar Yehuda as saying that eating a "sweet etrog" (אתילח אגורתא) filled with honey and placed on hot coals is an effective remedy for one who has drunk water left uncovered overnight (due to the fear that a venomous snake may have drunk from the water) or for someone who has been bitten by a venomous snake.[9]

> The etrog, the radish, and the egg are considered difficult to digest, to such an extent that it is said: 'if it were not for their outer peel, or egg white, they would never emerge from the intestines.'[10] … Furthermore, the etrog is included among the foods that increase sperm and was therefore not given to the High Priest on the eve of Yom Kippur due to the fear of inducing a nocturnal emission.[11]

In addition to its medicinal uses, an etrog used as part of the *arba minim* (four species) on Sukkot was credited with additional supernatural properties, a belief to which even the non-Jews apparently subscribed. One such example was the conviction that eating the etrog endowed a woman with "fragrant children." The Talmud tells of the wife of King Shapur of Persia who, after eating etrogim while pregnant, gave birth to such a "sweet-smelling daughter" that they used to place her in front of her father on top of all the spices.[12]

The midrash tells of a poor man who used to collect the etrogim thrown away in the synagogue on Hoshana Rabba (the last day of Sukkot). He sailed with a sack of them "on the great sea until he reached the king's land." It so happened that the king, who had been afflicted with a digestive ailment, had a dream in which he was told that he would be cured after eating etrogim upon which Jews had prayed on Hoshana Rabba. The king's emissaries searched the realm, finding only the poor Jew whose entire belongings consisted of a sack of etrogim. The king, having eaten of the etrogim and being cured of his ailment, duly rewarded the Jew for his sack of etrogim with a sack of gold coins.[13]

Asaph HaRofe's work, *Sefer Refuot* (The Book of Medicines)—the oldest Hebrew book of medicine in our possession—details the etrog's traits according to the Greek doctrine of elements and humors. The etrog's peel was defined as warm in nature while the inner section was considered cold. On the one hand, the etrog is considered as "increasing mucous and impeding the lower extremities (hemorrhoids)," while on the other, its seed are considered to be good for kidney pain and drops of oil infused with its peel were used for treating ear pain.[14] Etrog leaves are mentioned in Shabtai

[9] BT *Shabbat* 109b. *Etrog* seeds featured as an accepted means of treating poisoning in ancient medical literature. See Efraim Lev, *Medicinal Substances of the Medieval Levant* (Tel Aviv: Eretz Press, 2002), 112.

[10] BT *Shabbat* 108b.

[11] JT *Yoma* 1, 4, 39b; BT *Yoma* 18a.

[12] BT *Ketubot* 61a; cf. BT *Avoda Zara* 76b.

[13] Vayikra Rabba 37, 2.

[14] Zisman Muntner, "Sefer Asaph HaRofe," *Korot* 4 (1967): 39.

Donolo's tenth-century treatise as one of the medicaments he experimented with and examined for "employing as a cosmetic."[15]

Medieval Arab medical literature, in which Jewish physicians had a part, contains numerous mentions of the etrog's medicinal properties. This literature is based primarily on Greek medicine, chiefly Galenic, together with knowledge acquired from the experience of the contemporary physicians. A review of all the information cited in the classical sources is beyond the scope of this essay, and I will therefore present only a selection of relevant references to uses of the etrog.[16]

Chief among these references was the Rambam (Maimonides, 1138–1204), who served as the Ayyubid sultans' physician, most notably of Al-Malik al-Afdal, who acceded to power in Egypt in 1198. The Rambam dedicated several medical compositions to these rulers in which he mentioned the etrog on numerous occasions. For example, he named the etrog leaves as being among the medicaments "worthy of being found in the noble and lofty royal treasury."[17] In his work *Pirkei Refuah B'Moshe*, he wrote: "…and the peel of the etrog is beneficial to the bile that renews itself in the stomach, to the revitalization of the black humor and its awakening… the peel of the etrog strengthens the heart and its seeds are beneficial against toxins."[18]

In his treatise, *Poisons and Their Antidotes*, the Rambam cited practical instructions for using the etrog to treat poisoning:

> The seeds of the etrog act as an antibody against all the toxins that attack the human body, whether they entered the body by drinking or by being bitten. It should be used thus: the etrog seeds must be cleansed of their peel and their content grounded and swallowed as is. One should consume a quantity of between 1 mithqal and 2 dirhams[19]; and Ibn Sina (Avicenna) said: 2 mithqals. It should be consumed mixed with wine or cold water. And the same is true for the seeds of the sweet etrog and the sour etrog.[20]

R. Nathan ben Yoel Falaquera (second half of the thirteenth century) dedicated a large entry to the etrog in his medical encyclopedia. In the entry's final section, he wrote (my explanatory remarks in parentheses):

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[15] Zisman Muntner, *R. Shabtai Donolo* (Jerusalem: Mossad Harav Kook, 1949), 22.

[16] On the uses of the *etrog* in medieval Arabic literature, see Lev, *Medicinal Substances*, 111–12; Samuel Tolkowsky, *Pri Etz Hadar* (Jerusalem: The Bialik Institute, 1966), 106–12.

[17] Moshe ben Maimon, *Hanhagat Habriut* (Z. Muntner ed., Jerusalem: Mossad Harav Kook, 1957), 57; see also 55, 78.

[18] Moshe ben Maimon, *Medical Works* (Z. Muntner ed., Jerusalem: Mossad Harav Kook, 1961), 242, 274. He provides a precise prescription: "The julep (perfumed elixir) made from the leaves of the *etrog* in rosewater (is cooked) until they receive their potency or mix their juice with the rosewater—one third *etrog* leaves and two thirds (rosewater) is beneficial for those suffering from weakness of the heart." See also "Teshuvot Refuiot," in idem, *Biur Shemot Harefuot* (Z. Muntner ed., Jerusalem: Mossad Harav Kook, 1969), 146–47. In another work attributed to the Rambam, it is written that "another concoction, beneficial for coitus and sweetening the fragrance of the mouth: cassia, *etrog* peel, cinnamon, five darkemons of each," from idem, *Al Hahayim Hamini'im*, ed. Zisman Muntner (Jerusalem: Genizah Press, 1965), 22.

[19] Mithqal: in Egypt 4.68 g, in Iraq 4.46 g; Dirham: standard weight 3.125 g.

[20] Maimonides, *On Poisons and the Protection Against Lethal Drugs*, trans. and ed. Gerrit Bos (Chicago: University of Chicago Press, 2009), 18.

> And the sour (internal section) is beneficial for treating hot heart palpitations. And it is harmful to the chest. And the Lord makes (made) abundant goodness from it for the lung and the throat. And cooking it in its peel will improve the fragrance of the mouth and will cleanse the lines of the face (wrinkles), and "its fragrance will restore respiration and its seed in wine combats the deadly poisons."[21]

Like his predecessors, Meir Aldabi (fourteenth century) also wrote of the difficulty in digesting the etrog, recommending that "it is correct to eat it in honey or sugar prior to the meal, but not during the meal nor at its end and best when cooked in honey."[22]

The etrog is mentioned often in medical prescriptions found in the Cairo genizah, for example, the one for treating migraine and defective vision, however usually without stipulating a specific use.[23]

The rabbi and kabbalist R. Hayyim Vital (1543–1620) composed a medical treatise containing many prescriptions. Among them is a recommendation to give a nursing infant suffering from vomiting water steeped in etrog seeds and fennel.[24]

Physicians in the Modern Era have also sung the etrog's praises, as Tuvia Harofeh (1652–1729) wrote:

> Speak then in praise of the citrus fruit… pleasing to the sight and good for food, its interior is as beautiful as its exterior and possesses wonderful qualities, as its peel alleviates all internal pain and strengthens the tendons… the entire fruit gladdens the heart and strengthens the body and is a true succor for every ailment, particularly in infants who are stricken with (viral or measles) blisters. The physicians speak not of its tree, but the son undoubtedly confers merit upon the father. Therefore, the bards would say that the apple does not fall far from the tree. And in my humble opinion, in times when plants are scarce, one who lives in a place where medicines are not commonplace, should he cut a segment from the tree and cook it, his body will find therein a cure for his soul.

R. Haim Palachi (1788–1868) was another who cited medicinal qualities associated with the etrog. Citing R. Hayyim Vital, he recommended using distilled etrog water with the resin of the mastic tree to combat cholera. As a protection against evil spirits, he prescribed, among others, reciting a blessing over an etrog cooked in honey and sugar on the eve of Tu BeShvat.[25] It was a custom in Jerusalem to recite the *Shehekheyanu* blessing ("He Who has given us life") on pieces of etrog on the second night of Rosh Hashana.[26]

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[21] Zohar Amar and Yael Buchman, *Sori Haguf by R. Nathan ben Yoel Falaquera* (Tel Aviv: Unit of the History of Medicine, 2004), 158.

[22] *Sefer Shvilei Haemuna* (Jerusalem: Unknown editor and publisher, 1990), 269.

[23] Efraim Lev and Zohar Amar, *Practical Materia Medica of the Medieval Eastern Mediterranean According to the Cairo Genizah* (Sir Henry Wellcome Asian Series, 7; Leiden: Brill, 2008), 147.

[24] Yael Buchman and Zohar Amar, *Practical Medicine of Rabbi Hayyim Vital* (Jerusalem: Unit of the History of Medicine, 2007), 242. For recipes to prepare *etrog* syrup, see 279, 285.

[25] Haim Palachi, *Sefer Refuah Vehayim* (Jerusalem: Josef Ben Isshaq Press, 1997), 35, 275. On the reason for eating the *etrog* on Tu BeShvat, see Abraham O. Shemesh, *Plants, Nourishments and Ways of Eating in Blessing Literature: 1492–2000* (Ariel: Ariel University Press, 2014), 242 n. 324.

[26] Yaakov Gellis, *Minhagei Eretz Yisrael* (Jerusalem: Mossad Harav Kook, 1968), 275.

Countless other properties were attributed to the etrog, such as the use of its peel for enhancing male potency mentioned in one book of remedies which also refers to its benefit for someone who is "suddenly stricken with muteness."[27] Especially well known is the remedy whereby a woman suffering from infertility is given the blossom-end (*pitam*) of the etrog to bite on while reciting a prayer for a swift and easy childbirth.[28] Others claimed that it was a confirmed remedy for a male child,[29] a belief that persists even today in many Jewish communities.

Until recent generations, the etrog occupied an important role in the folk medicine of Oriental Jews. Yemenite Jews used the fruit for treating internal inflammations such as hepatitis or pyelonephritis, for reducing stomach acidity, and others. The peel was given for hiccups, eructation, and the common cold. The seeds were cooked and placed in compresses to counteract scorpion stings.[30] In Iraqi Jewish medicine, it was customary to cook unpeeled etrogim in sugared water and eat them every morning for several days, which was considered beneficial for kidney stones. In order to stop a nosebleed, dry grated etrog was placed on the nose. It was also believed that the etrog aided male potency and increased sperm.[31] The development of modern Western medicine has almost entirely overshadowed the rich medical tradition associated with the etrog.

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27 Unknown author, *Sefer Refuot* (Vienna: Jos. Schlesinger Publisher, 1927), 4, 32.

28 Haim Palachi, *Moed Lekol Hai* (Smyrna: Roditi Press, 1862), 208b.

29 B. Nahmias, *Hamsa: Kemi'ot, Emunot, Minhagim Urefuah 'Amamit Ba'ir Ha'atika Yerushalayim* (Tel Aviv: Modan, 1996), 144. For further sources on this property, see Tolkowsky, *Pri Etz Hadar*, 59.

30 Y. Raiany, "Popular Materia Medica used by Yemenite Jews," Final Thesis, School of Pharmacy, The Hebrew University of Jerusalem, 1963, 17.

31 A. Ben-Yaakov, *Popular Medicine of the Babylonian Jews* (Jerusalem: Yerid Hasfarim Press, 1992), 73, 126, 151, 217.

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Chapter 15
The Etrog Citron in Art

Rivka Ben-Sasson

Abstract This chapter describes the diverse representations of the etrog (pl. etrogim) in Jewish art from its first known appearance until modern times. Its earliest artistic appearance was on coins minted during the time of the first Jewish revolt (67–70 CE) when the second Temple was still standing. The etrog fruit's shape is not the same on all of them. From the middle of the third century CE to the end of the Byzantine rule, the etrog is included in every artistic medium in the Land of Israel and the Diaspora: architectural elements, mosaics, wall paintings, funerary inscriptions, and household items. It is found everywhere in the Roman Empire from Dura europos to Rome and Cologne. In the Middle Ages, we see that in Ashkenazi illuminated manuscripts, the etrog is represented as one of the "four species" in connection with the Sukkot (Feast of Tabernacle) rituals. In Sephardi illuminated manuscripts, there is no sign of the "four species" whatsoever. In the modern era, we see the etrog in the hands of men in scenes from Jewish life. During all these periods and with the use of various media, there are a number of ways in which the etrog has been described: with or without a "pitam," with or without a "*gartel*" (belt). The conclusion is that one indeed cannot learn from art which form of the etrog was particularly prized by earlier generations of observant Jews.

15.1 Introduction

This chapter examines the place of the etrog in art. Here, I will attempt to establish whether the etrog appears only in Jewish art, when such representations began, and if these representations reflect what we know of the etrog's related *halakhot* (Jewish law). I will explore possible variations in its appearance during different periods, different places where it is represented, and its probable perceived significance.

The etrog is native to Southeast Asia, but to the best of my knowledge does not appear there in art; rather, it is found in the context of mythology. In China, the unique etrog split into "many fingers" is known as "Buddha's hand," perhaps indicating the

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benevolent influence of the abundant fingers. In contrast, the etrog appears centrally at the very inception of Jewish art as one of the four species of the Sukkot festival, and during a certain period was selected to be the "fruit of the *hadar* tree."[1]

The etrog's place in Jewish art evolved over the course of its 2,000 years of representation. In ancient Jewish art, it appeared both on its own and as a part of the four species which symbolize the Sukkot festival, with its symbolic and messianic significance.[2] Beginning in the Middle Ages and up to the present day, a change occurred in the way the etrog was displayed in Jewish art, and it was almost always depicted in Ashkenazi art as part of the four species grasped in one's hand—clearly in the context of the Sukkot festival, but without the symbolic meanings associated with it in antiquity and the Byzantine era.

Of the dozens of artistic works I found depicting the etrog, I will present here lesser-known works, selected primarily for their iconographic (symbolic-visual) value. A few were chosen to demonstrate the variety of the etrog's depictions, and others to indicate its place in the culture and state of Jewish and Christian society at different periods, each with its characteristic style and medium.

15.2 The Etrog in Jewish Art in Antiquity and the Byzantine Period

The earliest findings of Jewish art date primarily to the end of the Second Temple period.[3] The majority of the relics are architectural from Herod's era. The few mosaics that survived from this period represent geometric and vegetal designs, and none feature a representation of the etrog or any other Jewish symbol.[4] The etrog is first

[1] This sentence in the Bible is translated in different ways according to the translator. Moreover, there is a discussion in the Babylonian Talmud about the meaning of the word *hadar*. There is a chapter about this question of identification in my dissertation, see Rivka Ben-Sasson, "Motivim tzimchiyim ba-omanut ha-Eretz-Israelit ba-tkufa ha-Romit ve-ad shilhei ha-tkufa ha-Byzantit" (Flora Motifs in the Art of the Land of Israel from the Roman Period to the End of the Byzantine era) (PhD diss., The Hebrew University of Jerusalem, 2013).

[2] Although some view the four species in the synagogue as liturgical objects without symbolic significance. See Steven Fine, "Parshanut liturgit le-memtzaei batei knesset atikim be-eretz Israel" (Liturgical Interpretation to Ancient Synagogues in Eretz Israel), in *Retzef u-temurah: Yehudim ve-yahadut be-eretz Israel ha-bizantit notzrit* (*Continuity and Change: Jews* and *Jewishness in Christian-Byzantine Eretz Israel*), ed. Israel L. Levin (Jerusalem: Merkaz Dinur le-heker toldot Israel, 2004), 402–19.

[3] However, earlier ivory and architectural objects, from the period of the Kingdom of Israel of 882–842 BC, were found in Samaria and Megiddo and are ascribed to Ahab and his household. They are dispersed in museums around the world, but they do not testify to being uniquely Jewish.

[4] Graffito found on walls represents the same designs that appeared on coins imprinted beginning in the Hasmonean period, such as the menorah and the anchor. On the menorah graffito known from the upper city of Jerusalem, see Nahman Avigad, *Ha-ir ha- 'elyona shel Yerushalaim* (*The Upper City of Jerusalem*) (Jerusalem: Shikmona Hevra le-hotza'a la-or Ltd., 1980), 147–50.

Fig. 15.1 Bronze half *shekel* first revolt against the Romans. Photo: B. Narkis Index of Jewish Art, curtesy of the Center of Jewish Art in the Hebrew University, Jerusalem

found on coins from the fourth year of the Jewish revolt against the Romans (69–71 CE) with a prominent *pitam* and clefts along its length (Fig. 15.1).[5]

The etrog also appeared on one side of the coins of the Bar-Kokhba revolt (132–135 CE) with the façade of the Temple on the other alongside an inscription: "For the Liberation of Jerusalem." On these coins, the *pitam* is not prominent and there is a narrowing at the middle of the fruit, a kind of belt, like those found on certain etrogim nowadays (Fig. 15.2).[6]

Impressing the etrog on coins from the first revolt, while the Temple still stood, expressed the yearning to renew worship in the Temple from a place of liberty, while the coins from the days of Bar-Kokhba expressed the aspiration to rebuild the Temple

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[5] The coins of the first revolt against the Romans were impressed while the Temple still stood, but the government was in Roman hands and the aspiration to be freed of foreign rule brought about the revolt. The symbols chosen for the coins are connected to the rituals of the Temple. Ya'akov Meshorer, *Otzar matbe'ot ha-yehudim mi-yemei shilton Paras ve-ad mered bar-Kokhba* (*A Treasury of Jewish Coins from the Persian Period to the Bar-Kokhba Rebellion*) (Jerusalem: Yad Izhak Ben-Zvi, 1997), 105–15.

[6] Moshe Bar-Yosef believes that this narrowing is caused by viroids which are the smallest causes of illness, smaller than viruses (discovered first in 1978). See Moshe Bar-Yosef, "Belted Etrogim" (Etrogim *keshurei moten*), *Galileo, The Israel Magazine for Science and Ecology* 7 (Nov.-Dec. 1994). On these coins, there are dots seen above the leaves of the myrtle, and Meshorer believes that these are the fruit of the myrtles. According to contemporary *halakha*, these types of myrtle cannot be used for the four species *do not delete anything*. Meshorer, *Otzar matbe'ot ha-yehudim mi-yemei shilton*, 113.

Fig. 15.2 Silver *Sela*–Tetradrama, Bar-Kokhba revolt. Photo: B. Narkis Index of Jewish Art, curtesy of the Center of Jewish Art in the Hebrew University, Jerusalem

anew.[7] Additionally, the festival of Sukkot is linked by the prophet Zecharia, to the end of days when all nations will ascend to the Temple (Zech. 14:15–20).

This assumption is strengthened by the fact that the blessing over the four species is recited throughout the seven days of the holiday in any location, not only in the Temple. This is one of a few rulings established by R. Yohanan ben Zakkai meant to evoke the Temple and worship in it after its destruction, as stated in M. *Rosh HaShanah*, 4:3.

At first, during the Temple era, the *lulav* was taken in the Temple in Jerusalem all seven days of *Sukkot*, and in the rest of the country it was taken only on one day, on the first day of the Festival. After the Temple was destroyed, R. Yoḥanan ben Zakkai instituted that the *lulav* should be taken even in the rest of the country all seven days in commemoration of the Temple.

[7] On the significance of Sukkot as a holiday selected to represent the days of the Temple, see, among others, Varda Sussman, *Nerot cheres me-utarim: mi-yemei churban bayit sheni ve-ad mered Bar-Kokhba* (*Ornamented Jewish Oil Lamps: From the Destruction of the Second Temple through the Bar-Kohkba Revolt*) (Jerusalem: The Bialik Institute and The Israel Exploration Society, 1972), 4; Rachel Wischnitzer-Bernstein, "Die Messianische Hütte in der jüdischen Kunst," *Monatsschrift für Geschichte und Wissenschaf* 80, no. 5 (1936): 337–90; Elisheva Revel-Neher. "L'Alliance et la Promesse: le symbolisme d'Eretz-Israël dans l'iconographie juive du moyen âge," *Jewish Art* 12-13 (1986–1987): 135–46; Arie Kindler, "Lulav and Etrog as Symbols of Jewish Identity," in *Shlomo: Studies in Epigraphy, Iconography, History and Archaeology in Honor of Shlomo Moussaieff*, ed. Robert Deutsch (Tel Aviv-Jaffe: Archaeological Center Publications, 2003), 139–45.

Fig. 15.3 Clay lamp. Photo: curtesy of the Center of Jewish Art in the Hebrew University, Jerusalem

Further evidence for the idea that the four species served at this time as an eschatological symbol (that is, connected to the belief in the world to come) is the fact that etrog adornments were found on other small items such as earthenware candles from the Bar-Kokhba period found in tombs and other hiding places. As with the coins, on the earthenware lamps we usually find the etrog positioned next to the *lulav* (palm-tree branch), and sometimes on its own. On a magnificent clay lamp with three openings from the days of Bar-Kokhba, we find a binding of the *lulav*, the myrtle, and the willow wrapped in a string, and beside them an etrog with a *pitam* and vertical clefts. Here again, we see a combination of the four species with the façade of the Temple, which resembles its appearance on the coins of that same period (Fig. 15.3).[8]

From the middle of the third century CE, in the combination of different motifs there is a resemblance between art from the Land of Israel and Jewish art in the Diaspora. Among the wall paintings of the synagogue in Dura Europos, Syria, from 245 CE, we find above the Torah niche an etrog alongside a *lulav*, a menorah, and the façade of the Temple (Fig. 15.4).

The etrog here is conspicuous in its unique spherical shape, a shape disqualifying it for etrogim according to BT *Sukkah*, 31a. Here we find the first complete combination of the four species alongside the seven-branched menorah and the Temple façade. This arrangement reappears for 400 years in synagogue mosaics in the Land of Israel. Thus, from about the same period—the third and fourth century CE—we find the

[8] Sussman, *Nerot cheres me-utarim*, 63.

Fig. 15.4 Wall painting above Tora niche in the Dura Europos 'synagogue, before 245 CE. Photo: Public domain https://commons.wikimedia.org/wiki/File

same formula in Rome on Jewish gold glasses and wall paintings in Jewish catacombs (Fig. 15.5).

The etrogim depicted in Rome are larger and different from those in the Land of Israel, with bumps on their surfaces, and there are always leaves attached to the wide tip, while at the narrow tip there is often an allusion to a *pitam*, but without a "belt."[9]

Beginning in the fourth century CE, various combinations of the etrog on its own or as a part of the four species alongside other symbols/objects such as the menorah, an architectural facade, shofar, and coal pan were found in synagogue mosaics in the Land of Israel. The earliest known synagogue mosaic is found at the synagogue of Hamat Tiberias from the fourth century, known as Severus' Synagogue. Here,

[9] "Gold glasses" refers to mostly bases of glass vessels made from two layers of glass with a gold leaf illustration between them featuring Christian, Jewish, and other symbols. Some of these are found imprinted in the plaster of the graves in the catacombs, especially in Rome. On Jewish gold glasses, see Rivka Ben-Sasson, "Zechuchiot ha'zahav ha'yehudiyot: nituah iconographi mehudash" (The Jewish Gold Glasses: A New Iconographic Analysis) (MA thesis, The Hebrew University of Jerusalem, 2002).

Fig. 15.5 Gold glass base (fourth century). Photo: courtesy of Dr. David and Yemima Jeselsohn, Swiss. Long-term loan to Israel Museum, Jerusalem

the etrogim are joined with the *lulav*, the myrtle, and the willow, and their shape resembles the shape of the etrogim shown in Rome including surface bumps.[10]

Further evidence of the eschatological significance of the four species can be found from that same period in a burial inscription from the Necropolis of Zoar in the Transjordan. These inscriptions, written primarily in Aramaic and Greek, are unique in including the calculated date, which is the year of the destruction of the Temple.[11] We know from the literature of the messianic hopes of the Jews during

[10] On the mosaics of the Land of Israel, see Rina Talgam, *Mosaics of Faith: Floors of Pagans, Jews, Samaritans, Christians and Muslims in the Holy Land* (Jerusalem: Yad Itzhak Ben-Zvi and University Park, Penn.: Pennsylvania State University Press, 2014), 265–66, Fig. 339.

[11] Yoseph Naveh, "Matzevot Zoar" (Zoar Tombstones), *Tarbitz* 4 (1995): 477–98.

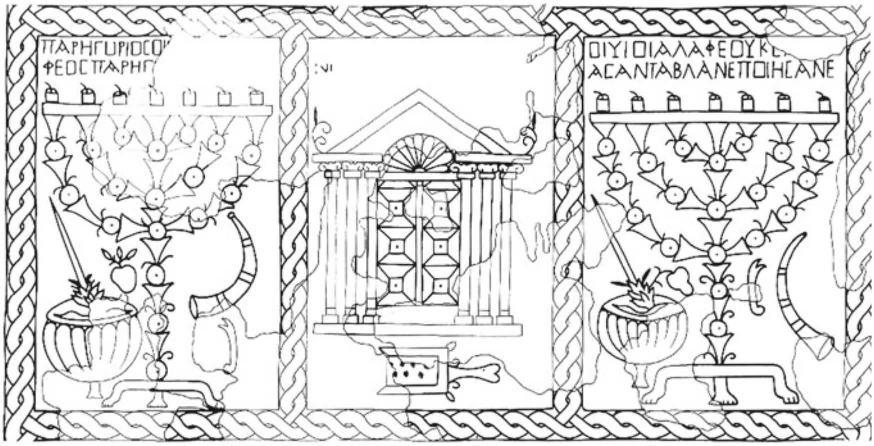

Fig. 15.6 Mosaic in the synagogue of Tzippori, (fifth century). Photo Courtesy of Prof. Zeev Weiss

the fourth century, with Julian's plan to rebuild the Temple in 363 CE at its zenith.[12] Despite this divergence between the inscription in Zoar and those of Rome and the Land of Israel, their resemblance lies in the fact that they all feature the menorah and the four species (generally only the *lulav*) painted in simple lines and with iconography similar to the one in Rome.[13]

In the mosaic of the Tzippori synagogue from the fifth century, we find two bunches of the four species, and among them there are two different etrogim. In one grouping, the etrog is bound with the *lulav*, the willows, and the myrtles, and in the second it appears on its own. The etrog bound with the *lulav* has a narrowing resembling a belt, and its broad section has a stipe with leaves. Furthermore, the method of binding the four species is different from the method typically prescribed by *halakha*, and they are placed in a copper vessel as the four species are represented in Rome (Fig. 15.6).[14]

This shape is not found in art of the Land of Israel, seemingly because it contradicts R. Judah's statement in the Mishnah: "One may bind the *lulav* only with its own

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[12] Shmuel Safrai, "Tkufat ha-Mishna ve-ha-Talmud," in *Toldot am Israel* (*A History of the Jewish People*), ed. Haim H. Ben-Sasson, Abraham Malamat, Haim Tadmor, Menahem Stern, and Shmuel Safrai (Tel Aviv: Dvir Co. Ltd., 1969), 339–41.

[13] Because the illustrations are very simple, it is difficult to establish whether the etrog has a *pitam* and a stipe, but it looks as though it does on the tombstone as it is seen in the article, Naveh, "Matzevot Zoar," n. 13. In addition to the calculation of the date based on the destruction of the Temple, they were also calculated based on the *shemitah* (sabbatical) year and, occasionally, the day of the week was also marked. The resemblance to the grave inscriptions in Rome is expressed also in the recurring use of the word *shalom* and in the bird illustration.

[14] On the resemblance to the four species in Vigna Randanini and the difference between the two bunches, see Zeev Weiss, *The Sepphoris Synagogue: Deciphering an Ancient Message through Its Archaeological and Socio-Historical Context* (Jerusalem: Israel Exploration Society, 2005), 70, 75–76.

Fig. 15.7 Mosaic in the synagogue of Ma'on (Nirim), (sixth century). Photo: Z. Radovan. The Israel Antiquities Authority

species." The manner of this binding can be interpreted according to M. *Sukkah* 3:8: "Even with a string with a cord. Rabbi Meir said: An incident involving the men of Jerusalem who would bind their *lulavim* with gold rings."[15]

In the mosaic of the Ma'on (Nirim) synagogue from the sixth century, the etrogim are more central than the other four species. These etrogim are large and prominent alongside the big menorah, while the four species ensemble is represented in smaller dimensions above one of the etrogim. Additionally, the "belts" of both etrogim are notably accentuated by different colors of the tesserae (mosaic stones) (Fig. 15.7).

Moreover, while the stipe is prominent the *pitam* is not discernable. The majority of the etrogim look similar in the synagogues, whether separate from the *lulav* as in the Hulda synagogue from the fifth century, or whether they are bound together as in the Bet Alpha synagogue of the sixth century. A lone etrog is found in the mosaic of the synagogue near Ma'oz Hayyim in a medallion in a frame which includes additional motifs such as the menorah and grape cluster. This etrog has a stipe, a "belt," and probably also a *pitam,* and it takes up considerable space in the frame (Fig. 15.8).

[15] It is possible that an example for this can be found in Fig. 15.3.

Fig. 15.8 *Etrog* in the mosaic of Maoz Hayyim synagogue, (sixth century). Photo: Curtesy of Bitmuna collection, A. Jacoby's album

There are additional instances in which the etrog takes a different shape than its typical representation. Thus, in the sixth-century synagogue at Husifa (Isifiya), the shape of the etrog resembles that of a peach, but the stipe is visible. It is impossible to know if the *pitam* was represented as well since this part of the mosaic was not preserved. Another atypical depiction is found in an ornament of a dedication inscription in the northern synagogue of Tiberius, also from the sixth century. Here the etrog has an egg shape and horizontal stripes, details apparently intended to emphasize its round shape and not because it had stripes. It appears that there is also a visual reference to a stipe, and the etrog is placed alongside a *lulav* to which many myrtles are tied with ropes. In select mosaics, the four species are not found at all, with most of these identified as belonging to Samaritan synagogues. This is not surprising considering that the Samaritans do not take the four species as do the Jews, but rather decorate the *sukkah* with different species including various citrus fruits and palm fronds.[16]

In other regions in Israel, we find the etrog on reliefs of stone screens in synagogue ruins. A screen like this from the sixth century was found in Ashkelon, alongside a menorah, shofar, and *lulav* on one side of the screen, and part of the etrog on the other side of the screen. Because the etrog was only partially preserved, it is impossible to

[16] Ruth Jacoby, "Arba'at ha-minim be-kerev ha-yehudim ve-ha- shomronim" (The Four Species among the Jews and Samaritans), *Eretz Israel* 25, n. 9 (1996): 404–09.

know its shape.[17] Similarly, the etrog appears on a stone screen from Corinth, found in digs dating from the fourth to the sixth centuries CE, alongside three menorahs. The four species are rendered on both sides of the middle menorah, and the etrog is tied by its stipe to the *lulav*.[18]

15.3 The Etrog in Christian Art in the Land of Israel

The appearance of the etrog in Jewish art as one of the four species or on its own is understandable within the context of the festival of Sukkot as a symbol for the Temple. In contrast, the depiction of the etrog as an individual fruit in the majority of the Christian mosaics in the Land of Israel during the Byzantine era is surprising. In these mosaics, an etrog or two are found generally in populated geometric or plant frames alongside other fruit, but sometimes also in more central places. Among others etrogim are found in the geometric frame in the mosaic remains of the Church of the Martir at Tel Eztaba in Beth Shean.[19] These etrogim do not have *pitams*, but have a narrowing at their center, and the stipes are visible as are the attached leaves. In a line of geometric medallions covering the floor mosaic of the church at Kursi on the Sea of Galilee from 585 CE, etrogim are represented among the fruit, flowers, and animals (Fig. 15.9).

In them, one can make out a clear protrusion that perhaps represents a *pitam*, a distinct "belt," and a stipe with a pair of leaves.[20] Additionally, there are mosaics with depictions of fruit trees, including etrogim, usually alongside animals. In the mosaic from the Byzantine palace in Caesarea from the sixth century, most of the mosaic is a large carpet of round medallions with different birds. In the frame, there are depictions of wild animals among various fruit trees, including an etrog tree (Fig. 15.10).

The fact that in Caesarea we find an etrog tree and not the etrog fruit alone may serve as evidence that etrogim were grown in the area during that time, and that perhaps there was an etrog orchard owned by the proprietor of the estate who commissioned the mosaic. On finding etrogim in Caesarea, we can look to the *Tosefta* (*Dmai* 3:14), where it is recounted that "R. Yosse sent to Rabbi a large etrog from Tzippori and said 'this etrog came to me from Caesarea.'

[17] Ephraim Stern (ed.),"Ashkelon," in *The New Encyclopedia of Archaeological Excavations in the Holy Land* (Jerusalem: Israel Exploration Society and Carta, 1992), vol. 1, 107.

[18] Gideon Foerster, "Sridei beit ha-knesset be-Corinth" (Traces of the Synagogue at Corinth), *Qadmoniot Journal for the Antiquities of Eretz-Israel and Bible Lands* 3, no. 3 (1970): 104.

[19] Talgam, *Mosaics of Faith*,108, Fig. 151.

[20] Vassilios Tzaferis, "The Excavations of Kursi-Geresa," *Atiqot* (*English Series) Jerusalem* 16 (1983): 24–25.

Fig. 15.9 *Etrog* in the mosaic of the church of Kursi. (585) Photo: author

Fig. 15.10 *Etrog* tree in the Birds Mosaic in Cesarea, (sixth century). Photo: author

15.4 Etrogim in Mosaics of the Transjordan

Interestingly, the etrog is also found in many mosaics in churches in the Transjordan, especially in the frames of the mosaics. An example of this can be found in the

Fig. 15.11 *Etrog* with a curved knife. Church of the Lions, Umm-al-Rasas, (sixth century). Photo: after Piccirillo, (1993). With the permission of the Studium Biblicum Franciscanum in Jerusalem

Presbytery mosaic frame in the Lion Church of Umm-al-Rasas (south of Amman). There we find depictions of lions among fruit trees below the apsis, framed in birds and various fruits including an etrog beside a curved knife (Fig. 15.11).[21]

A straight knife can be seen in the medallion frame of the Church of Deacon Thomas in Uyun Musa north of Mt. Nebo from the sixth century.[22] Etrogim are also found in conspicuous places in churches, and at the center of the mosaic carpet. For example, at the northern side of the Apostles Church in Madaba from 587 CE, there are two small mosaic panels in which two large etrogim can be seen.[23]

15.5 The Place of the Etrog in Byzantine Art

The abundance of etrogim in Byzantine mosaics raises a question regarding the curved or straight knife often found next to them. It appears that the etrog was known in ancient times to have many unique qualities, and was therefore an important tree and fruit. Already, Theophrastus (1961, IV:42) described the tree as evergreen, its flowers and reproductive organs large and fragrant. It blooms while still carrying the fruit of the previous season thus making it fruitful twice a year. It would seem that there were also edible varieties as described in the words of M. *Sukkah* 4:7: "Immediately children remove their *lulavim* and eat their etrogim."

[21] Michele Piccirillo, *The Mosaics of Jordan* (Amman: Acor Publications, 1993), 211, Fig. 338.

[22] Ibid., Fig. 334.

[23] Ibid., figs. 90, 92; On more mosaics which depict an etrog, see my dissertation, Ben-Sasson, "Motivim tzimchiyim.".

The Babylonian Talmud also relates that the King of Persia, Shapur, offered his Jewish guests an etrog, slicing it with a knife before serving it: “Like [that incident] involving Mar Yehuda and Bati bar Tuvi, who were sitting before King Shapur, [they] brought an etrog before them. [The king] cut and ate, cut and gave to Bati bar Tuvi” (BT. *Avoda Zara*), 76b. Also in *Midrash Tanhuma, Genesis Vayeshev* 5, we find a story of an etrog eaten with a knife:

> Our sages inform us that on one occasion Potiphar’s wife assembled a number of Egyptian women so that they might see how very handsome Joseph was. But before she summoned Joseph she gave each of them an etrog and a knife. When they saw Joseph’s handsome countenance, they cut their hands. She said to them: “If this can happen to you, who see him only once, how much more so does it happen to me, who must look at him constantly.”

These midrashim and a handful of *halakhot* connected to the etrog suggest that the etrog was considered a distinguished fruit, fit for a king’s table. It seems also that it was necessary to use a knife to eat it (in mosaics other fruits, such as the watermelon, are also accompanied occasionally by a knife). The etrog rendered alongside a knife belongs to the group of art works, mostly in mosaics, named *xenia* (hospitality in Greek) that were prevalent already from the Classical period.[24]

In the Hellenistic source, there are descriptions of delicacies that were offered to guests who were invited to feast, and which indicate the wealth of the host, his generosity, and the honor he granted his guests. In these descriptions, there are presentations of exotic fruit and vegetables, meat, and fish dishes. Such mosaics are found in Israel from as early as the first century CE, and they are prevalent also in churches of North Africa.[25]

15.6 The Etrog in Muslim Era Art

Since the Muslim era, from around the middle of the seventh century, we no longer find Jewish mosaic art in the Land of Israel, while Christian mosaics are still found in the eighth century, especially in the Transjordan. During that same century, a magnificent palace was constructed around Jericho, at Khirbat al-Mafjar, decorated with many mosaics. All the mosaics are made up of geometric patterns, aside from the Diwan mosaic which is figurative. In it, there is a large and highly stylized etrog with a knife beside it.[26] The etrog is connected to a small branch with leaves and features two “belts” much like the etrogim from the Ma’on synagogue (Nirim).

From that same period, a handful of illuminated manuscript fragments were preserved in the Eastern Byzant and the Latin West. While Christian art continues

[24] The Greek term that describes the gift sent by Greek hosts, and mentioned by Vitruvius from the first century BC, is hospitium = “guest gifts.” *The Architecture of M. Vitruvius. Pollio*, trans. W. Newton (London, 1791), VI:7, 4; Katherine M. D. Dunbabin, *The Roman Banquet: Images of Conviviality* (Cambridge: Cambridge University Press, 2003), 64.

[25] See Talgam, *Mosaics of Faith*, 48, Fig. 70.

[26] More details about this etrog in Richard Ettinghausen, *From Byzantium to Sassanian Iran and the Islamic World* (Leiden: Brill, 1972), 35–36.

to exist and is even preserved to a small extent, there is a gap in Jewish art of about 600 years between the mosaics and the illuminated manuscripts of Sepharad and Ashkenaz in which etrogim are found.[27] This is a "dark" period in Jewish art in general, and the manuscripts known to us are lone remnants in the sense of a "burning stick snatched from the fire," which were saved probably thanks to being small and transportable when the Jews were persecuted by clergy and individuals. Beginning at the end of the thirteenth century, we find Jewish manuscripts that are divided between Ashkenazi and Sephardi.

15.7 Etrog Illustrations in Ashkenazi Manuscripts

Since the Middle Ages, the etrog is depicted, especially in Ashkenazi mahzorim (holiday prayer books), as one of the four species held by a man.[28] The earliest Jewish manuscript that depicts the etrog is probably Mahzor Laud from southern Germany around 1290. At the head of the page with the poem for the "eighth" day of Sukkot when rain is prayed for, there is an illustration of two figures on either side of the opening word.[29] On the right side there is an illustration of a winged animal. The left side features a person grasping a *lulav* and three myrtle branches (apparently without willows) with his right hand, while his left presses a long, large, smooth etrog to his chest. In addition to the unique shape of the four species which do not seem to be accurate representations, the head of the man is that of a dog and not the face of a man.[30]

It appears that the illustrator was himself not familiar with the four species and that they were only described to him. In contrast, the illustration of the myrtles is more faithful to reality, as it is a known plant in Europe and is called *myrte* in German (Fig. 15.12). In the Leipzig Mahzor from 1320, there is a depiction of a man wearing

[27] Fragmented manuscripts were found in the Cairo Genizah from the ninth century on, some of them illuminated, but without representation of the four species. The extant illuminated manuscripts were randomly preserved, less so than the Christian and secular manuscripts because of the quality of life of the Jews who suffered persecution and expulsion from their Christian neighbors. Some of the few Jewish manuscripts survived in churches and monasteries.

[28] In Spain from that period, we know primarily of opening illustrated pages to Pentateuchs called Mikdashia. They generally depict the instruments of the tabernacle, while the four species do not appear in them at all. In the opening illustrated pages, Aaron's dry and flowering staffs appear instead of the four species, as demonstrated by Elisheva Revel-Neher, *Le temoignage de l'absence: les objets du sanctuaire a Byzance et dans l'art juif du XIe au XVe siecles* (Paris: De Boccard, 1998).

[29] This day is celebrated as the second day of holiday in the Diaspora, while in Israel it is celebrated as "*isru hag*" (the day after the holiday).

[30] The phenomenon of illustrating the faces of the figures as animal faces is known from many of the Jewish manuscripts of Germany from the thirteenth century until the beginning of the fourteenth century, as in the famous Bird's Head Haggadah. This phenomenon is unique to southern Germany, and derived apparently from the influence of Rabi Yehuda the Hassid who lived at the end of the twelfth century. Bezalel Narkiss, *Hebrew Illuminated Manuscripts* (Jerusalem: Keter Publishing, 1992), 90.

Fig. 15.12 Illustration in Mahzor Laud, (1290). MS. Laud. Or. 321. Photo: With the permission of Bodleian Libraries, University of Oxford

a pointed Jewish hat on the right margins of the page in which the *Yotzer* prayer for the first day of the Sukkot festival appears.[31] With his left hand, he grasps various branches which apparently represent the *lulav*, the myrtle, and the willow, and with his right he presents the etrog which has a protrusion on its tip, but no *pitam.* Neither the *lulav* and the accompanying branches nor the etrog look like the four species.

It appears that here too the artist only heard a description of them and drew them according to his understanding. The etrog looks more like a lemon and it has a yellow protrusion connected to the body of the fruit, unlike a *pitam* which could drop off the fruit because of its separateness. In an Ashkenazi *mahzor* from around Lake Constance in southern Germany dating to 1300–1324, an etrog appears at the margins of the page containing the prayer of "*Hosha'-na*" recited during the festival of Sukkot. One gets the impression that the etrog is held upside down, that is, that the stipe is facing upwards. This is how the etrog is held while reciting the blessing, and it is only subsequently turned so that the *pitam* faces upwards. This may have been the intention of the illustration.[32]

In the manuscript of a text that discusses the *halakhot* of Sukkot from 1374 Perugia, the top section of the page contains an illustration of a *sukkah* completely

[31] "*Yotzer*" is a type of poem said at different points in the prayer, and is a part of the Ashkenazi prayer *nusah (*musical style or tradition of a community). In the Middle Ages, the pointed hat was a required item for every Jew, imposed on the Jews of Europe as a mark of disgrace and to distinguish them from the non-Jewish population. Leipzig, *Mahzor*, South Germany (Leipzig: Universitätsbibliothek, ca. 1320), V 1102/II.

[32] Additions in Vienna *Siddur SeMak*, South Germany, Lake Constance; Northern Italy (1450–1470), Austria, Vienna: Österreichische Nationalbibliothek, 1300–1324. Cod. Hebr. 75.

Fig. 15.13 Isaiah of Trani II. Illustration in. *Decisions*, (Perugia, 1374). BL-Or.Ms.5024-fol.70v Photo: British Library, GB-United Kingdom

adorned with branches. Beneath the *sukkah* in the right margin there is a depiction of a man holding a *lulav* bound in a red string in his right hand, as well as myrtle and willow, and in his left an etrog with a protruding *pitam* at its head (Fig. 15.13).[33]

About 150 years later, in a mahzor dated to 1470, we find an illustration in the left margins of a page containing rulings for the festival of Sukkot.[34] In the illustration, a man is seen bringing the four species to his wife and children, who reach out their hands to receive and bless them, as is the Ashkenazi custom (Fig. 15.14).

Because the etrog is grasped in his hand, only the top section in which the *pitam* protrudes is visible, and it is therefore impossible to see if it has a stipe. The *lulav* appears to be wrapped in a red string (as in the illustration of the page of *halakhot* from Perugia mentioned above). At the base of the *lulav*, there is a lump of green which are the myrtles and willows, but their binding is indiscernible. The bundle that surrounds the entire *lulav* appears to contain a large number of myrtle branches, as is

[33] Isaiah of Trani II, *Decisions* (Perugia, 1374). British Library-Or. Ms.5024-fol. 70v.

[34] The *Weil-Jeselsohn Mahzor*, formerly the *Rothschild Mahzor*, Italy ca. 1470. National Library of Israel, Jerusalem, Heb. 80 4450.

Fig. 15.14 Illustration in Weil-Jeselson Mahzor, (formerly the NL Rothschild Mahzor). Italy, ca. 1470. Photo: courtesy Dr. David and Yemima Jeselsohn, Swiss, on long term loan to the National Library of Israel in Jerusalem, Heb. 80 4450

found in some of the Byzantine mosaics and as is the Yemenite custom to this day.[35] Similar illustrations are found in additional Jewish manuscripts.

15.8 The Etrog in Christian Renaissance Paintings

Citrus fruit trees, including etrog trees, appear in Christian renaissance paintings which depict figures from the Bible or Old Testament. The etrog tree, which did not grow in northern lands during that time, apparently symbolized the landscape of the Land of Israel as imagined by the artists. An example of this can be seen in "The Binding of Isaac" by Andrea Mantegna from 1492, which, in its foreground, contains a detailed illustration of an etrog tree behind Isaac's head, while the thicket from which the deer is peeking out is blurry.

This is similar to "The Virgin and Child with Saint Anne" by Gerolamo dai Libri (1510–1515), where a large, detailed etrog tree can be seen behind the figures. Here too the etrog has a protrusion on its sharpened tip, but it does not look like a *pitam*.[36] In certain places, it is possible to also see depictions of the etrog in Christian art, such as the Tree of Knowledge. This is not surprising as according to the Midrash in Genesis Rabbah 15:7, the fruit of the Tree of Knowledge was an etrog.[37] Thus, in the painting by Van Eyck from 1432, at the base of the altar in the Ghent Cathedral, Adam and Eve are depicted with Eve holding an etrog in her hand. This depiction was likely influenced by the words of the traveler Tietmar from 1217: "In this place (Jericho and the surroundings) grow fruit trees and their fruit are called 'Adam's Fruit,' and they have the conspicuous markings of man's bite. This is the species of the etrog (Citrus medica)."[38]

The etrogim were brought mainly by Jewish merchants from the inland of Mediterranean countries, generally Italy and Spain. Thus, the etrog became a fruit typical and unique to the Jewish people. The most detailed and precise drawing of the etrog appears in the botanical book by Christoph Volkamer from 1708. In this book, Volkamer described all the types of fruits from the family of Rutaceae that grew in the gardens of Nuremberg, including the etrog called Cedro col Pigolo, which means "the etrog with the *pitam*." According to Volkamer, it can also be called "The Jewish Etrog" because it is mostly found in Jewish uses of the four species.

[35] Zohar Amar, *Arba'at ha-minim, iyunim hilchatiyim be-mabat hystory, botany ve-Eretz-Israeli* (*The Four Species Anthology*) (Neve Tsuf: Z. Amar, 2009). See also Yaakov I. Stull, *Nahagu Yisrael: The Sukkot Festival* (Jerusalem: Author's Edition, 2020). I don't agree with his methodology, as in the critique of Menahem. M. Honig, *Le-heker heftzei mitzvah mi-tkufat ha-misna ve-ha-talmud vu-yemei ha-benayim: Bikoret al ha-sefer Nahagu Israel* (Critique on the Book *Israel's Customs*) (Jerusalem: Mekhilta ktav et le-Tora ve-hokhma (A), 2020), 337–51.

[36] The painting is housed in The National Gallery in London.

[37] On the identification of the etrog as the fruit of the Tree of Knowledge, see Mordechai Kislev, "Etz ha-da'at etrog haya" (The Etrog Was the Tree of Knowledge), *Sinai* 125 (2000-2001): 9–1.

[38] Tietmar, ch. XXIX, see Asaph Gur, *Toldot ha-*etrog *be-Eretz Israel be-khol ha-tkufot* (*The History of the* Etrog *in All Times*) (Tel Aviv: ShHM Ha-Mahlaka Le-pirsumim, Ha-kirya, 1966), 29.

Fig. 15.15 Illustrations in P.I C. Kirchner, Jüdische Ceremoniel (1724) p. 226. Photo: curtesy Leo Beack Library collection

Even before Volkamer we find illustrations in books that described Jewish customs. These books were written and illustrated by Christians (including converts); some are polemical and others objective. These books began to appear in the sixteenth and seventeenth centuries, and no fewer than five appeared from the beginning to the middle of the eighteenth century.[39] Among these illustrations, there is an interesting one of a Jew holding the four species while he is wrapped in his *tallit* (prayer shawl). The etrog in his hand, as well as an additional large etrog drawn on the side, have a strange *pitam*, resembling a "crown" of the pomegranate with three "horns."[40]

In another illustration from the convert Kirchner's book, various unrelated customs are depicted (Fig. 15.15).

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[39] Yaacov Deutsch, *Judaism in Christian Eyes: Ethnographic Descriptions of Jews and Judaism in Early Modern Europe* (New York: Oxford University Press, 2012), 48.

[40] Behind the Jew, illustrated separately, is a branch of a palm, a binding of myrtle, and two thin branches without leaves (perhaps willow branches?). Above, there is an illustration of three willow branches, apparently to be used for *hoshanot* on Hoshana Rabba. See Daniel Sperber, *Minhagei Yisrael: Mekorot ve-Toldot* (*Customs of Israel: Their Origins and History*) (Jerusalem: Mossad Harav Kook, 1998), vol. 6, 388. According to Christiani (1705), Leipzig.

In the right corner, we find a *halitza* shoe, a *lulav*, and an etrog. The etrog is represented in a way called “Adam’s bite” (as mentioned above).[41] Thus, through the eyes of Christians we see how between the fifteenth and eighteenth centuries the etrog was prevalent among Jews. With the advent of printing in Europe, Jewish art was mainly expressed in illustrating Hebrew books, which were made with simple wood etchings. Later, Passover haggadot were printed in Holland where copper etchings were developed, enabling much more sophisticated illustrations.

15.9 The Etrog in Works by Jewish Artists in the Modern Era

In the seventeenth and eighteenth centuries, synagogues in eastern and central Europe were decorated with murals and reliefs of various plants and animals.[42] Moreover, portraits of rabbis were made, but I did not find a depiction of any of them holding an etrog. From the middle of the eighteenth century, some well-connected Jews succeeded in obtaining education at art institutions of Europe, but many converted to Christianity to gain positions in museums and therefore did not deal with Jewish art. Beginning in the nineteenth century, Jewish artists started dealing also with Jewish subjects. First among them were the artists Solomon Hart (1806–1881) in England, the first Jewish member of the Royal Academy in London, and the better-known Moritz Oppenheim from Germany (1800–1882).[43]

From the next generation, we know of a 1905 portrait by the artist Isidor Kaufmann (1854–1921), which depicts a youth holding the four species in his left hand while his right hand clutches the edge of his *tallit*. The etrog in his hand is yellow and without a *pitam*, but there is a clear distinction between the myrtles and willows. Leopold Pilichowski (1869–1934) belongs to that same group of artists, depicting Jewish life in Poland in his paintings. Most of his works can be found at the National Museum of Krakow. One of his paintings is housed at the Jewish Museum of New York, and it depicts Jews in the synagogue during Sukkot. In this painting, one of them is shown proudly holding his especially beautiful etrog with a *pitam* and a stipe (Fig. 15.16).[44]

Marc Chagall (1887–1985) painted, as is known, many paintings of his birth town Vitebsk, to which he returned in 1914 after a sojourn in Paris. During that same year, he painted his famous work, “Feast Day” (Rabbi with Lemon). In this painting, a

[41] Engravings from Paul C. Kirchner, *Jüdische Ceremoniel* (*All Sorts of Jewish Customs*) (Nuremberg, 1724), 226.

[42] Rachel Wischnitzer-Bernstein, “Omanut,” *Encyclopaedia Hebraica* (*The Hebrew Encyclopedia*) (Jerusalem: Encyclopedia Publishing Co. Ltd.,1953–1954), vol. 4, 59.

[43] Among Oppenheim’s better-known paintings are “A Jewish Wedding” and “Sabbath Afternoon.” He drew the *sukkah*, but without the four species. On Jewish artists during the period of emancipation, see B. C. Roth, “Ha-omanut ha-yehudit me-tekufat ha-emantzipatziya ve-ad yameinu,” in *Ha-omanut ha-yehudit*, ed. B. C. Roth (Ramat Gan: Massada Ltd., 1974), 139–58.

[44] A rendering of this painting was used for greeting cards for Rosh HaShana written in German.

Fig. 15.16 "Sukkot" painting, L. Pilichowski (1869-1934). Photo: curtesy of The Jewish Museum of New York

Jew stands at the opening of an unmarked building, wrapped in a *tallit*. On his head, there is a small, inverted figure of himself. The man holds the etrog with only two fingers—not in the acceptable manner for the blessing. The *lulav* with the myrtles and without the willows are placed on his fully extended hand so that the *lulav* looks as if it is floating before the man's body. The entire painting, as with many of Chagall's works, is not realistic in its details. Upon further inspection, it is clear that there is no intention here of a realistic depiction, but rather something between fantastic-dreamy vision and reality, in classic Chagall style (Fig. 15.17).

Other Jewish artists have depicted Jewish life in a realistic style up to the present day. In all of these paintings, the four species are nearly as important as the man holding them. An emotional painting that emphasizes the focus of a person concentrated in his prayer, and not the four species, is "In Prayer During the Feast of the Tabernacles" by Paula Gans from Prague (1883–1941), painted in 1920.[45] This painting depicts an old, bearded Jew deep in prayer, holding an etrog and *lulav* with myrtles and willows in his right hand. The etrog is held upside-down, the stipe is on top, and the pinky finger hides the other end so that it is not possible to see if the etrog has a *pitam*.

[45] In 1941, Paula Gans was sent to a concentration camp in Germany, and it is unclear when or how she died.

Fig. 15.17 "Feast Day" (Rabbi with Lemon) painting, M. Chagall (1914). Photo: WikiArt.org (Public domain US).

Contemporary Israeli artist Nechama Shaish also painted a Jew blessing the four species, eyes closed devotionally. In her painting, he holds them carefully with the tip of the etrog displayed upwards, but it is unclear if it has a real *pitam*. The *lulav* and the branches of the myrtle and willow, and the small basket connecting them in one binding, are depicted precisely according to contemporary Ashkenazi custom.

Chezi Green, a Jewish artist from New York, who defines himself as an expressionist, painted a Jew holding an etrog with a clear and distinct *pitam* as though astonished by it, and he is not grasping the *lulav* with the myrtles and willows, so that in their absence the importance of the etrog is felt.

15.10 A Box for the Etrog

From the end of the seventeenth century, we also know of special boxes for preserving etrogim. Most of the boxes were not intended initially for preserving the etrogim, but were taken for this purpose because of their appropriate shape. Moreover, of the boxes intended for this purpose, few are shaped like an etrog. The oldest box shaped like an etrog that I found is from Augsburg and dates to approximately 1670. It is made of gold-covered silver, and is housed at the Jewish Museum of New York (Fig. 15.18).

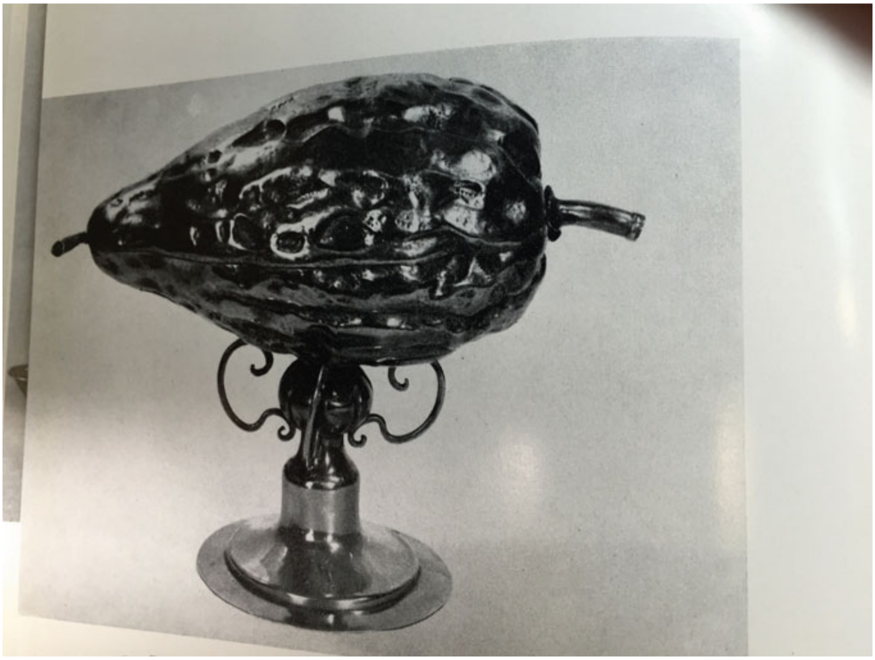

Fig. 15.18 *Etrog* box, gold-covered silver, Augsburg, Germany (1670-1680) Photo: curtesy of The Jewish Museum of New York

15.11 Conclusion

In this review, we can see that the etrog appeared in Jewish art in its various and diverse depictions, and served as a symbol for the Temple because of its connection to the worship held at first primarily in the Temple. It became a common symbol in ancient and Byzantine Jewish art, secondary in its prevalence only to the menorah. It appears on coins, burial inscriptions, mosaic floors, and on walls and pillars of synagogues in Israel and the Diaspora.

In Sephardi manuscripts from the Middle Ages, we no longer find the four species among the Temple objects, and the symbolism of the four species is exchanged with Aaron's dry branch and blooming branch. In contrast, in Ashkenazi manuscripts from the Middle Ages until the present day, the etrog is presented always in a man's hand as an illustration for a text connected to the festival of Sukkot—whether a text of prayer or a text of customs and rulings.

The etrog appears in a variety of ways on ancient coins, and it is therefore difficult to establish whether during certain periods importance was placed on its shape: Rounded or belted, with a *pitam* or without. Only from the debates of the sages do we understand how important these details are, and perhaps also from the nineteenth-century paintings where the *pitam* is emphasized.

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Chapter 16
The Etrog Citron in Rabbinic and Kabbalistic Literature

Moshe Hallamish

Abstract The term "*Pri Etz Hadar*" (Lev. 23:40) was interpreted in the Talmudic literature as referring to the fruit of the etrog citron trees. Much of the Talmudic discourse dealt with the details of the etrog fruit, form, structure, and splendor. In some cases, the word "*hadar*" was interpreted as remotely resembling the Greek word "hydro," meaning water, thereby attributing the selection of the etrog for the fall Sukkot (the Feast of Tabernacles) festival as a symbol of the significance of water to vegetation and human life. Other symbolic properties of the "Four Species" (ritually used during the Sukkot festival) related to their resemblance to different parts of the human body, were similarly suggested to signify the spiritual relationship between an observant Jew and nature. Medieval thinkers, especially kabbalists, introduced novel motives for these symbols, which eventually led to changes in the practice of holding the etrog fruit during the Sukkot prayers. Indeed, from the thirteenth century onwards, the blessing over the etrog fruit was recited while the etrog fruit was held in close contact with the three other species, thereby serving as a sign of the ideal unity between body and soul, both of the individual in prayer as well as his close ties to his community. Other kabbalistic interpretations of the ways of holding the etrog fruit during the Sukkot festival prayers, and the folkloristic attributes of the four species as traditional symbols of feminine qualities, are detailed throughout this chapter.

16.1 In Antiquity

During the festival of Sukkot, one must take (in Talmudic language *litol*) the four species mentioned in Leviticus 23:40, which according to the rabbinic tradition are the etrog (citron), *lulav* (palm frond), *hadas* (myrtle), and *arava* (willow). These

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were discussed in the Talmud and midrashim in a myriad of ways,[1] some of which we will elaborate on below.

It appears that the etrog flourished in the Land of Israel in ancient times. At some point the etrog was considered as edible as any other fruit, and the *terumot* (the gift to the priest) and tithes of the etrog were set aside. Evidence of the etrog's prevalence can be adduced from the account that "all the people pelted with their etrogim" anyone who performed the Temple water libation like a Sadducee (*Sukkah* 4:9). In one letter, Bar Kokhba demands that his military camp be provided with "*Lulavim*, etrogim… *hadassim* and *aravot*."[2] The four species were embossed on the Hasmonean and Bar Kokhba coins, embroidered on parokhets (curtains that cover synagogue arks), depicted on mosaic synagogue floors, and in later periods also on tombstones. Thus, the species were treated as sacred objects. The Roman rulers were aware of this, and they forbade the *netilah* (taking the four species) as they forbade other practices such as circumcision. As it is written, "Why did you receive a hundred lashes? Because I took the *lulav*."[3]

The Bible mentions "*peri etz hadar*," which is understood in the rabbinic literature as the etrog.[4] Different sources connect the two references. Nahmanides wrote in his commentary on Leviticus 23:40:

> The tree is called etrog in the Aramaic tongue, and in the holy tongue it is called *hadar*, for the meaning of etrog is *hemda* (desirability), as it is translated "*nehmad le-mare'e*" (pleasing to the eye)—"*demerageg le-mehazei*" [Aramaic] "*lo tahmod*" (you shall not covet)—"*lo tarog*" [Aramaic]… and the tree and the fruit were called one name, as is common with most fruit: fig, nut, pomegranate, olive and others. And here as well—the name of the tree and the fruit are both in Aramaic: "etrog," and in the holy tongue: "*hadar*."

The sages often discuss the beauty of the etrog and its external shape. Etrog size is discussed as early as the Mishna, and as summarized by R. Israel Lipschitz, "A *mehudar* (beautiful) etrog has five conditions" (cleanliness, many bumps along its surface, indented stipe [*oketz*], a whole stigma [*shoshanta*] facing the stipe). Moreover, it was decided that the species should be held "as they grew."[5] In other words, one is to hold the etrog with its stipe on the bottom and the *pitam* (blossom end)

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[1] See, e.g., Leviticus Rabbah 30; Yitzhak Heinemann, *Ta'amei ha-Mitzvot be-Sifrut Yisrael* (Jerusalem, 1959), vol. I, 31, noted midrashim concerned with compatibility and others that also add an ethical tone. R. Samson Raphael Hirsch noted their symbolic meaning. According to his understanding, the etrog symbolizes the enjoyment derived from nature without human effort, and the enjoyment derived from the fruit created by nature which man must perfect. See in his commentary, Samson Raphael Hirsch, *Horev* (New York, 1953) to Lev. 23:40.

[2] Shmuel Abramski, *Bar Kokhva Nesi Yisrael* (Tel Aviv, 1961), 203.

[3] *Mekhilta de Rabbi Yishmael*, *Masekhta ba-Hodesh*, 6. In slight variance from the Tanaitic midrash to Deut. 5:9.

[4] On identifying the etrog, see Josef Tabory, *Jewish Festivals in the Time of the Mishnah and Talmud* (Jerusalem, 1995), 175–78; Yehudah Felix, *'Atzei Peri le-Mineihem*: *Tzimhei ha-Tanakh ve-Hazal* (Jerusalem, 1994), 195–96; Samuel Tolkowsky, *Pri Etz Hadar* (Jerusalem: The Bialik Institute, 1966), esp. 49–68. On the etrog in Yemen, see Ovadia Melamed, *Mesoret ha-Tefilla ve-Shoresh ha-Minhag* (2006), 332.

[5] Israel Lipschitz, *Tiferet Israel* (Warsaw, 1863) on M *Sukkah* 3:37.

on top. Indeed, the rabbi of Altona, R. Jacob Ettlinger, questioned whether European emigres fulfill the commandment with four species grown on the "American islands and Australia," for the residents of those countries have their legs opposite our legs.[6] He eventually concluded that it is "probable" that it is permissible since the fruits are actually grown in this way.

It is possible that the word *hadar* was associated with the Greek "*hydor*" which means water. Thus, the commentator emphasized and reinforced the element of water which is essential to growing the four species, and which symbolizes the dawn of the agricultural period that required rainwater. This insight contributed to the motif of the female connection to water, which is the foundation of the masculine *hessed* (grace).

Homilies often connect the exterior appearance of the four species to specific parts of the human body, reinforcing the affinity of nature, man, and the earth.

Various midrashim offer an implicit linguistic connection between the four species and Temple worship, emphasizing their importance and sanctity.[7] For example, the verb "*leratzot*" (to appease) appears in the Torah in connection with sacrifices,[8] and in the Talmud regarding the four species: "As it is taught: From when does one mention the rains? Rabbi Eliezer says: From the time that one takes the *lulav*. Rabbi Yehoshua says: From the time that one puts it down. Rabbi Eliezer said: It is because these four species come only to offer appeasement for water" (*Ta'anit* 2b).

We should note the unique interpretation of the word *hadar*: "Rabbi says: Do not read *hadar* [meaning beautiful], but rather *hadir* [meaning sheep pen]. Just as in this pen there are large and small, unblemished and blemished [sheep], so too, this [tree] has large and small, unblemished and blemished [fruits]."[9] And most explicitly in the following homily:

Rabbi Abbahu said that Rabbi Elazar said: Anyone *who takes a lulav* in its binding and a myrtle branch in its thickly leaved form [*avoto*], the verse ascribes him credit *as though he built an altar and sacrificed an offering upon it*, as it is stated: 'Bind with thickly-leaved branches [*ba'avotim*] on the Festival until the horns of the altar.' (Ps. 118:27).[10] We find additional motifs among medieval sages. For example:

> By way of *peshat* [simple meaning]: These four species grow near water and require watering more than other fruit. For this reason we were commanded on the festival of Sukkot, which

[6] Jacob Ettlinger, *Bikkurei Ya'akov* (Altuna, 1858), printed in a collection of commentaries to M *Sukkah*, clause 651, 1996, 28c. See also Daniel Sperber, *Minhagei Israel* (Jerusalem: Mossad Harav Kook, 1991), vol. VI, 163 no. 17.

[7] Yaakov Nagen, "The Lulav as Korban in Rabbinical Halakha," *Da'at* 49 (2002): 5–33. See also David Ochs, *Maskil le-David* (Jerusalem, 1998), vol. I, 221–32.

[8] Lev. 1:4, 22:25.

[9] *Sukkah* 35a. There is no doubt that in this homily the homilist was not only speaking of the connection to Temple worship but also of the unitedness of the nation, as is emphasized in additional homilies concerning the four species.

[10] *Sukkah* 45a. And see the kabbalistic developments below (n. 36) from *Sefer ha-Kane* (Krakow, 1894).

> is the time of water libation and the day of judgement for the year's rainfall,[11] to appease the Holy One Blessed be He for water with those four species that indicate water.[12]

This sage-kabbalist, who was the rabbi of Saragossa in Spain, offers a simple and natural interpretation and adds in the spirit of the Midrash:

> This is what they said in the Midrash: etrog resembles the heart, *lulav* the spine, *hadassim* the eyes, *aravot* the lips.[13] This means that when a person fails by the sins of these parts of the body, he is found to deny these four species that correspond to them and resemble them, for with every sin one finds redemption when a person fulfills the corresponding commandment.[14]

This means that the connection to body parts—and one can certainly say central parts by which a person functions, for better or worse—carries with it important psychological-religious values. In this case, there appears to be a tendency toward equilibrium, the calculation of a commandment against its loss.

Not far off is the *Sefer Ha-Hinukh*[15] (commandment 324), which puts forward another idea following a principle that it reiterates:

> A person is activated through his consistent actions, and his ideas and thoughts are grasped following the actions of his hands, whether good or bad. Because the days of the festival are days of great joy to Israel since it is the time of harvesting the grain and the fruits of the trees into the home… and because joy greatly draws matter and causes one to forget the fear of God in that time, we were commanded by God to take things in our hands that remind us that all of the joy in our hearts is for His name and glory.

In other words, the physical performance of the commandment is meant to expand religious consciousness precisely at a time when there is danger of falling into the material world. He immediately continues and adds another idea, that the four species/body parts have a symbolic general external meaning, but also a specific internal one: "These four species have another matter, which is that they resemble the primary parts of a person's body. The etrog resembles the heart, which is the home of the intellect, alluding that one should worship one's creator with one's intellect." This indicates that intellectual examination is a necessary and integral part of the worship of God. The midrashic notion of corresponding the species to certain body parts therefore took on various forms and changed over the years.

Medieval philosophical literature was generally satisfied with whatever was brought up in rabbinic homilies. Maimonides noted three characteristics: (a) that they are found abundantly in the Land of Israel; (b) that they are beautiful and fresh, the etrog and *hadas* even give off sweet fragrance; and (c) that they stay fresh for all seven days of the holiday.[16]

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[11] Rosh HaShanah 16a.

[12] Bahya ben Asher, *R. Bahya 'al ha-Torah* (Jerusalem: Chavel Edition, 1966), II:551, commentary on Lev. 23:40.

[13] Leviticus Rabbah 30:13.

[14] Bahya ben Asher, *R. Bahya 'al ha-Torah*, 553.

[15] Aharon Halevy, *Sefer Ha-Hinukh* (Jerusalem: Eshkol Publications, 1958).

[16] Maimonides, *Guide of the Perplexed* (Tel Aviv: Schwartz Edition, 2008), 374. See also Isaac Arama, *'Akedath Isaac*, Gate 67.

16.2 In Kabbalah

Kabbalistic literature also makes use of these rabbinic midrashim and adapts them according to their values and requirements, even reinforcing what is said in rabbinic literature. For example, according to one of the opinions in the Midrash,[17] the fruit eaten by Adam was the etrog. According to Rabbeinu Bahya,[18] taking the etrog alongside the three other species is done to rectify Adam's sin. In his words: "And through this we shall be awakened to the unification, for our first father *kitzetz* (separated) and sinned with the etrog alone.[19] We do not bring the etrog alone, but rather we bring it with the other fruit to unify it with them all, and with that we rectify his falsification, and appease God."

Moreover, the midrashic correspondence of the etrog to the heart is often repeated among kabbalists. "It resembles the heart"[20]; and "The fruit of [the] *hadar* tree resembles the heart and alludes to the *kavod* (glory) that is made up of the thirty-two paths, and it is more *hadar* than any *hadar*."[21] This means that the etrog symbolizes not only the human heart, as stated in the midrash, but also the Divine sefirotic world, alluded to as usual with the word *kavod*. As we shall see presently, this has a particular connection with the feminine image. But first the words of R. Moshe ben Makhir, a Sefadian kabbalist: "The matter of etrog is that it has a taste and smell, it is beautiful to look at, and good to eat, and it resembles the human heart, that must be beautiful, good, and clean from any lichen or flaw—alluding that man must be clean of any blemish and clear of any evil thought."[22]

The word "etrog" was often interpreted with Aramaic, where the root רגג (*RGG*) means חמד (*HMD*—covet/desire). For example, the tenth commandment, "Thou shalt not covet," was translated as "*la tirog*," linking this word to the coveted feminine. The word "*hadar*," as in beauty, added to the feminine desirability. Thus, the feminine meaning of the etrog was already reinforced among early kabbalists.[23] Even if we

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[17] See Genesis Rabbah 15:8, 20:20. And see Mordekhai Kislev, "*Etz ha-Da'at* Etrog *Haya*," *Sinai* 125 (2009): 9–18.

[18] Bahya ben Asher, *R. Bahya 'al ha-Torah*, 556, in his commentary on Lev. 23:40. Found also in one of the kabbalistic classics, *Ma'arekhet ha-Elohut* (Jerusalem, 1963), 74a: "*Peri etz hadar* was said of the etrog, and Onkelos translated 'and the tree was desired to make one wise'—'*demargag lemehvei*' [Aramaic] in the language of *arag nehasin*, it was therefore the etrog with which Adam sinned.".

[19] Bahya ben Asher, *R. Bahya 'al ha-Torah*, alludes to his commentary on Lev. 22:27. And cf. his commentary on Gen. 3:6, "*Va-yokhal*.".

[20] Ya'akov ben Sheshet, *Meshiv Devarim Nekhohim* (Jerusalem, 1969), 175. And see the entire chapter there, 175–177.

[21] Bahya ben Asher, *R. Bahya 'al ha-Torah*, commentary on Lev. 23:40, ibid., 555. The word *kavod* has the numerical equivalency of *lev* (heart).

[22] Moshe ben Makhir, *Seder ha-Yom* (Jerusalem, 1985), 49d. And read also the important continuation.

[23] See, e.g., Moses de Leon, *The Book of the Pomegranate*, ed. Eliot Wolfson (Atlanta: Brown Judaic Studies, 1988), 184 no.13.

find differing opinions regarding the symbolism of the three other species,[24] they are unanimous when it comes to the etrog.[25]

"Etrog is the lower *shekhina*, it resembles the heart which is on the left, which is *Gevura* (strength), and for this reason a person must take the etrog in his left hand."[26] This author binds three motifs together: the etrog symbolizes the *shekhina*, the lowest *sefira* in the sefirotic constellation, also called *midat ha-din ha-rafa* (the soft attribute of judgement); the etrog resembles the human heart which is on the left side, symbolizing the *sefira* of *gevura* in the sefirotic constellation, also called *midat ha-din ha-kasha* (the hard attribute of judgement). Halakhic reasoning derives from all this that one must take the etrog in the left hand so as to rectify *gevura*.

This appears to be a series of symbolic gestures, but an additional meaning is offered elsewhere: "By way of the Kabbalah, it (the tree from which Adam ate) was the etrog alluded to in Scripture, as it is written 'desirable to make one wise,' translated by Onkelos '*umargag*,' for it is desirable and beautiful and its temperament is hot and it rules the intellect."[27] In other words, Adam sinned because the etrog, the heat temperament, took over his intellect. And thus the lesson: to impose the intellect on the heart (a central motif in R. Shneur Zalman of Liadi's *Tanya*).

The reasoning behind the unsuitability of certain etrog blemishes is offered in another place in the *Tikkunei Zohar*: "For it resembles the *shekhina*, about which it is said, 'You are altogether beautiful, my love; you have no flaw.'"[28] The feminine comparison itself demands aesthetic perfection. For example: "And if she is yellow her image is more excellent, because Esther was *yerakroket* (yellow), for it is said of her 'and Esther dressed in *malkhut* (royal robes),' etc."[29] The yellow shade discussed in the Talmud is integrated with kabbalistic motifs (the word *malkhut* in the verse once transposed takes on the meaning of the *sefira*).

The resemblance to the lowest *sefira* and femininity has another expression:

> The etrog is their entirety, just as the garden includes the saplings…and therefore she had to be composed of all of them, so that she can receive them since their actions are enacted through her. And from this we can understand Nahmanides' intention in saying that she is not with them in unity, despite being with them in emanation, which is that although they are all called "saplings," she is different because she is called "garden." And this is because she is the combination of their entirety, and therefore her unity is not like their unity.[30]

The lowest *sefira* is considered one of the *sefirot*, but she contains them all within her, as a woman who carries different fetuses and different identities within her womb.

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[24] Ibid., 184 no.8.

[25] See, e.g., *Ma'arekhet ha-Elohut*, ch. 13, 189b. And see Efraim Gottlieb, *Ha-Kabbalah be-Kitvei Rabbeinu Bahya Bar Asher* (Jerusalem, 1970), 17, 138.

[26] *Tikkunei Zohar* (Jerusalem, 1948), *tikkun* 21, 56b.

[27] Bahya ben Asher, *R. Bahya 'al ha-Torah*, commentary on Gen. 3:6, 77.

[28] *Tikkunei Zohar*, *tikkun* 13, 29a.

[29] David ben Zimra, *Metzudat David* (Zolkiew, 1862), commandment 118, 23a. On Esther as *yerakroket*, see Meg. 13a. It should be noted that throughout history *yarok* was identified with what we today call yellow.

[30] Yehuda Hayyat, "Minhat Yehuda," in *Ma'arekhet ha-Elohut*, 13.

Thirteenth-century kabbalists, therefore, called her "the image of all images." For this reason, the feminine lower etrog serves as an illustration and a model for the supernal sefirotic reality. We can thus understand the following:

> This fruit is desirable to look at because all of the supernal visions and all of the specula are seen in this fruit. Alternatively, it is called "fruit" because it receives the fruits of the supernal world, which is a deep river[31] wherein the fruit grow that are the souls of the righteous surrounding the deep river, and those fruit grow on the trees that were planted around the river.[32]

Without delving into its kabbalistic significance, I will briefly summarize this passage. In Kabbalah, the soul is compared to a bird or a fruit springing forth from a tree, and generally serves as symbol for *tiferet* (beauty) or *yesod* (foundation). Both of these *sefirot*, which symbolize the masculine, are closely tied to the last feminine *sefira*. This is the *sefira* that in the above passage is represented by a river in which the trees and saplings grow. The etrog is thus a "central figure" of the four species. This idea is further explicated by the same kabbalist:

> If you would say "why is the etrog not bound[33] to the other species in a single bundle?" It is already known that the etrog is *Knesset Yisrael* (the Jewish people) who stands outside of the curtain, as it were, and she was distressed and fraught from the King's house for not having her own image, only what others give her, and therefore in this regard she is not even a *sefira*. But regarding the unification, she includes them all, as we learned: their end was fixed in their beginning and their beginning in their end. Therefore when one takes the *lulav*, when shaking it, one should connect the etrog to the *lulav* so as to proclaim the unification and supernal union which exists during these days. For throughout the seven days of this festival there is a union of the King and his Lady. Therefore, every Jew must appear joyful during these days because it is a time of joy above and below. Thus anyone who makes himself joyful during this festival adds supernal and lower joy.[34]

The beginning of this passage can be understood according to our earlier discussion, but the author adds and expounds upon the requirement brought by kabbalists from the thirteenth century and onwards: that one must bind the four species together while reciting the blessing and while shaking, thereby instilling in one's consciousness the idea of unification—the human (as in the midrash) but also the Divine (as in Kabbalah). This is thereby tied to the commandment of joy, typical of the festival of Sukkot in Scripture: "And you shall rejoice in your feast" (Deut. 16:14). And the joy is "above and below." R. Moshe de Leon also wrote that the union of the species brings about joy, which explains the connection of joy to this festival.[35]

Again, another Talmudic homily received a typical kabbalistic revision:

> And, may they be blessed, said, "Any who fulfills the *lulav* in its binding, and myrtle in its thickly-leaved form it is as though he constructed an altar and made an offering," meaning

[31] Ibid., 94: "River alludes to the supernal crown which is called 'deep river.'".

[32] David ben Yehuda He-Hasid, *Mar'ot ha-Zove'ot* (Chico, CA: Daniel Matt Edition, 1982), 93.

[33] In the original Hebrew, the author uses the feminine here.

[34] Ibid., 95–96.

[35] De Leon, *The Book of the Pomegranate*, 186.

> that the offering [*korban*] draws near [*mekarev*] the spiritual powers.[36] Thus the *lulav* in its binding and myrtle in its thickly-leaved form, are the supernal archetypes and they connect the tent to be one, and tie them to the supernal place as a flame in coal. And the author of this account only alluded to *lulav* and myrtle and willow bound with the *lulav*, but he did not mention the etrog. And it is with them and they are with it, but it is not always bound with them and therefore it is alone for it is bound during certain times according to the supernal will.[37]

The etrog is not explicitly mentioned in the Talmudic homily, but it is alluded to for "it is with them and they are with it." The connection between the lower feminine *sefira* and those above her is not constant, but only "during certain times," according to circumstances and according to the dictation of kabbalistic literature. Nevertheless, there is a yearning for unification.

For more on the linking of the *lulav* to the etrog, and in further detail, we shall read the following passage by sixteenth-century kabbalist R. David ben Zimra:

> The etrog is not bound with them, as noted in the secret that we wrote a number of times—that she is emanated from them but is not united with them, and for that reason she must be individualized and conjoined with them. One must grasp the binding with the right and the etrog with the left and conjoin both hands and shake so as to draw down the influx from the spiritual world to the world of the *binyan* (the sefirotic structure) alluded to with the *lulav*, and from there to the world of *Malkhut* (kingdom) alluded to with the etrog, and from there to all the chariots and angels and spheres to the sublunary world.[38]

And more concisely: "*Hessed* and myrtle are all one, for the letters ACHH 'A are switched, and etrog is derived from the language of 'desired,' translated as 'for it was desirable to the eye'—*mergag*. 'Neither shall you lust,' 'neither shall you *tirog*,' in the language of etrog to allude that the supernal world desires this attribute to emanate into it and the lower world to receive from it."[39] This expresses the central status of the etrog-*shekhina*: the *sefirot* above her emanate into her, and the lower worlds imbibe from her and receive their existence from her. Thus, when a person takes the etrog and *lulav* he assists the *shekhina* in fulfilling her role.

An additional halakhic detail, that the *lulav* must be bound at its head, received a symbolic-mystical meaning as an allusion to the supernal *sefira* being bound with the entire sefirotic constellation without separation.

> Therefore the *lulav*, which is *tiferet*, must be bound on high with *keter elyon*, so that it unites and is bound with the supernal *sefirot* so that they all become one bundle (*aguda*), as it is

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[36] This linguistic homily, *korban* = *mekarev*, was put forward in *Sefer ha-Bahir* (Jerusalem: Margolioth Edition, 1951), no. 109, and is repeated frequently by kabbalists.

[37] *Sefer ha-Kane*, 82b.

[38] Ben Zimra, *Metzudat David*, *mitzvah* 118, 23a. And there: "The etrog resembles the heart and alludes to the attribute called *LeV* (heart), which is the last and is the *peri etz hadar*, for the joining of the fruit with the tree is *hadar* and it dwells (*dar*) in the tree all year, alluding in the joining—that one should not take the fruit on its own." And more explicitly later on (23d): "For it is with them and they are with it, only it is not bound with them always and it is therefore alone, for it is bound during certain times according to the supernal will. And this is 'Do not awaken, nor stir up love, until it pleases'—the supernal pleasure." This excerpt paraphrases the passage in *Sefer ha-Kane*.

[39] Ibid., 23b.

> written "And he has founded his strata (*agudato*) on the earth." Therefore, the tradition of some *hassidim* is to bind the head of the *lulav* above to allude to *keter elyon* which is bound and tied by the cause of causes, which has no division or *kitzutz* (separation). Rather, everything is perfect to the highest perfection so that all should resemble the supernal archetype.[40]

We thus have a "halakhic" detail whose performance reflects the kabbalistic doctrine of essential affinity between the supernal and lower worlds.

Alongside the feminine image is the spiritual image. The etrog symbolizes the yearning for the apprehension of intelligibles:

> "And the tree was desired to make one wise," for the soul (*neshama*) enjoys the good smell, as they, may their memory be a blessing, said, "Let everything that has breath (*neshama*) praise the Lord"—the thing that the soul enjoys is smell,[41] and for this reason we bless smell. And this is "and the tree is desirable," for from the soul's enjoyment of smell she apprehends the intelligibles, as it is said, "how pleasing is your fragrance," and the translation of "thou shall not lust" – shall not *tirog*, which is like an etrog that is fragrant.[42]

We also find that the commandment to be joyful is emphasized in the eighteenth century, with new ritual elements:

> During the last third of the night of the first day of the festival, one should prepare oneself to fulfill the positive commandment from the Torah of taking the four species… And one should first check if there is first light and then bless the *lulav* specifically in the *sukkah*. Thus wrote the AR"I (R. Isaac Luria), may his memory be a blessing, according to a great secret: the blessing on the *lulav* with shaking should be performed specifically in the *sukkah*, and this is the custom of those who respect and fear God's word. Before blessing one should recite "*leshem yihud"* (for the unification of) etc. with tremendous intention (*kavana*) and pray a brief prayer as though he intended with all the intentions intended by the Men of the Great Assembly. And one should bless the blessing of the *lulav* with tremendous joy and offer up a tremendous thanksgiving prayer to our Creator may His name be blessed that he granted us, the holy congregation, this grand commandment.[43]

16.3 In Folklore

In folklore as well, we find material on the etrog. Our sages said: "One who sees an etrog in a dream—he is *hadur* (beautiful) before his maker, as it is written: *peri etz hadar*."[44] The affinity between the etrog and *hadar* appears here again, and *hadar* is interpreted to mean *hadur* (beautiful) before God.

There are those who kiss the etrog before fulfilling the *mitzvah* (commandment) and afterwards.[45] It appears that this was an ancient custom, for already Meir of

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40 David ben Yehuda He-Hasid, *Mar'ot ha-Zove'ot*, 97–98.

41 See *Berakhot* 43b.

42 Abraham Sava, *Tzeror ha-Mor* (Brooklyn, 1961), Genesis 8b. Cf. with *Sefer ha-Hinukh*).

43 Alexander Ziskind of Grodno (d. 1794), *Yesod ve-Shoresh ha-Avoda*, *Sha'ar ha-Iton* (Bnei Brak, 1987), II, ch. 14, 115.

44 *Berakhot* 57a.

45 Shlomo Ashkenazi, *Dor Dor u-Minhagav* (Tel Aviv, 1987), 73. And there: the hassidic leader, R. Shlomo Leib from Łęczna loved the commandment of etrog so much that every day of Sukkot when reciting Hallel he would kiss it (*Emunat Tzadikim*, section 185).

Rothenburg (1220–1293) opposed it: "Those people who kiss it [the etrog], they cannot find their hands and feet and I call them 'the fool walks in the dark.'"[46] We also find the opposite position, as testified by Isaiah Horowitz:

> I saw some *bnei aliyah* (sons of ascent) who love *mitzvot*, kissing the *matzot* and the *maror* and all of the *mitzvot* when they were to be performed, and also the *sukkah* when entering and exiting as well as the four species of the *lulav*, and all out of love for the *mitzvot*… blessed is he who serves God with joy and a good heart.[47]

Because of the love of the *mitzvah*, it was decided that it would be forbidden to throw them into the trash, or to step on them, or to treat them in any other demeaning way.[48] There was also a warning not to rub the etrog,[49] so that it not be harmed or damaged and, even for the purpose of the *mitzvah*, it should not be carried without enclosure, without a hemp or wool cover.[50]

There were those who hung the etrog as a *sukkah* decoration.[51]

It is customary to place a piece of etrog in the perfume box, so as to bless it after the Sabbath, *Boreh minei besamim* (the creator of types of perfume). On its fragrance, during the week one blesses: "Blessed that he imbibed a sweet fragrance in fruit." And during Sukkot, "If one uses myrtle for *sekhakh* (branches used for the Sukka roof) or hangs an etrog as a *sukkah* decoration, it is permitted to smell it."[52] Thus in the *minhag* literature: "It is permitted to smell the etrog used for a *mitzvah.*

There are those who say that one should bless "*Asher natan reah tov ba-perot* (that he imbibed a sweet smell in fruit)" and there are those who say that one should not make the blessing."[53] And thus in the poem: "Seven days it is forbidden to smell the myrtle, but it is not forbidden to smell the etrog, the first day was allotted for this *mitzvah*, and therefore eating it is avoided."[54] In other words, it is forbidden to eat the etrog during Sukkot, but it is permitted to smell it.

In order to preserve and use the fragrance, the etrog is customarily wrapped in linen or hemp which absorbs the smell from the eve of the festival.[55] There is a custom among women to place etrogim in closets to perfume them. There are those who eat etrogim (mixed with honey or other ingredients) for good health.[56] There was once a

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[46] Eccl. 2:14. Meir of Rothenburg, *Sefer Minhagim*, ed. Israel Elfenbein (Jerusalem, 1938), 65.

[47] Isaiah Horowitz, *Ner Mitzvah* (Haifa, 1992), Pesahim, no. 39, 115b.

[48] See, e.g., Ovadia Yosef, *Hazon 'Ovadia* (Jerusalem, 2005), *Sukkot*, 449.

[49] Rosh HaShanah, 15a.

[50] Yom Tov Levinsky (ed.), *Sefer ha-Mo'adim*, *Sukkot* (Tel Aviv, 1951), 92.

[51] There is an interesting tradition of sages who intentionally had in their possession a great many etrogim (thirteen and 136). Eliezer Kestenbaum, *Pardes Eliezer* (Brooklyn, 2007), *Sukkot*, I:73.

[52] Moshe Isserles, *Orah Hayyim*, no. 638, *seif katan* (hereafter s"k), b. Cf. *Sukkah* 37b.

[53] Isaac Tyrnau, *Sefer ha-Minhagim* (Jerusalem, 1946), 55. However, in the *Shuklhan Arukh*, no. 653, s"k a, he wrote following the controversy that "one should avoid smelling it." These words of the *Shulkhan Arukh* are often quoted in later halakhic works.

[54] Berekhiya ha-Levi, "Azharot le Shabbat kodem Sukkot," in *Pithei Tefillah u–Mo'adim*, ed. Ya'akov Spiegel (Jerusalem, 2010), 332.

[55] Levinsky, *Sefer ha-Mo'adim*, 96.

[56] Shabbat 109b. And see also Leviticus Rabbah 37:2, from which the tale of the king is derived. See also Yehudah Ratzhabi, *Be-Ma'agelot Teiman* (Tel Aviv: Defus Malan, 1988), 218.

king from across the sea who was healed from a stomach illness by eating etrogim.[57] Others viewed it as a folk remedy for heart disease, since, as already discussed, the etrog corresponds to the heart.

"One who becomes mute and his ability for speech is taken from him, may God help us, should place a rind of an etrog in his mouth and he will see wonders."[58] "It (the etrog) is a *segula* (charm) for protecting the home to be saved from all tragedy, and also from any sin." In other words, physical and spiritual protection.[59]

Sages disputed whether before eating it one was obliged to recite the *shehehyanu* blessing, and various arguments were raised. I will suffice with a single source, which contains a number of details:

> On the etrog the rabbi said "*peri ha'adama*," which testified that it is customary to bless *shehehyanu* in the Holy City of Jerusalem, may it be rebuilt speedily in our days, eaten on the second night of Rosh HaShanah in place of a new fruit. In our city (Baghdad), may God protect it, the etrog is sweet, but is not easily found, and it is the custom in our home to eat an etrog before Yom Tov of the festival of Sukkot and bless *shehehyanu*. But our congregation does not customarily eat it before Sukkot, only on Tu beShvat when they are brought to the market. Those who buy an etrog to shake, put it aside until Tu beShvat and eat it, and they need not bless *shehehyanu*.[60]

In various places, there was the custom to make jam out the etrog or dry it and put it aside for Tu beShvat, the New Year for the trees.[61] This jam was given to any woman experiencing a difficult birth, so as to open her womb.

Indeed, it was viewed especially as a charm for women. A pregnant woman was advised to eat etrog so as to be blessed with a sweet-smelling child, as it is written in the Talmud: "One who eats etrog will have sweet-smelling children."[62] It is recounted there that the wife of the King of Shapur ate an etrog while she was pregnant and had a sweet-smelling daughter.

Over the course of history, the biting of the *pitam* as a charm for easy births was emphasized. A pregnant woman bites the *pitam* after the prayers on the day of *Hoshana Rabba*, when one is halakhically no longer permitted use the etrog:

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[57] See this story expounded in Leviticus Rabbah 37:2.

[58] Abraham Y. Sperling, *Ta'amei ha-Minhagim u-Mekorei ha-Dinim* (Jerusalem, 1957), 576.

[59] Rahamim N. Palacci, *Yaffe la-Lev* (Izmir, 1876). And: "We have seen elderly rabbis who preserve the four species every year and say that it is beneficial for protection" (Hayyim Y. D. Azulai, *Kikar la-Aden* [Livorno, 1801], 162a). And: "On the festival of Sukkot they (Moroccan Jews) put aside their etrogim until the following Sukkot as a *segulah* for protection" (Jacob Moses Toledano, *Ner ha-Ma'arav* [Jerusalem, 1989], 304).

[60] Hayyim Yosef, *Ben Ish Hai* (Jerusalem, 1972), *Shana rishona*, *Re'e*, 11. Haim Palachi, *Moed Lekol Ha*i (Jerusalem: Makash, 1985), added: "I say that in a place where etrogim are found, they should be offered as a sweet for Rosh HaShanah guests" (no. 12, s"k 23. And see Yosef, *Hazon 'Ovadia*, 449–50.

[61] For example, Palacci, *Yaffe la-lev*, II, no. 664, 15; Ya'akov Sofer, *Kaf ha-Hayyim* (Jerusalem, 1905), no. 662, s"k 15.

[62] *Ketubbot* 61a.

> I saw in a manuscript book that pregnant women would customarily take the etrog on *Hoshana Rabba*[63] and remove the *pitemet*. After removing the *pitemet* they distribute alms for the poor, each one according to her ability, and have intentions that the Holy One may He be blessed will save her during labor and that the baby should live… and then they prayed the following prayer: "Master of the universe, it is revealed and known before you that because Eve ate from the Tree of Knowledge her sin brought death into the world and pain of childbearing. If I were there at that time I would not have eaten from it nor would I have taken pleasure in it at all, just as I had no desire to disqualify this etrog during all the days of the festival that has now passed, for I disqualified it only because its *mitzvah* ended… Receive with desire my prayer, etc.[64]

In order to popularize this prayer among pregnant women, it was translated by R. Haim Palachi's son, R. Abraham, in his book *Hokhiah Avraham*, chapter 24. Among Ashkenazic groups a special *tehina* (supplication) (in Yiddish) was established for a woman biting the etrog's *pitemet*. However, in Ashkenaz, women would customarily wait until after the festival. It is worth noting that in the above passage, the biting of the *pitam* is accompanied by giving alms as an additional *segula*.

Another idea raised in this prayer is that beyond the symbolism of severing the *pitam*, the very biting of the *pitam*, which renders the etrog unusable, is done for the rectification of the sin of Adam and Eve, since the tree they ate from "was an etrog" (Genesis Rabbah 15:8), "If I were there at that time I would not have eaten from it."

It is accepted among women that the easier the removal of the *pitam* with one's teeth, the easier the birth. Among the Sefardi community there are those who make sure to eat seven *pitamim* of etrogim that were blessed during Sukkot for an easy birth.

Over the course of history, we find literary expressions for evaluating etrogim. Two verses from Psalm 19 are explained: "'Rejoicing the Heart'—this is an etrog that resembles the heart. 'The commandment of the Lord is pure, enlightening the eyes'—this is the etrog."[65]

There are those among the hassidim who noted the acronym of the etrog (ETRG): *E'muna* (faith), *T'eshuva* (repentance), *R'efua* (health), *G'eula* (redemption),[66] highlighting the values connected to the etrog.

Similarly, the *gematria* (numerical value) of etrog is 610. If you add the other three species you get 613. Moreover, the author of the *Turim* on Leviticus 23:40 writes that "*peri etz hadar*" adds up in *gematria* to "etrogim."

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[63] An important detail to note, for the *Shulkhan Arukh*, no, 665 s"k a, explicitly rules that: "On the seventh day etrog is forbidden for it was allocated for the seven." It appears that a *segula* from a *mitzvah* beyond its performance carries more weight from the people's perspective than the *halakhah* itself (which they may not have known). It is thus understood also by Shalom S. Tsherniak, *Hayyim u-Vrakha* (Warsaw, 1903), section 70, 228, 66.

[64] Palachi, *Mo'ed lekol hai*, no. 24, s"k 25, 324–25; Yosef, *Hazon 'Ovadia*, 449–50. And see on this Aliza Lavie, *Tefillat Nashim* (Rishon Letzion, 2005), 251–52. However, in his commentary on the Tur, Yair Bacharach, *Mekor Hayyim* (Jerusalem, 2018), no. 664 s"k 9, disagrees and writes: "How fortunate we are that these kinds of customs were uprooted.".

[65] *Zohar Hadash* (Jerusalem, 1948), *Ki Tissa*, 89.

[66] Shlomo Ashkenazi, *Avnei Hen* (Tel Aviv, 1990), 154.

One of the hassidic giants writes: "We received the tradition from our rabbis to pray on Tu beShvat for a kosher, beautiful, and glorified etrog, that would be summoned by *Hashem*, may He be blessed, at the time requiring the *mitzvah*."[67] Indeed, R. Yosef Hayyim of Baghdad composed a special prayer for Tu beShvat for the success of the etrog. In his introduction to this prayer he writes: "It is known that there is a tradition among the *Hakhmei Ashkenaz*, may their memory be a blessing, to request specifically on Tu beShvat that Israel should receive a good and beautiful etrog for the festival." Incidentally, the etrog receives a specific prayer in addition to the other fruit trees: "May it be Your will… that You bless all the etrog trees to fruit at the correct time… that You bless all kinds of trees to fruit with abundant oils and goodness," etc.[68]

16.4 In the Community

As is well known, in the cold climates of Northern and Eastern Europe it is impossible to grow etrogim, and our forefathers who inhabited those countries were dependent on imports from Mediterranean lands, especially Italy and Greece. This caused a medley of difficulties. Nevertheless, our forefathers pursued the etrog in general, and beautiful and prime etrogim in particular, often to the point of *mesirat nefesh* (self-sacrifice).

Among Ashkenazi Jews, there was an honorary post of "*etroger*," a professional versed in the qualities of the four species and the relevant *halakhah*, and a reliable judge of their kosher status (with regard to grafting and similar issues). This honorary post occasionally brought with it remuneration, and sometimes was accompanied by instances of fighting, lawsuits, and competition among the different contenders for the post.[69] In many communities, there were special organizations that dispatched messengers overseas beforehand to make the purchases on their behalf. Thus, for example, "*Hevra Lulav"* took care of obtaining the four species for the community.[70] In Bulgaria, there was a custom to purchase the "*mitzvah* that credits the public," and the buyer would allow anyone to use it.

Indeed, many wonderful tales are recounted about the giants of Israel, hassidic masters, hassidim, mitnagdim, miracle workers, and the like, who used various methods to obtain the four species. There are those who sold valuable items in return, and even renounced their place in the World to Come for the performance of

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[67] Zvi E. Shapira, *Benei Yisaskhar* (Lemberg, 1962), *Ma'amar Hodesh Shvat*, 2:2.

[68] Hayyim Yosef, *Leshon Hakhamim* (Jerusalem, 1990), 144–45.

[69] Ashkenazi, *Dor Dor u-Minhagav*, 79. See also Akiva Ben Ezra, *Minhagei Hagim* (Jerusalem, 1963), 75–77.

[70] Ashkenazi, *Dor Dor u-Minhagav*, 75.

this *mitzvah*.[71] The Jews of Yemen did not communally fulfill this *mitzvah*—rather, every person purchased his own species, even at a great price.[72]

Sometimes, they had to make do with a single etrog, as evidenced by R. Meir of Rothenburg: "They were accustomed to purchase an etrog together with the small coins of the community, and it would be gifted to the one blessing it so that he would fulfill the *mitzvah*. And when finished, he would gift it to a friend, and his friend to another friend, as we hold: a gift given with the intention of its return is [still] called a gift."[73]

However, this collaboration created an ironic situation: Rabbi Israel Isserlin, among the great Ashkenazi rabbis of the fifteenth century, was posed a question regarding an occurrence wherein a number of villages had only one etrog among them for the festival *mitzvah*, so "they cut the etrog into a few pieces and sent a piece to each town".[74]

These difficulties caused inflated prices and price gouging, leading to conflict. This was not the first time that prices were raised for a *mitzvah*, another example being phylacteries. It is known that R. Isaac Luria was accustomed to do so, and paid what was demanded.[75] Also, in BT *Sukkah* 41b there is an account of Rabban Gamliel who purchased an etrog for 1,000 *zuz*. This custom, particularly with regard to the etrog, incited a fierce controversy on the part of the Mabit (Moses ben Joseph di Trani), who was concerned about the price increase.[76]

The tension between the desire to beautify the *mitzvah* while ignoring the cost, and concern regarding the price increases and the financial burden on the public, has continued into later generations and remains unresolved.[77] In any case, regarding those who sold at inflated prices and gloated over their fancy etrogim, the kabbalists intoned *Al Tevo'eni Regel Ga'ava* ("May the foot of the proud not come against me") (Ps. 36:12)—acronym ETRoG.[78]

However, of interest is the following ruling: "According to the *Holy Zohar*, in *Teruma* one must not bless an etrog received without payment, for the *kelipot* (husks) suckle from *mitzvot* that are received without payment."[79] Thus, a *mitzvah* should not be performed offhandedly, but rather with invested effort.

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71 Ashkenazi, *Avnei Hen*, 142.

72 Ratzhabi, *Be-Ma'agelot Teiman*, 217.

73 Tyrnau, *Sefer Ha-Minhagim*, 65. And see *Sefer Hassidim* (Frankfurt, 1924), 398, no. 1634. The source is BT *Sukkah* 41b.

74 Israel Isserlein, *Terumat ha-Deshen* (Jerusalem, 1992), vol. II, *Pesakim u-Khtavim*, no. 52, 7a.

75 Hayyim Vital, *Sha'ar ha-Mitzvot* (Jerusalem, 1905), *Reish Parashat 'Ekev*, 37b. And see Meir Benayahu, *Sefer Toledot ha-Ari* (Jerusalem, 1967), 317, 348.

76 See ibid., 317 no. 5.

77 And see S.Y. Agnon, *Ha-Esh ve-ha-Etzim* (Tel Aviv, 1962), 115–117, 275, etc. Particularly known is the question of exaggerated prices of fish for the Sabbath. See, e.g., *Magen Avraham*, *Orah Hayyim*, no. 142, s"k 1. And see Moshe Hallamish, *Ha-Kabbalah ba-Tefillah ba-Halakha u-va-Minhag* (Ramat Gan, 2010), 493–95.

78 Levinsky, *Sefer ha-Mo'adim*, 94. Incidentally, the verse explicated was already discussed in connection with the etrog in the midrash.

79 Palachi, *Moed Lekol Hai*, no. 23 s"k 43, 293.

16.5 Joining the Species

In the Baraita it says:

> Rabbi Eliezer said to him: I might have thought that the etrog should be bound with the other species in one bundle. You could say: Does it say "The fruit of a beautiful tree and branches of a date palm"? But it says only "branches" [meaning, without the *vav* conjunction] And from where is it derived that failure to take each of the species prevents fulfillment of the *mitzva* with the others? The verse states: "And you shall take [*u'lekaḥtem*]," that it shall be a complete taking [*lekiḥa tamma*].[80]

According to the Talmud, *Sukkah* 37b, the *lulav* binds with it the myrtle and the willow, but the etrog remains separate. One is required to take all four species while making the blessing because failure to take one of them would prevent the fulfillment of the *mitzvah*, and in this respect they function as one bundle.[81]

The *lulav*, together with the myrtle and the willow, are taken with the right hand, while the etrog is taken with the left.[82] Thus Maimonides ruled: "The *mitzvah* according to the *halakhah* is to lift up the bundle of the three species with the right hand and the etrog with the left."[83] Also, other halakhic sages did not require binding the four species together. For example, R. Levi son of David of Narbonne, in the second half of the thirteenth century, explicitly wrote: "If one takes both with one hand… [he] did not fulfill [the *mitzvah*]."[84] Also, in other halakhic works such as *Tur*, *ha-Manhig*, *ha-Eshkol*, *ha-Ora*, *ha-Agur*, and more, there is no mention of a requirement to bind the four species together while reciting the blessing or while shaking.

In the school of the students of Nahmanides' student, R. Shlomo ibn Aderet, they concern themselves quite frequently with various matters connected to the four species, but do not discuss the requirement to bind them together. This applies to R. Shem Tov ibn Gaon, in his *Keter Shem Tov*; R. Yehoshua ibn Shuaib, in his commentary on the Torah, etc. Conversely, it may be possible to prove that ibn Shuaib was not even familiar with possibility of binding. For, as he writes: "The matter of taking the *lulav* with the right [hand] that has in it three species and the etrog with the left. And this has a profound meaning for the knowers of hidden wisdom."[85] Also, the supercommentary to Nahmanides (attributed to R. Meir Abusahula) unequivocally

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[80] *Sukkah* 34b. See there.

[81] The phrase "*aguda ahat* (one bundle)" with regard to the four species appears in the Talmud and in the midrash. See *Sukkah* 34b; *Menahot* 27a; Leviticus Rabbah 30. And see the Vilna Gaon's commentary on the *Shulkhan Arukh* no. 651, s"k 32, that ties the *halakhah* under discussion to Talmudic sources.

[82] See *Sukkah* 37b.

[83] *Hilkhot Lulav*, 7:9.

[84] Moshe Bloy, *Sefer ha-Mikhtam* (New York, 1959), 164. His words were also quoted in Aharon ha-Kohen, *Orhot Hayyim* (Florence, 1750), *Hilkhot Lulav*, 19. And see a discussion surrounding this in the *Turei zahav* to the *Shulkhan Arukh*, no. 651, s"k 14. And see also Menahem Ha-Meiri, *Beit ha-Behira* (Jerusalem, 1959), *Sukkah* 89.

[85] Yehoshua Ibn Shu'eib, *Derashot al ha-Torah* (Krakow, 1573), 94d.

states: "*Pri etz hadar*, which is the etrog, became attached to the other species, but not bound and not with the right, *but rather separated and with the left*."[86]

However, a different student of R. Shlomo ibn Aderet, R. Hayyim ben Shmuel of Toledo,[87] mentions an interesting speculation about Nahmanides:

> There are those who connect the *lulav* to the etrog when taking them. And I heard the opinion of Nahmanides, may his memory be a blessing, that when reciting the blessing one must join them, but during the shaking they should not be joined. And his reasoning, may his memory be a blessing, was that shaking is a sign of influx like "nodded his head" (Berakhot 7a). And the etrog is the *receiver* of the influx.

This passage teaches us:

a. There is a custom, seemingly among only a minority, to conjoin the *lulav* and the etrog.
b. There is speculation that Nahmanides attached them during the blessing, but not while shaking.
c. There is a basic differentiation between the *lulav* that influxes and the etrog that receives, like the feminine figure. However, already in the early generations, different kabbalists advocated for attaching the etrog and *lulav* while making the blessing so that they become one. The kabbalists viewed this as the perfection and unification desired between the masculine and feminine world. Below, we shall dedicate a brief discussion to the history of this practice.[88]

The Bahir emphasized[89] presenting the lowest feminine *sefira* as different and separate[90] from the nine *sefirot*, but nevertheless united with them as part of the general sefirotic world that includes aspects of the masculine and feminine as one. The relationship between the *lulav* and the etrog served as a good example for his view. The etrog symbolizes the feminine and is therefore different than the other three. However, its sexuality is important because— "it is with everyone, and everyone is with it." This principle corresponds to the *halakhah* that dictates that although the *lulav* and etrog are taken with different hands, the etrog is nevertheless considered bound with the rest, for the *mitzvah* demands taking all four. And, indeed, this is what the Bahir writes: "The etrog is separate from the bind[ing] of the *lulav* and the *mitzvah* of *lulav* only exists with it, and it is also bound with all."[91]

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[86] Meir Abusahula, *Beur le-Perush ha-Ramban al-ha-Torah* (Warsaw, 1875), 37b. And emphasized in *Ma'arekhet ha-Elohut* (192a): "The etrog must come together with it, alluding to the *'Atara* but not in one bind [!], because it is not in their unity.".

[87] *Tzeror ha-Hayyim* (Jerusalem, 1965), 105. And see the opposition of Sofer, *Kaf ha-Hayyim*, no. 651, s"k 105.

[88] I elaborated on this in my book, *Ha-Kabbalah ba-Tefillah ba-Halakha u-va-Minhag*, ch. 29.

[89] A view repeated a number of times in a few sections, suggesting that the book ascribes importance to it. For example, in *Sefer ha-Bahir*, §44, §133, §175. We briefly discussed the significance of this idea in Kabbalah above.

[90] "In the secret of women as a nation to themselves," in the words of R. Isaac ha-Kohen, who discusses this same matter. R. Isaac was active in Morocco in the sixteenth and seventeenth centuries. And regarding this subject, see Moshe Idel, *R. Menahem Recanati the Kabbalist* (Jerusalem, 1998), 215–31.

[91] See *Sefer ha-Bahir*, §171–75.

The *Zohar* clearly expresses the connection between the symbol in the supernal world and the action of the lower: "Some of them are connected with the Holy Name, such as *lulav*, etrog, myrtle, and willow, all are linked with his Holy Name above. So we must grasp them and perform an action with them, in order to arouse the one linked with them."[92] Closely following and influenced by this was Recanati,[93] who preferred to rely on a dream,[94] which many viewed as a reliable source and therefore served as adequate proof. He was joined by *Sefer ha-Peliah*, which was written in Byzantium at the end of the fourteenth century.

R. David ben Yehuda He-Hasid, an early fourteenth-century kabbalist, also spoke of the requirement to attach them, and he also employed the term *yihud* (unification) and others like it. These are his words:

> If you say, "why is the etrog not bound with the other species in one bind," one could say… for she needs the others because she does not have her own light, and regarding this matter she is not included in the bind of the *sefirot*, but with regard to the *yihud* she is included… therefore one who takes the etrog when he shakes it he must affix the etrog to the *lulav* to demonstrate the bind of faith and the supernal *zivug* (union).[95]

This kabbalist's importance lies also in the fact that he traveled to North Africa and apparently influenced a number of sixteenth- and seventeenth-century kabbalists in Morocco who shared a uniform style. For example, R. Yosef Al-Ashkar,[96] Moshe Elbaz,[97] Abraham Adrutiel,[98] and Isaac ha-Kohen,[99] followed closely by Ya'akov Ifergan.[100]

This idea was not confined to North Africa. R. David ben Zimra, one of the great Egyptian rabbis who had literary links to North Africa, writes in the name of

92 *Zohar*, Prizker ed. (Stanford: Stanford University Press, 2016), I, 220b, vol. VIII:176. And even more in the sentence that follows it that is phrased like a principle: "Concerning this we have learned: By word and deed, one must demonstrate to matter, so as to arouse another matter." Cf. also *Zohar* II, 125b (vol. V, 173): "For the matter depends on action, an action below arousing above," and more like this.

93 Menahem Recanati, *Perush al ha-Torah* (Lemberg, 1880), section *Emor*, 67d. On the dream, see below.

94 Later on, in Abraham Klausner, *Sefer Minhagim* (Jerusalem, 1978), 49, the dream story is related in an explanatory note (seemingly by Klausner), stating that one should join the etrog to the *lulav*. This source is of interest because, up to the present, I have no other Ashkenazi source that requires binding.

95 David ben Yehuda He-Hasid, *Or Zarua*, MS JTS 2203 (F 11,301), 90b; MS BL 771 (F 5454), 91b. And see his words in his book, David ben Yehuda He-Hasid, *Mar'ot ha-Zove'ot*, 95–96.

96 Yosef Al-Ashkar, *Zafenat Pa'ane'ah*, MS Jerusalem 4 154, 45b.

97 Moshe Elbaz, *Heikhal ha-Kodesh* (Amsterdam, 1653), 75a.

98 Abraham Adrutiel, *Avnei Zikkaron*, MS JTS 1746 (F 10,844), 110b.

99 Abraham ben Isaac ha-Kohen, *Ginat Bitan*, ed. Moshe Hallamish (Lod, 1998), 51, 67, 82, 83.

100 Ya'akov Ifergan, *Minha Hadasha*, ed. Moshe Hallamish (Lod, 2002), 523 (MS Liverpool M12044 [F 14584], 497b).

Recanati: "One must join the etrog and *lulav* and lead and bring with both hands to unify the four-letter name. *And this is the custom of the Musta'arav*."[101]

In any case, in the fifteenth and sixteenth centuries, the requirement to attach is stated explicitly in works of *halakhah* such as: Jacob Weil's *Responsa*, no. 191; *Beit Yosef*; *Shulkhan Arukh*, no. 651 s"k 11 (and R. Moshe Isserles did not comment on it!); *Zekan Aharon Responsa*, and more. The overwhelming majority of these relied on Recanati, and seemingly followed *Beit Yosef*:

> R. Menahem from Recanat (the Recanati) wrote in the *Emor* section: The etrog should be fixed with the rest of the species so as not to separate from the *binyan*. This secret was revealed to me in a dream on the first night of *yom tov* of Sukkot, while I was lodging with an Ashkenazi hassid by the name of R. Isaac, and I saw in a dream that he was writing the name yu"d he"h and was distancing the last he"h from the first three letters. I said to him: "What have you done?" and he replied: "this is the custom in our place." I protested and wrote it whole, and I was astonished at the sight, and I could not understand. The following day, while taking the *lulav*, I saw that he was shaking the *lulav* only with the species, and without the etrog, and suddenly I understood the meaning of my dream and he changed his mind.[102]

It is safe to assume that R. Yosef Karo's decision was what influenced the wide reception of this ruling.

It appears that Lurianic Kabbalah contributed to it as well. R. Hayyim Vital speaks of "the *prohibition* of separating the etrog from the *lulav* when taking it," relying on the dream brought by Recanati.[103] Articulated elsewhere[104]: "One must not separate the etrog at all from the *lulav*, but rather have both hands close together joining the *lulav* and etrog together."[105] Beginning at the end of the sixteenth century, all kabbalists require binding. These sources, with the addition of R. Yosef Karo, suffice to explain the broad acceptance of this custom by the public.[106]

I will conclude with the words of a kabbalist from the generation of the expulsion, who lived in Constantinople: "The etrog must be connected to the *lulav* while shaking, and he who decries this will be judged, for all our actions must be in the supernal

[101] David ben Zimra, *Shut ha-RaDBaZ (Responsa)* (Jerusalem, 1882), *responsa*, IV, *Alef*, 328 (257). In another place, he notes: "And I am careful that my fingers do not separate the *lulav* and the etrog" (idem, *Metzudat David*, *mitzvah* 118, 23c).

[102] The words of the *Beit Yosef*, *Orah Hayyim*, no. 651. And see Nahman Kahana, *Orhot Hayyim* (Jerusalem, 1962), on the Tur, 149a, s"k 27. Hayyim of Volozhyn, *Keter Rosh* (Jerusalem, 2017), no. 108, relied also on the acronym *EELeH* (Let me climb) [=Etrog, *Arava*, *Lulav*, *Hadas*] *be-tamar* (the palm).

[103] Hayyim Vital, *Sha'ar ha-Kavvanot* (Jerusalem, 1902), 105c.

[104] Idem, *Peri Etz Hayyim* (Koretz, 1785), *Sha'ar ha-Lulav*, ch. III, 129b.

[105] Vital, *Sha'ar ha-Kavvanot*, 23c. And see Immanuel Hai Ricchi, *Mishnat Hassidim* (Amsterdam, 1727), *Masekhet Yemei Mitzvah ve-Sukkah*, ch. 5, Mishna 2, 125b. See also *Petora de-Aba* (Jerusalem, 1905), II, s"k 58, 45c; *Shulkhan Arukh ha-Ari* (Jerusalem, 1961), 166: "The etrog should not be separated." And there is no room to elaborate further.

[106] Indeed, Isaac Yosef, *Yalkut Yosef*, *Mo'adim* (Jerusalem, 1988), 162, relies on *Beit Yosef* (Jerusalem, 1960) and the *Sha'ar ha-Kavvanot*.

likeness for this is necessitated by the awesome wisdom."[107] Alongside this extreme ruling, we shall note a moderate position of a halakhic figure: "It must be connected, etc.—for a choice *mitzvah*, but according to the law there is no need to join them together."[108]

We briefly discussed various aspects of the Talmudic literature, the *aggada*, and the *halakhah.* Some of them were employed by the kabbalists for the expansion of ideals, and some brought with them various practical and moral conclusions. The requirement to grasp together the four species in the hands of the one making the blessing became well known, as it was viewed as a symbol and reflection of the value of unity. It is likely that you would be hard pressed to find a single person who opposes this kabbalistic ruling, which has become common practice.

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[107] Meir ibn Gabbai, *Tola'at Ya'akov*, *Sod Arba'a Minim* (Warsaw, 1876), 41d. This entire chapter is a kind of adaptation and summary of the previous kabbalists.

[108] *Eliya Rabbah*, no. 651 s"k 29, in the name of the Bah (Joel Sirkis).

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Chapter 17
From 'an Etrog' to 'One's Etrog': A Literary Analysis of S. Y. Agnon's Story

Yehudith Bar-Yesha Gershovitz

Abstract This chapter discusses the two strata—the obvious and the subtle—at which S.Y. Agnon's short story, "The Tzaddik's Etrog" may be read and understood. At the obvious level, Agnon describes a person who wishes to observe the halakhic injunction concerning the "Four Species" with extreme piety, paying careful attention to the excellence of the etrog. But upon arriving home with his precious etrog, the fruit accidentally falls on the ground, and thereby is no longer fit to be used to fulfill the law of the "Four Species." At the deeper, hidden level, the reader becomes aware of the double meaning of the purchase of an expensive etrog. By making this purchase, the tzaddik (righteous man) places his costly citron above all human needs and completely ignores his commitments to his wife and family. By reading Agnon's story at these two levels, the etrog is transformed from a botanical object used for a religious ritual into a symbol of a set of values that illuminates the priorities one must set in making crucial decisions during a lifetime.

17.1 Introduction

The origin and foundation of the genre of the "hassidic tale" coincides with the emergence of the "Ba'al Shem Tov," R. Israel son of Eliezer and Sarah, who lived in Podolia (then a district in the southern kingdom of Poland, now in central Ukraine) between 1700 and 1760. The Ba'al Shem Tov himself did not write stories, but he told them to his followers as a supplementary tool to explicate his religious path. His stories were collected in 1815, about fifty years after his passing.

The stories have two main roles:

1. *As hagiography*, the purpose of which is to glorify the tzaddik, the leader of the community, as a unique personality who views his leadership methods as derived

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from his power to influence its fate and to redeem it from daily hardships. The community sees the tzaddik as the messenger of the Holy One Blessed be He, and his stories strengthen its faith in Him, its way of life as a community which maintains its existence in the conditions of exile with all of its implications, and its dependence on hidden powers that exist within the tzaddik for its salvation as a community and as individuals.

2. *Disseminating the Ba'al Shem Tov's teachings while making them accessible to those studying in the beit midrash and to laypeople alike.* As an educational tool, the story has its own power to strengthen their faith in all of the above. By understanding the souls and abilities of his followers, the Ba'al Shem Tov succeeded in transmitting his teachings to each person according to their way—whether in person or via later writings. There were few during his lifetime who studied, as most were concerned with their livelihood. Thus, the stories' lessons pierced the hearts of both the common audience and the minds of the students learning his teachings in the beit midrash [study hall].

Following the Ba'al Shem Tov, the hassidic movement in its various manifestations and forms adopted the hassidic story as a regular method in delivering hassidic teachings. Hassidism never considered the story as a work of art, but rather only as an extension of the holy texts. With the arrival of *Shivhei ha-Besht* (*In Praise of the Ba'al Shem Tov*), the stories reached other hassidic communities and were exposed to the critique of Yiddish readers. The Hebrew (or Yiddish) literature critics who discussed this genre of writing were critical not only of the style of writing, but primarily of the content of the stories. (Best-known among them is Joseph Perl who wrote *Megaleh Temirim* [*Revealer of the Secrets*] in 1819, which became a symbol for the struggles of the Haskala movement against the hassidic movement). Today, the hassidic story stands on the bookshelf as the preferred genre for every lover of stories and for the literary critic.

Agnon, whose story "The Tzaddik's Etrog" appears below, gave the Ba'al Shem Tov's tales a modern design, presenting a different understanding of their morals and rendering them universal and relevant to anyone regardless of religion, faith, and worldview, in any time and place.

17.2 Between the Etrog and '*Etrogo*': A Study of S. Y. Agnon's Story

It was within the narrative framework surrounding a particular tale transmitted through the generations in a hassidic community that Agnon wrote his story "*Etrogo shel oto tzaddik*"—"The Tzaddik's Etrog." The storyteller knows that the tale he is about to record was passed from one hassid to another and from a man to his household. It was in this way that it reached the author, who, knowing that each storyteller before him recounted it in his own way out of a desire to make it more pleasing to his audience, took his own literary liberties. Exercising his own artistic creativity, Agnon tells his story to the audience and ends it with the words: "It is worthwhile to hear this tale twice."[1] This sentence establishes the difference between the etrog and *etrogo* for the reader.

The etrog is a citrus fruit, a scientific species with different strains, and is defined by genetics and botany. The scientific terminology is subject to change according to changes in nature, historical evidence, the genetic makeup of the species, and continuing study. For this reason, the scientific specification of the etrog should be treated as an emerging study as evidence accumulates for continued consideration.

"And you shall take for yourselves on the first day the fruit of beautiful trees, branches of palm trees, the boughs of leafy trees, and willows of the brook" (Lev. 23:40), states the scriptural verse. It does not only say "and you shall take," which already contains the essential commandment itself, but rather continues with the added "for yourselves," valuable in that it instills the object with its belonging to a particular being.

The same is true of the *etrogo* in the title of the story, where the pronominal suffix instills the etrog with belonging, or being owned. This etrog may have been purchased, planted in a garden, or given as a gift, and thus does not resemble any other etrog past or present, and its uniqueness is in belonging to a particular individual. As such, in our story it has a unique significance distinguishing it from the scientifically defined botanical etrog mentioned above.

The event, originally recounted by R. Michel, the Maggid of Zlotchev's daughter-in-law, is transformed by Agnon from an account into a fable. It was thus removed from the context of a historical anecdote concerning the holy Maggid of Zlotchev—as his hassidim called him—and transposed into the realm of literature. And because the life story of every person is a proverb for anyone who takes an interest in him or her, the meaning of that "fabled etrog" becomes the "*etrogo*" of every listener and reader who can imbue it with personal significance.

Thus, "it is worthwhile to hear this tale twice": the first understanding pertains to the historical significance of transmitting family-testified events with the closest possible precision—and this is the meaning that the Maggid ascribes to his etrog. The second is the meaning that the reader will attribute to it according to his or her own worldview. Thus, the "scientific etrog," which is of interest to many authors of this present work, is transformed into an etrog that serves as a symbol which forms an existential reality that is not necessarily a historical truth, but may hold meaning for any person, at any time, and in any place.

The Maggid of Zlotchev was a pauper "unconcerned with his own needs but with the needs of the *Shekhinah* [the Divine spirit], which are the Torah, prayer, and good deeds." His wife, who "knew the soul of her righteous husband," managed the sparse household, taking great care not to disturb her husband with such matters "so that he should not desist from his holy work." One must note the author's irony which accompanies the story in its entirety, by considering the verse upon which this description is based: "The righteous man knows the life/soul [*nefesh*] of his

[1] Unless otherwise stated, all the quotes are from the story, "The Tzaddik's Etrog," in S.Y. Agnon, *The Fire and the Trees* (Jerusalem: Schocken, 1974), 115–16. Emphases are by the article's author.

animal" (Prov. 12:10) That is to say, the righteous one knows the soul of the other (an animal or a person likened to one). But here, the soul revealed to the other is the one called "righteous," while the sensitive wife who is so considerate of her husband is symbolized according to the scriptural parallel in the verse by referring to the inferiority of an animal.

Similar circumstances are found in the words of R. Akiva, who, upon returning from twenty-four years of study during which he was uninterruptedly dedicated to his holy work, encounters his wife: "When she went out to meet him she wore tatters; her friends said to her, 'Borrow pleasant garments and get dressed and go out to him.' She responded, 'The righteous man knows the *nefesh* of his animal.'"[2] Rabbi Akiva's wife's character in this midrash illuminates the wife of the Maggid in two ways. (Both are unnamed by the narrator. As such, they serve as representative characters, and it is important to see them in this way). First: both know their husband's soul well. Second: both diminish this knowledge which strengthens their personalities for the benefit of elevating the status of their husbands. Agnon, who employed older Hebrew literary foundations, did this with the purpose of saying something about the characters he was writing about. Thus, it appears that Agnon, in his ironic way, presented matters such that in his eyes the ones the "righteous man knows," referenced in this story and in the story of R. Akiva, are the women, placing the woman above her husband. This will be elaborated on below.

17.3 The Story

Once, on the eve of Sukkot, the wife of the Maggid dared to stand at the doorway to his room and inform him that she still did not have the means to purchase the holiday necessities. The Maggid reproached her in his response, saying, "You are concerned with the fish and meat, while I am concerned with the etrog that I lack." The wife left his room "disappointed."

This is their first dialogue that continues throughout the story, establishing their differing needs surrounding the general situation that the family finds itself in on the eve of the festival. The wife is concerned with her family, and the Maggid is concerned with himself. The word "*me*" becomes a central motif in the ongoing dialogue. This divergence can be broadened when taking into consideration that the festival of Sukkot is the only one of the three holidays regarding which there is a commandment: "You shall observe the Feast of Tabernacles seven days, when you have gathered from your threshing floor and from your winepress. *And you shall rejoice in your feast*,[3] you and your son and your daughter, your male servant and your female servant and the Levite, the stranger and the fatherless and the widow, who are within your gates" (Deut. 16:13–14) From the wife's perspective, the commandment emphasizes the joy of the entire family.

[2] *Masekhtot ketanot*, *Masekhet avot de-rabbi Natan*, second addition to the first version, ch. 8.

[3] The emphases in the verses are all mine.

Upon his wife's exit, the Maggid's thoughts turn to contemplating how he will purchase an etrog for himself. In his contemplations, the possibility occurs to him of selling his phylacteries which were considered very valuable because "a holy man of God scribed them." He justifies the idea of this unusual sale by reasoning that during the nine days of the festival, one is forbidden to wear phylacteries anyway.[4] The Maggid does not concern himself with the days following the festival when he will need his phylacteries for the rest of the year. He takes his phylacteries, goes to the beit midrash, and sells them for a gold dinar. He then runs off to the etrog seller and chooses a handsome etrog which he found to be "kosher and beautiful," and pays for it with the gold dinar. He cheerfully goes home, finishes building the sukkah, and returns "to *his* room of seclusion." There, he ponders the uniqueness of the festival of Sukkot that "God adorned with many commandments."

Someone apparently informed "his wife, the rebbetzin" that the Maggid was in the market, and she again permitted herself to enter his room. Seeing the tremendous joy on his face, she said, "You must have brought *us* all of our festival necessities," and added that "the day is turning and going." The Maggid stood up from his chair and covered his eyes with his hands, blessing his creator for "meriting *me* with his grace and giving *me* all that *I* was lacking."

The rebbetzin, who understood from these words that he included herself and her children in these words, waited for him to give her the goods that she assumed he had brought, while he "went back to sitting and told her that he merited a kosher etrog." She responded, astonished, "From whence did you have coins to purchase an etrog *for yourself*?" He told her how he sold his phylacteries and "bought *myself* the etrog," to which she responded by requesting that he "give *me* the change."

This is one of the continuously intensifying climatic peaks of the story. At this point, the reader already knows that all the money was handed over in return for the etrog. The reader also knows that it was a lot of money, and he can imagine—already before the wife—the terrible upheaval about to occur. The Maggid's wife does not yet know what is awaiting her. This gap between the reader's knowledge and the wife's delayed understanding intensifies the storm of profound pain that is waiting to overwhelm her at any moment.

The Maggid, unable to comprehend her question which expressed her great astonishment at his actions, responded as though it was self-evident: "*I* was not given change, all the money that was given to *me* in my prayer *I* gave for *my* etrog." He then began exalting the virtues of the etrog with great enthusiasm.

This is the first instance in their loaded dialogue where she uses the word "*me*"—the only time in this entire exchange when she demands: "give me." And although it is expressed using simple words, without overtones of pain, disappointment, or anger, her cry, the sigh of misunderstanding, and her great sadness can be heard in that single word "*me*," which establishes all that she lacks in contrast to the Maggid's great fullness in his joy allotted to him by his God.

[4] Outside of the land of Israel, because due to the "second day of holiday in Diaspora" the number of the days of the festival are nine and not eight as they are in Israel.

Their dialogue is like two parallel lines that do not meet. He does not comprehend her needs, and she does not comprehend his elevated spirit on the eve of the festival when they lack all the basic festival necessities for the household. She understands the need for an etrog, but cannot understand why the Maggid did not divide his money between their physical needs and his spiritual ones. In his joy, he misinterprets the reason for her entering his room, and wishes to share his joy in the beautiful etrog with her. She restrains herself from crying before him, but does not understand why he fails to see her misery and the misery of her children.

At this point in the story the etrog symbolizes the entirety of the various elements of their relationship, as well as the unbridgeable gap in their essential understandings of these different elements. The etrog is "his etrog"—that of the Maggid alone, who views it as one of the elements of the spiritual world without which life is not worth living. The rebbetzin views the etrog as only one aspect of life which is "the Torah," but knows that it must be joined with the same devotion to the aspect of "flour," without which her life and her children's lives are not livable.

The Maggid's wife restrained herself from crying so as not to disturb his joy, perhaps because she understood that her tears would be futile, and said, "I want to see the bargain you found." The Maggid mistakenly thought that she wished to join in his happiness and removed the etrog from its wrappings. Here, the author writes, "Its beauty shone and its good scent rose, a delight to the eyes and desirable to bless." This description is recounted by the "all-knowing narrator," who knows the thoughts of the characters in his story.

The reader must ask himself from which vantage point the narrator examines the description taken from the Tree of Knowledge in the Garden of Eden, as it is written: "When the woman saw that the tree was good for eating and a delight to the eyes, and that the tree was desirable as a source of wisdom, she took of its fruit and ate. She also gave some to her husband, and he ate" (Gen. 3:6) If we examine this verse from Genesis and compare it to the subsequent line in the story, "she outstretched her hand and took the etrog," we must conclude that these descriptions are intended from the perspective of the Maggid's wife, the reality unfolding before her eyes. Like Eve, who sees that the fruit is a delight to the eyes and "took of its fruit," she too "took the etrog."

The resemblance ends here. From this point, in contrast to Eve who took, ate, and gave some to her husband and they ate together, the wife of the Maggid took, "and remembered the sorrow of her children, who had *nothing* to eat, and now the holiday of Sukkot was upon them and she had *nothing* with which to make it joyful. Her hands collapsed in sorrow and the etrog dropped and *fell*. *Because* it fell, its *pitam* [blossom end] broke, and *because* its *pitam* broke, it was rendered *pasul* [disqualified for the mitzvah]." In their repetition, the three central words—"nothing," "fell," and "because"—intensify what transpired, and their presence in the passage is not unintentional. By repeating the words in the segment, the author emphasizes what is necessarily expected to transpire, as a series of dominos that knock each other over in an excited child's game. Or perhaps we should say that it resembles a turning wheel which is not controlled by any cause, but only moves from the initial push that perpetuated it.

It transpired thus: the woman remained in her emptiness, filled with sadness, and as a result she did not drop or let the etrog fall, rather "it fell," as though it was granted its own powers for "falling." After this, the author describes the chain of events which could not be stopped until it arrived at its final predestined end. Thus, the repeated word "because" creates the feeling of necessity that everything that is caused creates a necessary result: was dropped [*nishmat*], fell [*nafal*], broke [*nishbar*], rendered *pasul* [*nifsal*]. All are passive verbs, the "*nif'al*" conjugation; and the passive is inactive. Or perhaps the necessary damaging of "the etrog of that *tzaddik*" can only be attributed to God, whom the Maggid thanked: "Lauded is the name of God, may he be blessed and elevated, that he merited me in his grace and gave me all that I was lacking."

This moment, the women's emptiness in her inability to provide her home with anything for the joy of the festival, is equal to the Maggid's emptiness in his lack of joy in his now-worthless etrog. If the story had ended here, we would have been able to say that this story is one with a moral of *midah ke-neged middah* (measure for measure). By the same measure meted out by the Maggid for his family, leaving them with "absence," God measured for him the same "nothing" in his festival joy. He who prevented the joy of the festival from his family saw his own joy upended.

Yet the story does not end here, and Agnon concludes with the words of the tzaddik examining what had transpired while pondering what to do, and so "he spread out the palms of his hands in despair and said: 'I have *no* phylacteries, I have *no* etrog, I have *nothing* left but anger. But I shall *not* be angry, I shall *not* be angry.'" The two hands with which he enthusiastically held the etrog in all its brilliance and beauty now expressed a great despair. The repeating word "no"/"nothing"/(*ein*) is a testament to the great lack of the thing that was supposed to give him great joy. The repeating word "not" is also a testament to the lack of an emotional resilience to cope with his new reality. The Maggid's cry, "I have nothing left but anger" indicates that of all the tools that he had, beginning with his faith, his learnedness, and ending with his holiness, he has nothing but anger with which to cope with the forlorn reality that has befallen him.

Who is the Maggid angry at? At God, may He be blessed, who merited him with an etrog and took it away before he had blessed it? At his wife, whose great sadness made her helpless to the point that the strength left her hands, thus dropping the etrog so delightful to the eyes? It appears that neither one is the target of his anger. Rather, he himself renounces the anger that remained in him and prevents himself from using it, perhaps through observing the damaged etrog on the ground which to him symbolizes his failure in organizing the order of his world. For indeed, as in the beauty-filled tales of tragedy, it is not fate that brings down calamity upon man, but rather man himself, in his blindness to his fellow-man. The hubris that situated him at the center of his own existence carried him too far down his chosen path and guided him in a direction from which there was no rectification.

R. Michel, the Holy Maggid of Zlotchev, who viewed the beautification of the mitzvah of the etrog as the highest value and preferred it to his own household, withdrew in his glowing loneliness to the heights of his holiness. He was blind to the distraught living close by, and thus brought great despair upon himself. However, unlike the classic tragedies, in the end the Maggid succeeds in taking the reality of his life and turning it toward a path with an end in sight, the path without anger. In this hassidic tale, although everything appears predictable, choice is granted for a person to choose the correct path to walk on.

The narrator does not tell us if in the end there was an etrog for that festival of Sukkot, if family necessities were provided, or if there was great joy. This is not essential in a story in which the "tzaddik's etrog" served as the criterion for the behavior of a person concerned with his own needs and ignoring others. As for the rest—go and learn it.

So, what connection does "The Tzaddik's Etrog," the fable with a classic literary moral, have to the scientific etrog, with its taste and scent, that they should reside in tandem in the one book? It seems to me that each know that reality and imagination are intermixed both in the story and in science, and that both are worthy of different "readings" that complete each other in goodness and harmony.

Part IV
History

Chapter 18
The History of Citron: Botanical Remains and Ancient Art and Texts

Dafna Langgut

Abstract Citron (*Citrus medica*), which originated in the central Himalayan foothills, seems to have made its way from the South-East to the Near-East via Persia, and from the Eastern Mediterranean, it spread into the entire Mediterranean Basin and Europe. The first robust evidence of citron cultivation originates from Ramat-Rahel near Jerusalem, where fossil *C. medica* pollen grains were found in a Royal Persian garden dated to the fifth-fourth centuries BCE. The citron was probably brought from the Iranian-Plateau to flaunt the power of the imperial Persian administration. Theophrastus's writings corroborate that by the fourth century BCE, the citron was already well established in Persia and Medea. ISince the third century BCE, citron remains were also found in relation to prestigious gardens in Rome and Pompeii. This elite product slowly penetrated into Judaism. Based on the textual evidence and the appearance on coins, it seems that the citron became a fixed element in the feast of Sukkot in the first century AD.

18.1 Introduction

The area of origin of citron (*Citrus medica*), like all other citrus forms, lies in South East Asia. More specifically, citron originated in central Himalayan foothills, where it was most probably first brought under domestication (Weisskopf and Fuller 2013). In a recent study conducted by Langgut (2017a), the westward migration route of citron was traced by using three lines of evidence: (i) micro and macro archaeobotanical remains; (ii) ancient texts; and (iii) ancient art artifacts (wall reliefs, coins, mosaics). In the case of the archaeo-botanical remains, the validity of some of the remnants is questionable because of several limitations such as identification issues and the archaeological contexts where the remains were found (mainly uncertainties relating to stratigraphy and/or chronology). This article summarizes all relevant information related to the history of citron in the land of Israel, the Near East and the

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Mediterranean Basin. Additionally, this study will show that citron was introduced into the Near East as an elite product (rather than a cash crop) and that it gradually penetrated the Jewish culture and tradition.

18.2 Archaeo-Botanical Evidence

Citrus seeds dating to the Sumerian period (4,000 years BCE) were revealed in Nippur archaeological excavation, in the south of Babylonia (Bonavia 1894). Since the seeds found in the excavation were charred, they can only be identified as *Citrus*, and specific species cannot be determined. Tolkowsky (1966) pointed out that the period to which these seeds belong cannot be precisely dated. Furthermore, he emphasized that their presence in Nippur does not necessarily indicate that the tree from which they came was cultivated in Babylonia at the time. If the citron tree had grown there on a limited scale in ancient times, Tolkowsky believed that it would have become a common tree during Alexander the Great's conquest in the late fourth century BCE. The Greek botanists accompanying Alexander reported that the citron was grown only in Persia and Media (described in Theophrastus's book, "Enquiry into Plants", *ca.* 310 BCE). Tolkowsky, therefore, found the evidence from Nippur to be inconclusive; however, he claimed that if these seed assemblages were identified correctly, they were probably citron seeds brought to Nippur either as an offering to divinity or as a gift to a king. Since the seeds were not directly dated, their age being assessed only by their archaeological context which seems to be insecure, and since recent investigations show that citrus seeds' identification requires advanced identification methods (Coubray et al. 2010; Pagnoux et al. 2013), which were not available at that time, it is, therefore, possible that the seeds were misidentified. This is also the case with the seeds which were recovered from the archaeological site Hala Sultan Tekke (Cyprus), where seeds resembling *Citrus* were discovered in a layer dated to the twelfth century BCE. However, the exact species could not be identified (Hjelmqvist 1979). Thus, these remains have not yet been directly dated to confirm their antiquity (e.g., by accelerator mass spectrometry radiocarbon dating; Zohary et al. 2012). Furthermore, those seeds are from an insecure archaeological context since they were found in an unsealed stratum. Since the remains could not be found, the attempts to re-examine the seeds assemblage were unfortunately not successful (David Moster, personal communication).

Even if we accept the indefinite identifications and inconclusive dating and context of the remains from Nippur and Cyprus, the presence of citrus seeds can only indicate that the fruit was imported, but this is not necessarily proof that it was grown locally. Indeed, it appears that the citron was considered a valuable commodity since antiquity due to its healing qualities, symbolic use and pleasant smell on the one hand, and its rarity on the other (e.g., Zohary et al. 2012), possibly making the citron known to the people in the region by reputation. Liran (2013) reached a similar conclusion, suggesting that the citron was grown by the wealthy and represented the rich as it was a rare commodity that only they could afford. Also, citron, unlike other citrus species can be preserved for months due to its thick albedo and unlike other *Citrus* species, it is not an edible fruit.

New recently published pollen findings from a Persian Royal Garden adjacent to an extravagant palace excavated in Ramat Rahel site near Jerusalem (Israel) (Lipschits et al. 2012), shed new light on the earliest possible dating of the cultivation of *C. medica* in the Mediterranean (Langgut et al. 2013). While examining one of the plastered pools in the garden, dating to the fifth-fourth century BCE, fossilized *C. medica* pollen was identified. It had been trapped in one of the plaster layers (various structures within the garden were plastered in several layers, most probably due to ongoing maintenance). The unique palynological spectra extracted from this plaster layer included, in addition to *C. medica*, other palynological evidence of trees introduced from remote parts of the Persian empire (e.g., the cedar of Lebanonn and the Persian walnut), together with native fruit trees and various ornamentals such as myrtle, grapevine and common fig.

The next botanical evidence in chronological order derives from an area outside the Near East: within the sediment of the Punic port of Carthage (Tunis, North Africa), pollen from the level contemporary with the 4th/early third centuries was extracted. This palynological evidence suggesting early cultivation in Carthage (van Zeist et al. 2001).

The occurrence of both pollen and citron seeds remains in several sites throughout the Mediterranean dated to the Roman period, attests that by that time citron was well known in the region. Seeds assemblages from secure contexts were retrieved from Roman quarry settlements in Egyptian remote desert locations (van-der Veen 2001; Van der Veen and Tabinor 2007; Bouchaud et al. 2017). Since the remains were desiccated, they were very well preserved. For example, in the Mons Porphyrites complex, citron seeds start to appear from the second century AD. In southern Italy relatively rich ensembles of both micro-and macro-botanical remains are available, starting to appear even before the Egyptian evidence: during the 3rd/second centuries BCE (Grüger and Thulin 1998; Mariotti-Lippi 2000; Grüger et al. 2002; Jashemski et al. 2002; Ciaraldi 2007; Fiorentino and Marinò 2008; Russo-Ermolli and Messager 2013; Russo-Ermolli et al. 2014). In most cases, the remnants were recovered from high-class gardens owned by the affluent. The palynological evidence from southern Italy shows that *C. medica* was the first *Citrus* species that migrated to the west, probably via the Near East, and that lemon (*C. limon*) was the second to arrive (Russo-Ermolli et al. 2017).

18.3 The Citron in the Hebrew Bible and Jewish Tradition

The verse in Leviticus 23:40 instructing the holding of the four species over the feast of Tabernacles ("*And ye shall take you on the first day the fruit of goodly tree, branches of palm trees, and the boughs of thick trees, and willows of the brook; and ye shall rejoice before the Lord your God seven days*") refers to two known species (willow and palm), however, researchers are finding it difficult to determine whether "*the fruit of goodly tree*" and "*boughs of thick trees*" refer to specific species or can be summarized as general instructions. The word "*hädär*" ("goodly") mentioned in Leviticus does not necessarily point to a tree. It may be also a noun with the meaning of "glory" or "grandeur", which is typical to the poetry and prophecy in the Hebrew Bible.

As for the "*fruit of goodly tree*", the Septuagint (third century BCE) determined the phrase consists of a noun referring to a grand and delightful fruit. This appears to be the intention in Leviticus 27:30 and in Nehemiah 10:36, where the verses do not refer to any specific kind of tree. The phrase "*fruit of goodly tree*" is not mentioned in the description on the feast of Tabernacles in Nehemiah 8:13–15 where five different species are mentioned. Within the description in the Books of the Maccabees 2 10:6–7 there is no mention of "*the fruit of goodly tree*", but rather "*ivy-wreathed wands and beautiful branches and also fronds of palm*" (Schwartz 2005).

Since the first century AD there is a significant change in texts in which the four species mentioned in Leviticus 23:40 are defined: palm, willow, myrtle and citron. In Antiquities of the Jews 13 13:5 372; (late first century AD), Flavius Josephus describes how the Jews threw citrons at Alexander Jannaeus for disrespecting the libation ritual (compare to Mishna tractate Sukkah 4:9). The documents from the days of Chazal indicate that the citron was fully accepted as part of the holiday tradition with no mention of any kind of objection (Amar 2012: 108–109). Therefore, it seems that before the days of Chazal other traditions were not practiced. A survey of the Jewish written sources of citron was published a few years ago by Langgut (2015).

18.4 The Citron in Greco-Roman Sources

According to Tolkowsky (1966), the first textual evidence where the citron was probably mentioned, comes from the play—the Beotias, written by Antiphanes (408–334 BCE). Only a short part of this play survived by mentioning it several centuries later in the *Deipnosophistae* ("dinner-table philosophers"), which was written by Athenaeus in the early third century AD. The citron is not mentioned by name—only good-looking and very delicious apples are described as part of a delivery from the Persian Ruler; it is explained as a unique fruit, very rare and therefore very expensive.

Fifty years later (ca. 310 BCE), a much more reliable written source is available when a precise description of the citron is given by Theophrastus in his book *Enquiry into Plants*:

> …And in general the lands of the East and South appear to have peculiar plants, as they have peculiar animals; for instance, Media and Persia have, among many others, that which is called the 'Median' or 'Persian apple'. This tree has a leaf-like to and almost identical with that of the Arbutus, but it has thorns like those of the pear or white-thorn, which however are smooth and very sharp and strong. The 'apple' is not eaten, but it is very fragrant, as also is the leaf of the tree. And if the 'apple' is placed among clothes, it keeps them from being

moth-eaten. It is also useful when one has drunk deadly poison; for being given in wine it upsets the stomach and brings up the poison….

The text goes on giving exact instructions on how to grow the tree along with two key observations: the first being the tree's unique quality of bearing fruit during several seasons—making the citron tree a symbol of eternal spring, fertility and inspiring many poets and artists (this means that new fruit may grow on the same tree alongside fruit that grew during the previous year). The second observation has to do with the tree's flowers having a prominent pistil, making them more fertile as opposed to other flowers found to be sterile. From a different piece written by Theophrastus, it appears that the discovery of sterile flowers with no pedicle was first made by Persian gardeners, who informed the Greek botanists. However, they and perhaps Theophrastus himself first recognized this trait's significance in identification (Tolkowsky 1966). The pedicle of the citron develops from the style and the stigma. In other *Citrus* species, this part degenerates whereas in the citron it develops into a pedicle (Felix 1987). Nowadays some citrons no longer produce pedicles due to cross-breeding with other *Citrus* types. In isolated, faraway places, where other species of *Citrus* are not grown, all citrons grow a pedicle (for further discussions on the topic of the pedicle see: Felix 1994). The *Arbutus* mentioned in Theophrastus's text is related to the eastern strawberry tree—*Arbutus andrachne*. Tolkowsky (1966) holds that the description of the citron leaf as having a round base and a pointed end much like the arbutus eliminates any intent to perhaps refer to a different *Citrus* since they all have either winged petioles or very narrow chisel-shaped leaves. The pear within this text is related to the wild Syrian pear—*Pyrus syriaca*.

Scholars argue that Theophrastus emphasizing that the tree grew in Media and Persia is further evidence that before *ca.* 300 years BCE the citron was not widely cultivated outside Media and Persia (e.g., Tolkowsky 1966). Theophrastus's descriptions in "Enquiry into Plants" are based on observations by several Greek scholars who accompanied Alexander the Great and his army on all their campaigns and conquests through Asia Minor, Syria, Israel, Egypt, and Persia and even reached the region that is today's Pakistan. Around 310 BCE, Theophrastus published his book "Enquiry into Plants" including the observations of those accompanying Alexander the Great in his journeys. If so, they passed twice through the area west of Persia and did not mention observing the growing of citron trees. This leads to the conclusion that the citron tree was limited to the Iranian plateau and had not yet been cultivated west of there. On the other hand, Theophrastus was not describing the fruit itself, but rather its characteristics that may suggest the citron fruit was known to the Greeks. In approximately 35 BCE the citron was still described as an exotic fruit: the Roman author and poet Virgil mentions the citron as antitoxic and having scented oil. He names the citron the "Median Apple". A complete survey of the Greco-Roman written sources of citron (and other citrus species) can be found in Pagnoux (2017).

18.5 Ancient Art Artifacts

Citron fruits appear in the following Near Eastern ancient artifacts: reliefs, coins and mosaics. The main problems lie with the association of the citron's early appearance on those artifacts in terms of: (i) presence's significance; and (ii) identification.

The appearance of citrus on ancient art artifacts does not necessarily point to authentic cultivation but can suggest familiarity with citron (rather than growing in a certain region).

Citrus identification is mainly doubtful in the case of wall reliefs. Several suggestions were previously raised to connect fruits evident on ancient Near Eastern reliefs to citron. For example, the French archaeologist Loret (1891), claimed that at the Karnak Temple, Egypt, which was built in the time of Thutmosis III (1,490–1,450 years BCE), citrons are evident in the relief. Another example originates from an Assyrian relief where cone-shaped objects held by figures were suggested by Bonavia (1894) to be citrons. In my opinion, it is impossible to clearly define what was depicted in those two reliefs. Other scholars reached the same conclusions when they failed to find a clear connection between the reliefs and the citron (e.g., Andrews 1961; Tolkowsky 1966; Amar 2009).

More robust evidence derives from first century AD coins where the citron appears alongside the palm branch on coins of the 4th year of the Great Jewish Revolt (69–70 AD). Several decades later, the citron was coined again, in the days of Simon bar Kokhba (132–136 AD), together with the other three species which are used in the Feast of Tabernacles; citron also appears on oil lamps which were found in ancient Israel, dated to the same period (Sussman 1972). These artifacts corroborate the textual evidence which indicates that by the first century AD the citron was a fixed element in the feast of Tabernacles. Later, citrons are seen in the Dura-Europos synagogue wall paintings in Syria (before 256 AD) in the decoration above the Torah niche (Kraeling 1956). From the fourth century AD, during the Byzantine era, citron appears not only in synagogue mosaic pavements, lintels and screens but also in many Christian mosaics in Israel and Jordan (see review by Ben-Sasson 2012).

It is interesting to note that in some of these Byzantine mosaics the citron fruits appear with "thin hips"; according to Bar-Joseph (1996), it shows malformation symptoms similar to those caused by viroid infection. Similar symptoms were also present on the Bar Kokhba coins mentioned above, dated to the second century AD. These findings indicate, with a reasonable conviction, cases of CVD (Citrus Viroid Disease) infections in citrus trees growing in the Near East almost two millennia ago (Bar-Joseph 1996).

18.6 Summary

Citron which has originated in the central Himalayan foothills, seems to have made its way from the South East to the Near East via Persia, and from the Eastern Mediterranean, it spread into the entire Mediterranean Basin and Europe. The first robust evidence of citron cultivation originates from Ramat Rahel near Jerusalem, where fossil *C. medica* pollen grains were found in a Royal Persian garden dated to the fifth-fourth centuries BCE. The citron was probably brought from the Iranian Plateau to flaunt the power of the imperial Persian administration. Theophrastus's writings corroborate that by the fourth century BCE, citron was already well established in Persia and Media. In later periods, citron remains were also found in relation to prestigious gardens, representing the rich, as it was a rare plant that only they could afford. It is therefore suggested here that the spread of citron, a non-edible fruit, was helped more by its representation of high social status, its significance in religion and magical features (e.g., healing qualities), rather than by its culinary qualities.

Two unique features may explain why the citron was the first citrus crop to migrate westwards: (i) citron originated in the westernmost area in comparison to other citrus species; and (ii) citron, unlike other citrus species, can be preserved for months due to its very thick albedo, resulting in a relatively long shelf life. It was therefore possible to use the citron in antiquity as a long-distance trading product. The suggested route of diffusion: central Himalayan–Persia–ancient Israel, lies on the same latitude range and therefore while being grown along this route, *C. medica* benefited from similarities in day length and seasonal cycles that encouraged its diffusion and success in the new regions of cultivation.

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Chapter 19
The Etrog Citron Trail to the North: Genoa and Trieste

Shimon Schwarzfuchs

Abstract Medieval Jewish communities in Europe always experienced great difficulty in organizing a regular supply of etrog citron fruits (etrogim), which were an essential element of the Sukkot holiday (the feast of Tabernacles) ritual. Etrog citrons are very sensitive and can be grown in warm regions only. The period of time between fruit ripening and the Sukkot holiday is very short and the etrog citrons are of no use when they arrive late to market. There was, moreover, the grafting problem, which became more widespread in an effort to strengthen the etrog and improve its appearance. The European Jewish communities were obliged to organize a procedure which would ensure a regular supply of etrogim. This chapter will attempt to describe how the etrog supply system functioned in transporting from the warm regions surrounding the Mediterranean sea, i.e., from the Italian Riviera, the island of Corfu and neighboring areas, and from the Holy Land to the ports of Genoa and Trieste, both of which played pivotal roles in these shipment routes. The organization overseeing the etrog supply was active until the end of the nineteenth century when new transportation possibilities made it superfluous.

During the seven days of Sukkot, Jews are commanded to take four species—a citron (etrog), a date palm frond (*lulav*), myrtle boughs (*hadassim*), and willow branches (*aravot*)—to hold them together and shake them. These species were always available in Israel and other hot lands, and it was easy to perform this commandment, but in other countries it was problematic. The only one of the Four Species to grow in their areas was the willow, while the myrtle, etrog, and palm tree did not grow in many regions. Yet, despite the difficulties, Jews across the world performed this

Places and regions mentioned in this chapter can be found in the map on placed in end of this chapter.

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commandment of taking the Four Species by importing them from other countries, especially the etrog (pl. etrogim).[1] ‘

Importing the etrog in time for Sukkot was not an easy task as the etrog is a seasonal fruit, delicate and extremely vulnerable and, worst of all, the etrog is totally worthless if it arrives after the festival! Even if the etrog arrives after the first day of Sukkot, it has lost much of its significance as the main commandment is to hold it on the first day. This is the source of the proverb, "There is nothing less practical than an etrog after Sukkot," referring to an item that is outdated and no longer relevant. Therefore, one thing is clear: this expensive and essential fruit must arrive before the holiday!

As it was not possible to buy and send the etrog before it was ripe, it could only be sent abroad from mid-September, allowing only a short timeframe in which to send the etrog to the whole of Europe, including remote areas in Russia. This required a large transportation network—the development of the train service during the Industrial Revolution in the 1800s solved most of these problems.

Since the previous year's etrog could not be used, it was necessary to reorganize every year, i.e., to buy and distribute fresh etrogim to all Jewish areas. Therefore, providing the etrog was more challenging than acquiring the other species which could be kept from one year to the next.

The etrog first appeared in Europe in 100 BCE in several areas in Italy.[2] It was grown in southern Italy's Apulia region and also in the northwestern Liguria, bordering the Ligurian Sea and near the French border. It is possible that the etrog was also grown during the Roman Empire in other regions with suitable climates, but its range certainly did not pass the Lake Garda district, which itself was an exception, as will be discussed later.

As the etrog is a weak tree, some farmers used to graft it on the stronger lemon rootstock, which gives the fruit a smoother and uniform appearance and a longer preservation time. Lemons are considerably easier to grow than etrogim, which led to the rapid spread of grafting attempts, but many rabbis ruled that these grafted

[1] Regarding the problem of the etrog citron, see Immanuel Löw, *Die Flora der Juden* (Vienna: W. Loewit Vertrag, 1924), vol. 3, 278–316; Samuel Tolkowsky, *Pri Etz Hadar* (Jerusalem: The Bialik Institute, 1966), 55, 142, 227–30; Rosanna Urbani, *Nuovi documenti sulla formazione della Nazione Ebrea nel Genovesato durante il XVII secolo*, Italia Judaica II (Rome: Ministerio per I beni culturali, 1986), 194–96; Guido N. Zazzu, *The Jews in Genoa*, I–II (Leiden: Brill, 1998–1999) and Mimma Figari, "Consedirazioni sullinsidiament ebraico-genovese (1600–1750)," in *Atti della Societa ligure di storia patria*, nuova serie, XXIX (Genoa: Ministerio per I beni culturali, 1989), 305–37. Regarding the growth of fruits in this region, see Antonella Ricci, *Frutti mediterreanei e grano del Baltico nel secolo*, La Storia dei Genovesi, VII (Genoa, 1987), 153–85 and Olandesi E. Mussa, "Gli agrumi nellestremo, Ponente Ligure (1110–1843)," *Rivista Ingauna e intemelia* (1985): 37–42. It is my pleasant duty to thank Rosanna Urbani for her significant help. This article is deeply indebted to her. I would also like to thank F. Fiandra, the director of Imperia's State archives, for her considerable assistance.

[2] See Tolkowsky, *Pri Etz Hadar*, 78–84.

etrogim were invalid,[3] and could not be used for the Four Species. However, it is not always possible to differentiate between the grafted and non-grafted etrog, and the tests were not always decisive. An orchard's fame was often used as a proof of its validity, but the number of orchards producing valid etrogim was limited.

None of the many medieval authors who mentioned etrogim acknowledged their source, and the first mention is from 1389, albeit from a non-Jewish writer! On June 29, 1389, Archduke Albrecht of Austria gave permission for three Jews to bring from Italy the fruits he termed "Oepfel" (apples) "and whatever is needed together with them," meaning myrtle branches and palm fronds. He also exempted them from paying any of the taxes relating to their import.[4] It is almost certain that he was referring to etrogim, which were later named "Paradiesapfel" (apples from paradise). In this source, there is no reference to their exact location in Italy.

In 1435, we find in the laws of San Remo, an Italian city on the coast of Liguria, that Jews who came to buy and sell etrogim could only buy etrogim still on the trees.[5] It appears that the Italian Riviera coastal strip from Nice to San Remo, passing Menton and Bordighera, was already the main source of etrogim for the Jewish communities in Europe, as well as the source for their *lulavim* (we don't have any information regarding their source of myrtles).

However, during that same period, in the middle of the fifteenth century, Yosef ben Moshe, a disciple of the renowned Rabbi Israel Isserlein, wrote,

> "My master said, I favor an etrog from Pul (Apulia), which has a stronger taste and smell than the citron from Raum…"[6] The etrogim are first brought to Marburg, and then to Neustadt,[7] and my master said the Jews in Marburg have the first choice since they pay for their etrogim, enabling the sellers to continue to Neustadt, but the sellers put aside the nice etrogim for some of Neustadt's nobles.[8]

In the sixteenth century, Rabbi Shmuel Yehudah Katzenellenbogen (1521–1597) wrote from Padua to the great Torah authority Rabbi Moses Isserles (the Rema) in Kracow regarding the grafted etrogim, relating that in his grandfather's times in Padua "there was once only one etrog for the whole community, and when they sent the etrog from the Ashkenazi synagogue to the Italian synagogue, students attacked the Jew carrying the etrog and stole it from him. The Italians had to redeem the etrog

[3] See the different—and sometimes even contradictory—views of the rabbis in Shlomo Zalman Lifshitz, *Chemdas Shlomo*, Orach Chaim (Lakewood, NJ: Machon Mishnas Rabbi Aaron,1922), *siman* 37.

[4] The certificate was published by Johann E. Schlager, *Wiener Skizzen aus dem Mittelalter, zweite Reihe* (Vienna, 1836), 214–15. See Eduard M. Lichnowsky, *Geschichte des Hauses Habsburg* (Vienna, 1839), vol. 4, 777 n. 2; Meir Wiener, *Regesten zur Geschichte der Juden in Deutschland während des Mittelalters* (Hanover, 1862), vol. 1, 235 n. 136.

[5] Urbani, *Nuovi documenti* and Zazzu, *Ebrei a Genova*, 22; Nilo Calvini, *Statuti comunali di San Remo* (Taggia: Tipografia San Giuseppe, 1983), 221.

[6] A distortion of [San] Remo. Some mistakenly decipher this as Rome, but no etrogim grow in Rome's environs.

[7] Wiener Neustadt.

[8] Joseph Ben Moses, *Leket Yosher* (Berlin: Yaakov Freimann Edition, 1903), 149.

for a high sum since they didn't want to use the many grafted etrogim available in the city."

We see from these quotations that they would only use the Apulian etrogim which were not grafted. R. Katzenellenbogen, who lived near the region where the etrogim were grown, added to his letter three signs to easily identify the non-grafted etrogim. He apparently understood that this information was not general knowledge in Poland, and he therefore sent the list to warn the Polish Jews how to protect themselves from fraudsters.[9]

This letter is an eye-opener as it implied that even in Italy the non-grafted etrogim were rare, and the suspicion of grafting was realistic. Perhaps R. Katzenellenbogen's letter arrived together with a delivery of etrogim which he authorized, and it is also probable that the grafted etrogim discussed in his letter were, as Rabbi Mordechai Yaffa (1530–1612) wrote, "from the orchard called Gardasee, or Lago di Garda (Italy's Lake Garda), and I say they are totally invalid, as it is known they are grafted with orange or lemon tree branches, or vice versa."[10] There was a consensus that the San Remo etrogim were the most commendable, and more preferable than the Lago di Garda etrogim which benefitted from a microclimate that enabled them to be grown despite their distance from the Mediterranean coast. But San Remo etrogim were not always attainable.[11]

There are many testimonies regarding San Remo etrogim from this period and later, although they should be more correctly called "Riviera etrogim." Often they were very significantly termed Yanover or Yaniver etrogim, referring to the port city Genoa, emphasizing the important role Genoa played in the trade. But the center point of activity stayed in San Remo with its many lemons, oranges, and etrogim, and the German Jews, as well as Jews from other countries, would buy there their etrogim needed for the festival of Sukkot, as a church official noted in 1537.[12]

San Remo's large archives shed light on the etrog market. Due to transportation and haulage complications, the market was most active in July–August, and there are many mentions of illegal sales and violation of regulations.[13] For example, on August 19, 1575 the San Remo council criticized a sale in which the Germans, the Lombards (Germans who settled in Italy) and the Jews violated common practice.[14]

In 1584, the council renewed its condemnation to remind the "Ebrei Teutonici––the Teutonic (German) Jews" and the Italians of the ban on buying fruits without checking their quality, and the law not to touch the fruit on the tree. Instead, the buyer had to point to the desired etrog and the workers would cut it off the tree. In 1588,

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[9] *Teshuvot Harema* (Jerusalem: Asher Ziv Edition, 1971), *siman* 126.

[10] *Levush* 641:4.

[11] Yitzchak Mazia, *Yefei Nof* (Jerusalem, 1986), 60 *siman* 116. The author was born around 1570. His cousin Aharon Rappaport, in *Teshuvot Eitan Haezrachi* (Ostrog, 1796), *siman* 39, also mentions the Lago di Gardia etrogim.

[12] Agostino Giustiniani, *Castigatissimi annali di Genova* (Genoa, 1537), vol. I, 3.

[13] The following data was received from Mrs. F. Fiandra, and the documents are part of the San Remo collection in the State Archives, Ventimiglia.

[14] San Remo Archives, Carte Pinelli, reg. 65, f. 195v-196r.

there were several unfortunate incidents during the harvesting “as was the practice of the Germans and the Jews,” when they picked fruits from the trees outside the given locations and allotted times. The council, on July 18, therefore appointed four clerks to advise how to prevent these offences from being committed.[15]

It can be assumed that the buyers outwitted the council’s inspectors so as to evade paying the exaggerated taxes. This presumption can be supported by an incident in 1592, when the Jews who arrived to buy “cedri e palme et alter cose” (etrogim, palm branches, and other items) asked for the etrogim and palm branches to be cut three days before the given date; the buyers and business partners paid the requested prices, disregarding the fixed prices set by the authorities. They were warned on July 27, 1592 to follow the rules.[16]

From 1597, the authorities set two separate times for selling etrogim: July and the beginning of August for the German Jews who arrived from afar, and the end of August for the Italian Jews who lived nearby. Nevertheless, the offences continued. In July 1599, the Jews were reminded that those who violated the ban to pick or buy etrogim without the permission of the censal (the authorities’ mediator) would be fined one scudo (a large Italian silver coin), which would be paid a third to the podesta (the holder of the highest civil office in the local government), a third to the local council, and a third to the informer.[17]

On July 28, 1600 it was claimed that “the Jews coming here every year to buy the etrogim and other items [probably referring to the palm leaves and myrtles]” did not comply with the rules regarding the picking and selling of the etrogim and other fruits, and they were admonished to be more obedient, under threat that all their possessions would be confiscated.[18]

It is almost certain that San Remo was accustomed to the sight of Jews buying etrogim and palm fronds, and the city council was interested in continuing these sales. The city therefore became concerned when, on August 30, 1604, the Jews bought their etrogim in Menton, Monaco, and Ventimiglia, and they intended to buy 1,000 palm fronds in San Remo. The council found it necessary to oppose this move, which could financially damage the city.[19] Realizing the huge profits made by the sale of etrogim, the local council quickly renewed the ban on harvesting etrogim or palm trees without its censal’s presence.[20]

In order to avoid severing connections with the Jewish etrog merchants, the San Remo Council, on July 22, 1633, permitted them to bring to San Remo etrogim not grown there, probably because there weren’t enough home-grown etrogim, and also to prevent the Jews from buying their *lulavim* elsewhere.[21] On July 16, 1638, the

15 Ibid., 117r.

16 Ibid., reg. 69, f. 39r.

17 Ibid., reg. 70, f. 5r.

18 Ibid., 51v-52r.

19 Ibid., reg. 68, f. 74v–75v.

20 Ibid., reg. 71, f. 74v.

21 Ibid., reg. 74 f. 282v; reg. 76, f. 252r. There is mentioned the decision taken on that day due to the fears of the local merchants.

local council ruled that the Jews must pay the censal for their etrogim and *lulavim* before cutting them from the tree, and also ordered the Jews to buy the same quantity of each species.[22]

The Jews were by now seeking more sources for their etrogim, but why'weren't the San Remo etrogim enough for their needs? Is it possible that the etrogim became scarcer in the second half of the seventeenth century, or perhaps it was merely the growth in demand. It is evident that the city's permission to import etrogim from other cities indicates a crucial change in the market's conditions. One cannot rule out the possibility that fixing the price of the *lulav* was due to overproduction, which caused the prices to drop.[23] Yet San Remo continued to rule the market.

Among the merchants swarming to San Remo, were, of course, Italian merchants and German Jews. But who was identified as German? The publications and opinion of the researcher and archivist Rosanna Urbani provide an answer[24]: on July 9, 1614 we read of "four German Jews riding on their horses in Gavi," named Moses Forte, David Lazaro of Prague, Solomon Negro (Schwartz) and Lazaro Bianco (Weiss) of Poland. They were forced to swear over "Hebrew letters" (probably a Hebrew Bible) that they left Prague five weeks earlier, around June 4, and their route was Liz, Salzburg, Innsbruck, Bolzano, Trente, Riva, Lezzese, Mantova, Guastalla, Parma, Piacenza, Voghera, Tortona, and Gavi, where they were stuck due to rumors of infection. According to the reports, an epidemic had broken out and they had to swear they had not passed through an infected town.

The four declared that they wanted to continue traveling as they had to purchase palm leaves and etrogim in Genoa, and they feared they were running out of time. A gentile German affirmed their report. A fifth Jewish traveler, Isaac the son of Jacob of Posen, from Poland, who also rode a horse and left Prague together with them, although he stayed in Mantova, planned to arrive the next day on foot to Gavi to join his friends who had seemingly already departed to Milano.[25] It is not known what happened in the end to the Jews, but it does teach us that the term "German Jews" can also refer to Jews from Poland or Bohemia.

In 1618, there is documentation regarding three Jews (and probably more) in San Remo who bought etrogim.[26] In 1654, two Jewish merchants stayed in San Remo—Isaac Frizel[27] of Prague who had a passport issued by the kaiser, and Shmuel of Lithuania who had a passport issued by the king of Poland—to buy "cedri bossi"[28] (boxwood citrons) and palm branches weighing 24 "soma,"[29] which

22 Ibid., reg. 76, f. 253v.

23 Ibid., reg. 80, f. 80, f. 32r, 34r.

24 See her excellent work mentioned in n. 2.

25 Genoa Archive Magistrato di Sanita, n. 103; Urbani, *Nuovi documenti* and Figari, "Consedirazioni sullinsidiament," 331–32.

26 Urbani, *Nuovi documenti*, 194.

27 This name has several spellings—Fresel, Friesel, or even Freshel as Isaac signs his name in Hebrew.

28 "Boxwood" may be referring to the etrog's many bumps and wrinkles.

29 As Prof. Ariel Toaff notes, this may refer to the weight of the etrogim.

is around 1,600 kg, as well as four boxes of large lemons and regular lemons for the two rulers of Prague and Poland. It is certain that this cargo of fruit covered the merchants' passports costs. The two partners, worried that the fruits might decay, were anxious to send their goods as soon as possible, and they requested that the Genoa authorities make sure the ship's captain and the city chiefs did not delay them.[30]

Frizel is mentioned again in Genoa in 1667 together with his companion Elijah Rumble,[31] and then again in 1674 when he promised before a notary to pay a certain sum in Genoa, which obviously was connected to the etrog trade. He wrote, in Hebrew, the following text, which was originally in German:

"I owe 300 Reichstaler [silver coin], I confirm 300 Reichstaler, before Passover

Isaac Pershel Esroger[32] at Present". [33]

In 1676, Frizel was once again in San Remo, this time with Matteo Verbingo of Kracow, Kalman Druckel of Hanau, and Samuel Perla of Lithuania. They were arrested for not wearing the Jewish yellow hat, and for playing cards at their inn. Their interrogation revealed that Frizel had been traveling to San Remo for many years to buy etrogim, palms and myrtles. It was also learned that he had a passport from the kaiser, spoke Italian, and was friendly with the inn's owner. During the interrogation he served as an interpreter for his friends, who declared they were careful not to act against the Christian religion, and they argued that the obligation to wear a yellow hat was only valid in Genoa, and not in Riviera.

On August 4, 1678, Matthias Perlanga[34] and Frizel were in Genoa, where they had a business partnership with the lawyer Andrea of Athens. A few days later, another two Jews from Frankfurt arrived, Elias Hogan and Natan Kulpf, who operated their businesses in Genoa, as well as the businesses of their partners Wolf Metzker, Kalman Proucher, and Abram Levy. They also had business connections with Andrea of Athens,[35] who undertook to obtain permits to San Remo within three days of their arrival in Genoa, as well as the other necessary licenses.[36]

In 1683 and 1684, the authorities found it again necessary to supervise the annual July sale of etrogim in Lago della Bardineto (Lake of Bardineto) and to approve the regulations in order to prevent a price collapse.[37] In 1684, several Jews established a company for the next twenty years to buy and send to Frankfurt the etrogim and

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[30] Genoa Archive Senato Diversorum Collegi, n. 10. Urbani, *Nuovi documenti* and Figari, "Consedirazioni sullinsidiament," 232.

[31] Ibid.

[32] *Esroger*, an etrog merchant.

[33] Genoa Archive: Francesco Notaio, Maria Cambiaso, filza 3 Urbani, *Nuovi documenti* and Figari, "Consedirazioni sullinsidiament," 332–33.

[34] Perhaps this is the same Verbingo mentioned above.

[35] Does the intervention of the lawyer Andrea of Athens in these deals hint to a partnership in the business?

[36] Urbani, *Nuovi documenti* and Figari, "Consedirazioni sullinsidiament," 195.

[37] Ibid.

lulavim for the city's Jews, confirming their commitment by swearing on the "Book of the Jews."[38] Fifteen years later, on August 18, 1699, two Jews, Isaac Jaar and Moses Alankava, testified that 180 etrogim sent from Menton to Genoa via San Remo to Messrs. Natan and Skaff were invalid because they were stained and had no picciolo (the petiole, *pitam* in Hebrew, on the tip of the etrog).[39]

Being a period when Christianity was particularly interested in the Jews' actions, Christian observers showed interest in the etrog trade. In 1603, Johann Buxtorf wrote in his book *Synagoga Judaica* that sixteen Jews traveled to Spain each year to "to obtain lemons (meaning etrogim), palmen oel (palm oil),[40] and myrtles, and they bring back as much as possible. They later sell them all over Germany, wherever there are Jews." He also noted that "last year an etrog was sold for four golden coins!".[41]

This testimony raises several questions: Why were there sixteen merchants and, principally, how did they travel to Spain after the Spanish Expulsion in 1492? This notwithstanding, it is evident that Boxstorf was aware of the annual Jewish network of purchasing and distributing etrogim, *lulavim*, and myrtles.

Towards the end of the first half of the seventeenth century, the Jesuit father Jean Baptiste Ferrarius wrote that some Jewish merchants from Poland, Germany, and Mantua would come every year in early August to the Liguria coast, beginning in San Remo, to buy etrogim and palms. They would demand that they be allowed to pick the etrogim themselves in order to ease the sorting and choosing stage. However, they would also buy more attractive and expensive etrogim from the island of Corfu, and these purchases were sent in boxes to Italy, the Low Countries, and other places. This writer is the first to mention two sources of supply, the largest being from the Riviera, while the second one—of minor importance—was from Corfu.[42]

In 1708, the botanist Johann Christoph Volkamer confirmed that Jews paid extremely high prices for the etrogim that were exported from Italy at great expense. He wrote that the Jews sought perfect etrogim, and could not easily procure more than one for their whole community.[43] In another book,[44] published in 1713, Volkamer detailed how the fruits was transported in crates, and that etrog trees were common in Spain and even more so in the Kingdom of Naples—in Calabria and especially in Reggio. He added that the fruits of these areas were quite cheap. Is it possible to conclude that the Riviera etrogim were in decline? This is not implied by other evidence that will be discussed.

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[38] Ibid., 333–34. It is mistakenly written as Brei, and instead should be read Ebrei.

[39] Urbani, *Nuovi documenti*, 195; ibid. and Zazzu, *Ebrei a Genova*, 42. Regarding the picciolo, see n. 72.

[40] He is referring to palm trees, of course.

[41] See Johann Buxtorf, *Synagoga Judaica, das ist Judenschul* (Basel, 1603), 468.

[42] See his book, Jean Baptiste Ferrarius, *Hesperides sive de malorum aureorum cultura et usi libri quatuor* (Rome, 1646), 39.

[43] Johann C. Volkamer, *Nürnbergische Hesperides* (Nüremberg, 1708), 12. He also notes on p. 84 that there are many cheap myrtles around the Lago de Gardia.

[44] Idem, *Continuatio des Nürnbergischen Hesperidum* (Nüremberg, 1713), 34, 35, 40.

All this information is indirectly confirmed, not by growers or buyers, but by consumers from Central and Eastern Europe. According to Mähren (Moravia) state regulations from 1650, it was decided in Gaia that before the *esroger* traveled to Italy to buy etrogim he had to swear to distribute them equally and impartially between the various provinces, according to the list prepared by the state officials.[45] The community's income from the sale of the etrogim is also mentioned several times, as well as the etrogim income's share in the rabbi's salary.[46] The state was therefore responsible for the etrog trade, both religiously and financially, and it also appears that the State determined who would be the *esroger*.[47]

The state of Lithuania also realized its role in supplying etrogim, and as early as 1639 it systematized the etrogim' distribution and payments involved.[48] It divided the districts among Pinsk, Brest-Litovsk, and Grodno,[49] and apparently the state granted a monopoly for the supply of etrogim, *lulavim*, and myrtles to the state-appointed *esroger*. We find that in 1720 Ziskind ben Shemaiah was the appointed *esroger* and was given the authority to confiscate illegal imports at the Breslau fair and to prosecute the criminals in court.[50]

Poland's Council of Four Lands adopted the same policy regarding the etrogim, although due to its vast territory one *esroger* could not provide for all the communities, and they therefore appointed several people to this post. Around 1650, the *esrogers* were reminded to return home in time to distribute the etrogim, even in remote communities, before the holiday and early enough to prevent competition with the Lago di Guardia etrogim that arrived early and were sold at the Lukow and Jarosław fairs, as the Council of Four Lands feared that the inferior etrogim could override the trade of the superior ones![51]

On February 5, 1693, Chaim David (Joachim David) of Lvov, Faivish Yosef of Poznan, Helman Shmuel of Krotoszyn, and Yaakov ben Eliezer (Lazarovitz) of Pinczow granted Heshel Benjamin of Byton, Upper Silesia, the monopoly to import etrogim to Poland via Breslau. According to the contract, whoever managed to acquire the same monopoly from a Polish magnate would have to compensate them, and if that person refused to do so, he would have to pay 1,000 thalers to the emperor, 1,000 to Poland's king and 2,000 to the four above investors.[52]

It appears that the fears of unfair competition were not exaggerated, as we learn that about two months later, on March 11, Poland's King John III Sobieski, asked the Breslau City Council to intervene against the initiatives of Hirsch of Bedzin (Bedzin is also in Upper Silesia, and this is probably the same Heshel of Byton) who was

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[45] Israel Halperin, *Takanot Medinat Mähren* (Jerusalem: Mekizei Nirdamim, 1952), 102 *siman* 310.

[46] Ibid., 136 (1688), 142–43 (1688).

[47] Ibid., 110 (1659).

[48] Shimon Dubnov, *Sefer Pinkas Hamedinah* (Berlin, 1925), 80 *siman* 397.

[49] Ibid., 92 *siman* 436 (1647).

[50] Israel Halperin, *Addendum and Postcripts to Pinkas Hamedinah* (Jerusalem: Mossad Bialik, 1935), 35.

[51] Israel Halperin, *Pinkas Vaad Arba Ha'aratzot* (Jerusalem: Mossad Bialik, 1945), 17 *siman* 53.

[52] Ibid., XXXIII, certificate no. 35.

at the time in Breslau, and whose trading could harm the king's citizen Matthias Worling who supplied etrogim to Poland.[53] A few years later, on September 7, 1700, Leibel Baruch, the *shamash* (beadle)[54] of Krotoszyn, Leibel Yaakov of Opatów, and Hershel Benjamin of Byton, told the Breslau City Council that Hertz Avraham of Zulz, who was in charge of supplying etrogim (Paradiesäpfel), palms, and myrtles for Poland's Jews as ordered by Christoph Bressler of Italy, would pay him the full price in one payment as soon as he returned. The three undertook to honor this agreement, and if they did not meet their obligation they would be punished by confiscation of their assets or by deportation.

The Council of Four Lands also intervened to settle conflicts between communities regarding the distribution of the etrogim among the various districts,[55] as well as to dispose of unsuccessful etrog crops.[56] From the Hamburg Regulations of 1685 it can be learned that the *esroger* had clear instructions how to distribute the etrogim among the three neighboring communities.[57]

From all this evidence, both Jewish and non-Jewish, it can be concluded that from the fourteenth century, and perhaps even earlier, the large Jewish communities of Europe established a remarkable commercial system that provided—via companies that may have had non-Jewish partners and with the necessary different contracts––the etrogim needed for all the Jewish communities in Europe. Every year, small groups of buyers and etrog-pickers set out to the Riviera, the etrog-growing area, in August, sending back boxes of etrogim, palms, and myrtles for the holiday, and these monopolistic *esrogers* were also responsible for the distribution of the species.

Every year they traveled the same fixed routes, with Breslau seemingly being the center for Eastern Europe, and Nuremberg for Germany,[58] but it is also possible that there were secondary routes less familiar to us. One can deduce from an unrelated comment that towards the end of the fourteenth century France was the origin of the myrtles and etrogim used in the Rhine Valley.[59] There may have been a route from the Mediterranean Sea towards northern France and the large communities of West Germany.

This whole system was established to ensure the orderly and sufficient supply of etrogim, but this was not always the case, and more than once the etrogim arrived late. And one year in Prague only grafted etrogim arrived, which were subsequently deemed invalid.[60]

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[53] Ibid., 231 *siman* 491.

[54] Bernhard Brilling shows that a power of attorney brought from any Polish Jewish state permitted a so-called shamash to stay in Breslau; see Bernhard Brilling, *Geschichte der Juden in Breslau* (Stuttgart: W. Kohlhammer, 1960), 40–42.

[55] Ibid., 481.

[56] Ibid., 494.

[57] Heinz Mosche Graupe, *Die Statuten der drei Gemeinden Altona, Hamburg und. Wansbeck* (Hamburg: Hans Christian Verlag, 1973), vol. I, 127–29; vol. II, 65–67.

[58] Ibid., 128.

[59] Yaacov Molin, *Sefer Maharil* (Jerusalem: S. Spitzer Edition, 1989), 392.

[60] Jacob Reischer, *She'elot U'Teshuvot Shevut Yaakov* (Jerusalem: Mekhon Even Yiśraʾel, 2004), 59 *siman* 36.

The etrog is a delicate fruit and subject to the weather's ravages: the historian Yosef Hacohen documented that in 1600 "there was an extreme frost on the borders of Genoa and all good trees died. The frost also affected all the citrus trees, and no etrogim were found in the whole of Italy, raising the price of an etrog to ten golden coins, which is unprecedented…. Nevertheless, the wealthy Jews paid the money."[61]

Further evidence shows that, following a snowstorm in 1701, the communities of Genoa and Livorno had to write to every possible place to obtain etrogim, because the snowstorm's effect on the etrogim was widespread and not just a local one. The heads of communities under the pope's jurisdiction wrote back from Nizza (Nice) that they did not have any etrogim.[62] Due to the crisis, many rabbis wondered whether it was permissible to use etrogim from the previous year, but although they generally permitted the use of last year's *lulav* and dried myrtle, Jewish law vehemently opposed the use of dry etrogim. Instead, in these circumstances, some rabbis reluctantly permitted grafted etrogim as a last resort.[63]

It is evident that the authorities showed interest in this important trade, and in the Jews' adherence to its existence. When the etrogim sent to Eastern Europe crossed from Vienna into Salzburg a customs duty of between 8 to 12 pfennig was imposed, a tax that was in practice until at least 1775 when it is last mentioned.[64] Jewish merchants from Prague who sent buyers to Calabria[65] to obtain etrogim and which they sold for five, six, and even nine florins, claimed in July 1744 that they needed to import at least 12,000 etrogim, and they offered Empress Maria Theresa to purchase the trade's monopoly at an annual cost of 30,000 florins. But the empress preferred the continuation of free trade and, instead, imposed a tax of 40,000 florins on the Jews: seven twelfths to be paid by Bohemia's Jews, a third by those in Moravia, and the rest by the Jews of Silesia. However, this plan was shelved since the Jews were banished from Prague towards the end of that year.[66]

Meanwhile, Genoa's etrog trade had sunk into deep crisis. Although the Citrus Order adopted in Bordigera in 1776, which essentially represented the situation then prevailing on the Ligurian coast, still included an entire chapter devoted to the pruning and sale of cedri all'Ebrea (the Jews' etrog),[67] there were many signs of close competition with the Corfu etrogim. Nevertheless, Genoa continued to grow

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[61] In his *sefer Emek Habachah*, on this date.

[62] See the Valabrega manuscript, microfilm 2/4598, p. 258 in the Central Archives for the History of the Jewish People.

[63] See n. 3 above.

[64] See Löw, *Die Flora der Juden*, 307.

[65] Doubtless, this minor source of etrogim was known in those days.

[66] See Gerson Wolf, "Zur Geschichte der Juden in Böhmen," *ZGJD* III (1889): 91–92; Salomon H. Lieben, "Die von Maria Theresa projektierte Essrogimsteuer," *MGW* 53 (1909): 720–22. Regarding the income from this etrog tax, see Hyeronimus von Scari, *Systematische Darstellungn der in Betreff der Juden in Mäehren* (Brünn, 1835), 82, 173 n. 3.

[67] Mussa, "Gli agrumi nellestremo," 153 n. 1. See AD Alpes Maritimes, Fonds Consulat et Empire, M 377.

etrogim, and in 1819 a lemon-growing expert wrote[68] that the etrog trade continued in San Remo and Bordigera, where the Jews obtained practically all the etrogim for the whole of Europe. He noted that in Italy the etrog was called Pittina,[69] and in French it was termed Cédrats des Juifs (the Jews' etrog).

Jewish sources indicate a rise of Corfu etrogim over Genoa's produce, although the Genoa etrogim had not yet been surpassed. Rabbi Ephraim Zalman Margolis of Brody wrote in 1818 that the Corfu etrogim first appeared in Eastern Europe thirty years earlier, and that they were more attractive than the Genoa etrogim. He had already heard rumors that Corfu etrogim were grafted, but he permitted their use if the farmers designated them for sale rather than as delicacies. He was convinced that only those from Corfu were grafted.[70]

Rabbi Meir Posner mentioned a letter from the Rabbi of Grodno "concerning etrogim that were recently brought to our country, called Corfu etrogim, and many used them for the commandment on the past Sukkot." He had to rule before the festival whether they were permissible.[71]

Rabbi Daniel Tirni related how in 1802 he ruled that the etrogim brought by Christian tramps from Genoa were invalid, and although the tramps claimed the etrogim were kosher, he did not trust them. He added,

> It has long been customary in the city not to take etrogim grown here because they are regarded as grafted, and I have always ruled for my community to only use an etrog with a seal of approval from Jews that it isn't grafted, as the regular practice in Italy is that even etrogim brought from Corfu to Venice, or from Venice to other countries… must be endorsed by a Rabbi that they are not grafted.[72]

According to another source, the Corfu etrogim arrived in Eastern Europe between the years 1804 and 1810.[73]

Kerner wrote: "I remember, due to the wars in Italy in 5569/1809… they didn't bring etrogim from Genoa, only from the island of Corfu which were considered grafted etrogim."[74]

These citations show that the rise of the Corfu etrog occurred during the Revolutionary and Napoleonic Wars fought in Italy, which began with the annexation of Nice and the wars of 1796–1800, and ended with the battles against Russia and Austria.

The merchants' new source of etrogim was not a financial matter, but political. It appears they were asked to keep away from countries under French rule and not to

68 Etienne Marcel, *Histoire du citronnier* (Paris, 1819) (=Nouveau Duhamel ou traité des arbres et arbustes que l'on cultive en France), vol. VII, 69.

69 A distortion of the Hebrew word *pitam*, the top part of the etrog.

70 *Teshuvot Beit Efraim*, *Orach Chaim* (Lemberg, 1818), no. 56, 409.

71 *Teshuvot Beit Meir*, *Orach Chaim* (Josefow, 1876), 103a and 104a. Probably, in its first stage, the export from Curfo passed via Venice, and only later via Trieste.

72 *Sefer Ikrei Dinim* on *Orach Chaim*, known as *Ikrei Had"t*, the laws of *lulav*, 32, 2:3 (Vilna, 1879).

73 See *Hamelitz* 154, June 23, 1891; *Hatzefirah* 165, 1893, 28. *Teshuvot Beit Meir*, where the year is 1802 or 1805.

74 *Sefer Birkat Moshe* (Berlin, 1833), 28.

cross the borders into certain countries. It is also apparent that the Riviera etrogim became less attractive due to the bad weather that prevailed there in 1789, 1809–1812, and 1814–1815,[75] causing a large decrease in etrog-picking, or eliminating it all together. So it is conceivable that the merchants decided to search for other sources.

But it should not be inferred from these facts that the Genoa etrog market completely disappeared. It recovered and continued to operate, albeit with less intensity; but its significance should not be underestimated. The Chatam Sofer, Rabbi Moshe Schreiber, the leading rabbinical authority in those days, wrote to the Rabbi of Vienna as late as 1834 that the Genoa etrogim were better than those "originating from the islands," referring to the Corfu etrogim. In this matter, he relied on the previous rabbis of France and Germany who used the Genoa etrogim, and noted that the etrogim not originating from Genoa might only be used if they had a rabbinical certificate attesting to their validity.[76]

The Jewish community in Carpentras still imported etrogim and palms from Genoa between the years 1837–1864. They were sent from Genoa to Marseille on a steamer and were then loaded onto a Diligence stagecoach (the public coach used to carry passengers and packages on long journeys) to reach Carpentras.[77] In 1860, the rabbi of Genoa was still printing forms to confirm the validity of the etrogim sent from his city[78] and, at the end of the century, advertisements mentioned Genoa etrogim together with those from Corfu and the Holy Land.[79]

The etrog merchants turned to other sources of supply such as Corsica[80] (perhaps because Corsica was subject to Genoa), Morocco,[81] Madagascar, or America.[82] However, with the exception of Morocco, these sources did not play an important role in the etrog trade.

Although the Corfu etrogim competed with the Genoa etrogim, they failed to take control of the market as quickly as expected. In fact, these etrogim were not grown in Corfu—they probably received their name because they were sent from Corfu––but were actually grown in the small port town Parga on the Greek coast near the Albanian border, and from the two nearby cities Rapiza and Agia.

As Rabbi Shlomo Kluger noted in 1846:

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[75] See Massimo Quaini, *Per la storia del paesaggio agrario in Liguria*, n.s., XII, 2 (Rome: Laterza, 1972), 214 n. 30.

[76] *Teshuvot Chatam Sofer*, *Orach Chaim* (Jerusalem: Machon HaMaor, 1970), *siman* 207.

[77] The Central Archives F. Car. 740.

[78] Catalogue of the Freilich Public Auction, 1989, no. 547 (with a photograph).

[79] *Hatzefirah*, July 9, 1888, 128.

[80] Etrogim were grown here until the 1970s, see Henri Rebour, *Les agrumes* (Paris: Baillière Edition, 1957), 59, le verger corse d'agrumes en 1971–1972, Ministère de l'agriculture et du développement rural, Direction départementale de l'agriculture de la Corse, s.l. s.d.

[81] In the 1800s, etrogim were already imported from Morocco to England, see *Hamelitz*, May 24, 1891.

[82] See *Sdei Chemed*, *Asifat Dinim*, *Arba'ah Minim* 1, 4; *Ma'arechet Halamed*, rule 141, *se'if katan* 32, 33.

> The Parga Garden belongs to the Sultan and is sold every year to whoever rents all the King's income from it. The Garden's etrogim are known to be kosher, as is know that the Jews of Constantine, Adrianople, Smyrna and Salonika will only use an etrog from the Parga Garden, even though Parga is distanced from them and they have to pay a high price, similar to the price paid in Poland, for these etrogim.
>
> All the etrogim for sale belong to the Sultan, or the Pasha who represents him, and whoever plants a citrus tree, its fruits belong to the Sultan. However, recently the Sultan had changed his policy and has permitting the planting of citrus trees, but the grower has to pay a certain tax. Subsequently, the local Greeks and Tartars began to plant etrog trees, and have been growing them for the past three years.[83]

Rabbi Zvi Hirsch Chajes, Rabbi of Zolkiev, provides more details:

> Following the Sultan's new law permitting all his residents, both Jewish and non-Jewish, to sell and grow etrogim, most of the non-Jews' etrogim are from Albania and are certainly grafted. Many non-religious Jews have established partnerships with them, and they deceived the Rabbi of Corfu, telling him that the invalid Albanian etrogim grew in the Parga Garden whose etrogim are acknowledged as being kosher.[84]

These testimonies are from 1846 at the latest, and they describe a situation that began three years earlier. Obviously, this is a result of the Tanzimat (the period of reform in the Ottoman Empire) which began in 1839. The proposed changes included the abolition of the tax leasing system, which eventually led to the end of the agricultural crops' old-fashioned system.[85] The peasants of the Parga area, who realized the importance the Jews attached to the Parga etrog, jumped on the opportunity and planted many new etrog orchards. To ensure the etrog's efficiency, they probably did not hesitate to graft the etrog trees in order to produce less sensitive and more beautiful fruits. They rushed to organize their exports and flooded the etrog markets with their fruits. This war of competition affected the Parga and Riviera etrogim, despite the fact that the Rabbi of Corfu validated all the etrogim grown in his area.

The problem worsened when the Jews began to suspect that some of the Parga etrogim actually originated in nearby Albania, with the cooperation of several Jews. But the Rabbi of Trieste, the northeastern port city which naturally became the center of the etrog trade, trusted the Rabbi of Corfu and added his recommendation for the Parga etrogim.

Ziskind Mintz of Brody, one of the leading etrog traders of the period, boasted about having revealed the grafted etrogim deception which created havoc in the market. He was of the opinion that the Genoa etrogim were also grafted, just like those of Lago di Guardia, and that only Calabrian etrogim transported through Genoa—which is why they were called Genoese etrogim—were kosher.[86]

Although the Rabbi of Trieste confirmed the validity of the Corfu, Genoa, Corsica, and Parga etrogim that passed through his city, the etrog merchant Mintz was

[83] *She'elot Uteshuvot Pri Etz Hadar* (Lemberg, 1846), 2a. See also 18a.

[84] Ibid., 18b.

[85] Robert Mantran (ed.), *Histoire de l'Empire Ottoman* (Paris: Fayard, 1989), 484–85.

[86] See *She'elot Uteshuvot Pri Etz Hadar*, 9b.

unwilling to trust the rabbi. Mintz's opinion was that the only kosher etrogim which met the halakhic requirements were the Parga etrogim grown in the Benozzi orchard on the island of Corfu, the etrogim of Tunisia, those grown in Marrakesh, and the few etrogim grown in the Land of Israel, but not the Lebanon etrogim which were all grafted. He also accepted the Corsica and Calabria etrogim which grew wild without human intervention.[87] He noted that Greek merchants had recently come to Russia and sold their goods there.[88]

Finally, Rabbi Shlomo Kluger, who was recognized as one of the most important rabbinical authorities in Russia, issued a call for religious Jews to buy only etrogim from Parga and Genoa, which were known as Yaniver (Genoa) etrogim, and those from Corsica.[89]

One would have thought the fate of the Corfu etrogim was now sealed, but this was not the case: the controversy continued because the Rabbi of Corfu did not accept his dismissal, nor were the etrog traders willing to quit a fruitful business. Instead, the cultivation and export of Corfu etrogim expanded, despite the rabbis' warnings. In 1883, the journalist Zalman Epstein wrote that most of the etrogim exported to Russia came from Trieste, enriching the "deceitful Greeks" who were suspected of grafting etrogim. Epstein recommended buying etrogim from the Holy Land, which, although less beautiful, were definitely valid for the *mitzvah*.[90] This is how a new factor—Holy Land etrogim—entered the market, and over time totally overran the market.

The new Jewish settlement in the Land of Israel was taking its first steps, and the main concern was finding markets for its agricultural produce which, unlike in the past, was the produce of Jewish workers. The increasing efficiency of the steamships cut the time of the etrog shipments, helping the Holy Land's etrog trade. The first etrogim from the Land of Israel soon arrived in Trieste.[91]

The Greek merchants who gathered in Trieste tended to take advantage of the situation by emphasizing the time factor. The Jewish merchants' timeslot for buying etrogim was limited as they had to send their etrogim to Poland and Russia in time for the holiday, while the Greeks, who were confident they would be able to sell their goods, could afford to wait until the last minute, and were sure they would get the price they demanded. Thus the Jews were always in a losing position and had to concede, but at some point the Jews decided to take a stand. The inevitable conflict erupted in 1883.

About eighty Jewish buyers used to go together every year to Trieste, where a strong etrog market was held. As described in the press, merchants arrived from all over the world, but since Trieste was far from the central Jewish communities, their expenses were high. There were also wholesalers and agents who signed agreements with middlemen who undertook to buy the necessary quantities of etrogim in their

[87] Ibid., 32a.

[88] Ibid., 33b.

[89] Ibid., 37a.

[90] *Hamelitz* 34, May 6, 1883, 535–37.

[91] Ibid., 43, 678–82.

city. All individual merchants undertook to appoint a representative no later than the month of Av (July–August), when the shipments commenced, and they had to rely on this representative to get what they wanted.[92]

Relations with the Greeks were unsettled; the merchants claimed the Greeks are as cunning as snakes. The Greeks knew that the merchants could not return home empty-handed, so they laughed at, insulted, and mocked the buyers. They were sure that prices would only rise and that they would always win at the end of the season.[93] Already in 1881, the Jewish merchants complained that they had to pay two and a half golden coins for bad goods sold by the Greeks. The continued price-rise led to the establishment of a committee of Jewish merchants, which negotiated with the Greeks and inspected the possibility of returning to the old method of buying etrogim in Genoa and Corsica, and even reconsidered the etrogim from the Holy Land and America. Finally, the Jews organized an economic boycott in 1882 and the Greeks grudgingly surrendered.[94] Business between the two parties resumed, but the atmosphere was tense.

In 1891, a vicious blood libel was spread against Corfu's Jews, affecting all Jewish communities in Europe. The opposition to the Corfu etrogim increased, and the Jews doubted whether it was possible to continue doing business with the Greeks as if nothing had happened, while the Greeks were getting rich at their expense, and endangering the Jews' safety and lives.[95] The Jews decided to act against the island's etrogim and forbid their use, and instead recommend the Holy Land's etrogim. Indeed, one by one, all Russia's rabbis banned the Corfu etrogim.

There were some who wondered if such a move could endanger Corfu's Jews who would have to endure the hostility and revenge of the Greek merchants. These sceptics also warned of the Turkish authorities' reaction at the loss of its hefty revenues. But those supporting the ban quashed their fears: there were no Greek etrog merchants living permanently in Trieste, and no more than a few Greek businesses that gave advance payments to the island's farmers in early summer. Thus the fear of revenge was not relevant. Also, Jewish businesses were not at stake as there were merely two Jewish brokers in Trieste who traded in etrogim and charged eight percent brokerage fees and, at the time, there were no Jewish etrog traders in Trieste who would have been economically harmed by the boycott.

As for the Turkish authorities, their loss of income from taxes on the sale of the Corfu etrogim would be counterbalanced by income from the sale of etrogim from the Land of Israel. And, regarding Corfu's Jews, there was also nothing to lose: first, the buying power was not a factor in preventing more attacks against them and, second, the local Jews were not involved in the etrog trade and therefore there was no reason they should suffer from its termination.[96]

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92 Ibid.

93 Ibid., 44, 696.

94 Ibid., 696.

95 Zvi Hershkopf, *Pri Etz Hadar* (Munkatch, 1891), 3–5.

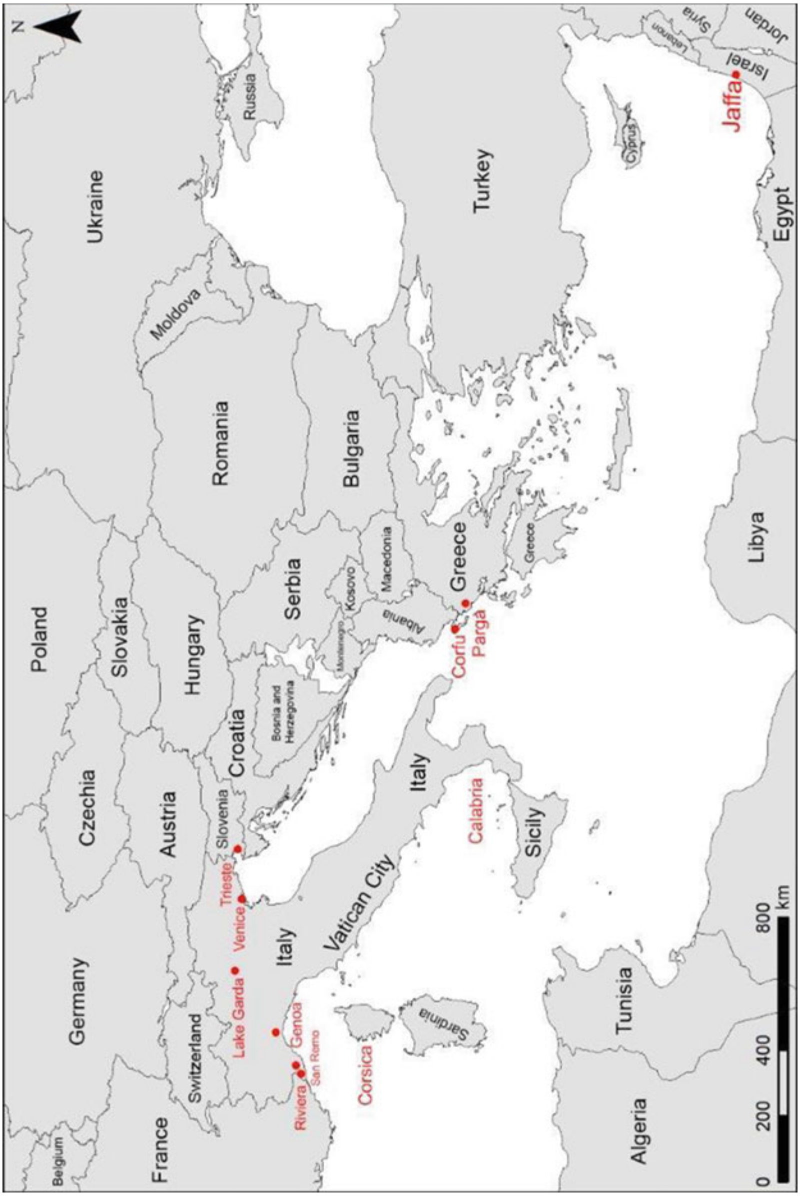
96 *Hatzefirah* 116, May 26, 1891; 128, June 11, 1891; and 165, at the beginning of the month of Av.

These public calls were somewhat successful. In 1898, Alessandro Levy Matriast's advertisement offered an etrog from Parga, Corfu, and the Land of Israel; the Corfu etrogim were the cheapest, selling for less than those imported from the Holy Land and Parga. But the palms still came from Genoa and its surroundings.[97]

Meanwhile, following the blood libel in Corfu, a many from its Jewish population left and moved to Trieste and, due to the decline of the local community, the need to care for its members' financial welfare decreased. The Trieste etrog market continued to exist until World War One, while the Holy Land etrogim were on the rise. After a while, the Holy Land etrogim conquered the market and the etrog completely disappeared from Corfu's landscape.

Thus came to an end a system of buying, transporting, and distributing which lasted for nearly a thousand years and also enabled the Jewish communities of Europe to maintain regular ties among them. With the end of the Corfu etrog, Trieste's market was terminated as there was no longer any justification for its continued activity.

[97] The Central Archive 932 IT. It is worth noting that the regulations from 1806 (Comune di San Remo, serie III, reg. 79) only mention "palme all'Ebrea" and not the etrogim, similarly in 1826 and 1837. Ibid. The supply of myrtles was solved differently: according to the testimony of Maharik (Italy, sixteenth century), *teshuvot* 413, and Reischer, *She'elot U'Teshuvot Shevut Yaakov*, 57 *siman* 36, the German Jews took Prague myrtles that did not meet all the halakhic requirements.



Map of the Mediterranean basin. Places and regions related to the growth and commerce of etrog citrons marked in red. Kindly prepared by Mr. Saar Zini, according to data of http://www.naturalearthdata.com/downloads

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Chapter 20
The Corfu Etrog Citron Polemic

Yosef Salmon

Abstract The Corfu etrog citron (pl. etrogim) polemic raged within the Jewish community of Europe during the course of the nineteenth century. This polemic was part of a larger controversy regarding the use of etrogim from grafted trees that began in the sixteenth century, initially in Italy and the Land of Israel.

From the end of the eighteenth century, the Corfu etrogim dominated the market because of their quality, their reasonable price, and their availability. The etrog polemic generated a large amount of literature because of the complexity of the issue, which involved a variety of halakhic concerns. The Corfu etrogim were first used by Sefardic communities in the middle of the eighteenth century. The question of the suitability of the Corfu Etrogim arose toward the end of the eighteenth century in Ashkenazic communities. A public polemic regarding the etrogim from Corfu erupted in 1845 with the publication of rabbinic responsa that forbade their use.

The debate was made public by Alexander Ziskind Mintz, an etrog merchant from Brody, who sought to have the sale of etrogim from new regions forbidden in order to protect his personal domination of the market, based on etrogim from Parga, opposite the island of Corfu. He also claimed that the etrogim from the lake regions of Italy and the Italian Riviera were grafted, in direct contradiction to the position of the Hatam Sofer. Mintz also claimed that the criteria used by the rabbis to differentiate between grafted and non-grafted etrogim were not trustworthy, and that it was therefore necessary to rely solely on the authority of the local rabbinic councils at the source. To support his position, Mintz enlisted the support of well-known halakhic authorities, such as R. Shlomo Kluger of Brody.

Opposing these men were a group of rabbis who permitted the Corfu etrogim, led by R. Hayim Falagi, one of the most prominent Sefardic halakhic authorities. He asserted that the etrogim of Corfu, Rhodes, and Phonecia were, in fact, not grafted.

Places and regions mentioned in this chapter can be found in the Map of the Mediterranean, p. 500 at the end of Chap. 19

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He was joined by R. Yehudah Bibas, the Rabbi of Corfu. In the final analysis, the controversy was resolved in favor of the etrogim of Corfu in both the Ashkenazic and Sefardic communities.

The controversy surrounding the grafted etrogim began in the sixteenth century and continues up to the present day. What made this fairly specific halakhic issue, of interest for merely one week a year, such a central controversy, unparalleled in halakhic literature?

In this article, we will try to explain the history of the controversy, shedding light on its significance and uniqueness. The issue is based on the Torah's commandment "and you shall take… the fruit of the citrus tree" (Lev. 22:5). Although the Torah does not actually define the citrus fruit in question, its identification as the etrog was delivered to Moses on Mt. Sinai (Maimonides' introduction to the Mishnah, Zeraim), and our Sages (Sukkah 35a) added support to this identification based on the language of the verse, as well as relating to differences in the size, shape, and color of the etrogim.

While our Sages elaborated on the various kinds of etrog—ruling which are kosher and which are not—they abstained from discussing the law of a grafted etrog, and the issue was only first discussed in the sixteenth century, in Eretz Israel (Responsa of Rabbi Moshe Alshich) and in Italy (Maharam of Padua and his son Maharshik—Rabbi Shmuel Yehudah Katzenellenbogen). It is puzzling that the issue was not addressed until then—the grafting techniques were already known in the times of the Sages and are discussed in the intricate laws of *kilayim* (the prohibition of grafting or planting different seeds together) and *orlah* (not benefitting from a tree's produce in its first three years), yet the issue of the grafted etrog was only raised 1,000 years later!

The later halakhic authorities gave the following signs to recognize which etrog is not grafted: its pedicel is sunken into the fruit, unlike the grafted etrog whose pedicel protrudes; the etrog has small bumps, unlike the grafted etrog whose skin is smooth; its skin is thick, unlike the grafted etrog whose skin in thin; the inner part of the etrog is small with little juice (it is practically dry), unlike the grafted etrog which has a large inner part and is juicy and, finally, the non-grafted etrog's seeds lie longitudinally (i.e., parallel to the long axis), while in the grafted etrog the seeds lie latitudinally (horizontally).

Since these signs are not specified in the Torah or in the works of the Sages and are only determined by ancestral tradition, we need not totally rely on them. Therefore, if we have a tradition regarding a certain etrog tree that it is kosher and non-grafted, we cannot invalidate it just because it does not have the signs of a non-grafted etrog. However, some claim that the sign of the thick peel is ordained by the Torah, as our Sages derive from the wording of the Torah that the etrog differs from other fruits in which "its taste is the same as the taste of its wood."

On the other hand, there are some who nevertheless determine the etrog's halakhic validity via its signs, basing their view on the fact that the Torah gives signs regarding other laws.

The pros and cons of the etrog's validity is a complicated issue, involving many halakhic issues, including matters of tradition, size, and symptoms, which are all discussed in the controversy regarding these etrogim.

It is also worth mentioning that the *mitzvah* of taking a lulav and etrog on the festival of Tabernacles is one of the most enjoyable commandments, and is the only *mitzvah* about which the Torah explicitly states that it should be "elegant."

But the central question that has shaken Jewish communities for centuries is related to the laws of *kilayim* and *orlah*. Is the grafted etrog the fruit intended by the Torah?

This question has not yet been finally decided, and it continues to be discussed in halakhic literature. It seems that the doubt lies in the difficulty to determine how the grafted etrog differs from the non-grafted one. The controversy also involves varied approaches among different communities, Sephardim versus Ashkenazim, and Jews from Western and Central Europe versus Jews from Eastern Europe.

From ancient times, most etrogim were exported via the port of Genoa to communities in central and eastern Europe, with the etrogim originating from the areas of the northern Italian lakes Lago Di Garda and the Riviera, and in southern Italy's Calabria and Puglia. After the eighteenth century, the supply expanded to include etrogim from Spain, Corsica, North Africa, the Greek islands and the coast of Albania, and later also from the Land of Israel.

The sophistication of trade and transport, especially from the first quarter of the nineteenth century, opened the door for etrogim from warmer regions, and the etrogim from some of these new sources were more elegant that those from the northern regions.

Once the etrog supply centers moved from Italy to Greece and the islands (including the coast of Albania), the port of departure and marketing moved from Genoa to Venice and Trieste, which were closer to the new growing areas.

Corfu etrogim only arrived in the European communities at the end of the eighteenth century and the beginning of the nineteenth century and, due to their availability, beauty, and lower price they quickly dominated the market. But it appears that even before the use of these etrogim by the Jewish communities, the fruit was common throughout the Ottoman Empire, which ruled over the areas where these etrogim were grown.

The roots of the controversy regarding the Corfu etrogim lie in the negotiations between the halakhic authorities regarding the question of the grafted etrog, an issue that, as mentioned, dates back to the sixteenth century, with certain aspects of these discussions based on Talmudic discussions and the rulings of the early commentators. This controversy was one of the most discussed halakhic controversies of the nineteenth century, and was accompanied by the publication of rich literature on the subject.

The halakhic negotiations span many years and encompass various Jewish communities and, aside the halakhic concerns, economic and public-interest considerations were also involved. That literature on this issue is still being published up to the present-day is live testimony to the fact that this halakhic matter has not yet been finally decided.

This article focuses mainly on the social and historical facts of the controversy, while the halakhic sides are mainly discussed in other articles in this volume.

The Sages, the former commentators and Torah authorities up to Rabbi Joseph Caro (1488–1575), who was one of the leading halakhic authorities of all generations, did not relate to the question of the grafted etrog, probably because commercial use of grafted etrogim began after their times.

To the best of our knowledge, the interest in grafting etrogim and other citrus trees arose in the fashionable tree gardens of Italy's nobles during the early Modern Era, between the twelfth and fifteenth centuries.[1] The first to relate to the issue of the grafted etrog—and who forbade its use—were Maharam of Padua and Rabbi Moshe Alshich[2] in the first half of the sixteenth century. They were familiar with the procedure of growing etrogim from their locations, with one living in Italy and the other in the Land of Israel. From the later rabbis' responsa, it is quite clear that prior to the prohibition imposed by these two rabbis against the use of the grafted etrog, the interest in grafting etrogim was limited to the gardeners of ornamental gardens in Europe, but not in Israel.[3] According to the testimony of R. Alshich, Safed sages in the generation before him "were extremely stringent against using [a grafted etrog]," yet he nevertheless deemed it necessary to reiterate the prohibition in order to close any loopholes raised by a certain Jew who opposed the ban, although R. Alshich does not mention him by name[4]:

> According to the rule of the law, if no kosher etrog is found for the four species, no other fruit can replace it, and in such a scenario one cannot fulfil the *mitzvah* of taking an etrog, otherwise [one will be transgressing the prohibition of reciting] a blessing in vain.

Another halakhic issue is the definition of the etrog's elegancy, which is an elemental factor of the etrog, with some explaining the Torah's words, "a beautiful fruit," as being directed specifically to this *mitzvah*. The desire to glorify the *mitzvot* of the four species already led the Amoraim to limit the level of beauty necessary, mainly to protect the underprivileged by lowering the expenses involved in excessive stringency.[5] But despite the restraining ruling, Jews have for generations continued to invest in the beauty of the Four Species, often paying more than the fixed amount—ruled at a third more than the given price—designated for enhancing one's *mitzvot*.

A detailed discussion on this problem can already be found in the work of Rabbi Moshe of Trani (the Mabit, 1504–1585), with his description reflecting the reality

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[1] 1 Eliezer Goldschmidt, "The Problem of the Grafted Etrog Today," *Techumin* II (1980): 135–45.

[2] R. Alshich's exact description of the grafting methods and the testimony he received from the gardeners reflect on-hand knowledge of the cultivation of etrogim. See *She'elot Uteshuvot Maharam Alshich* (Bnei Brak, 1982), *siman* 110.

[3] See ibid.; *She'elot Uteshuvot Rema*, *siman* 117. The Rema (Rabbi Moses Isserles) writes: "I will not malign the former Jews whose custom was to make a blessing on a false [grafted, Y. S.] etrog in extreme circumstances." See the reactions of the Bach (Rabbi Joel Sirkis) Hayeshanot, *siman* 135. See also the letter of Yaakov of Warsaw in *Divrei Miluim Lehachoveret Hora'at Heter* (Vilna, 1876; Brooklyn: Photo Edition, 1994), 448.

[4] See *She'elot Uteshuvot Maharam Alshich.*

[5] See Sukkah 34b, "Shmuel told the myrtle sellers: 'Lower your prices…'".

of Safed at the time, indicating that people in Safed sought out the most elegant etrogim. And, although our Sages ruled that one should only pay up to a third more than the regular price for an enhanced *mitzvah*, they paid far higher prices for their etrogim. Moreover, those who failed to buy such elegant etrogim preferred to make the blessing over other people's etrogim instead of acquiring a set of Four Species of their own. The Mabit criticized these people and emphasized the obligation of the *mitzvah* "and you shall take yourselves" is to take one's own Four Species and, therefore, he also facilitated the laws of what is a valid etrog. He writes that those who followed his rulings "will find many kosher and cheaper etrogim, which every poor person will be able to buy in order to fulfill the *mitzvah* and won't need to take the etrog that belongs to the congregation."[6]

On the other hand, Rabbi Chaim Palagi of Izmir, in the middle of the nineteenth century, ruled that it is better to take a single elegant etrog for the whole congregation in the circumstance of a large loss.[7]

It is worth noting the mental and emotional difficulties of the rabbinic authorities to come to terms with the notion that so many Jews and their rabbis who took grafted etrogim did not correctly observe the *mitzvah* of the Four Species for many generations, and perhaps even transgressed the prohibition of reciting a blessing in vain, as if God caused them to sin by presenting them with invalid etrogim. This emotional consideration has played a partial role in the responsa literature since the beginning of the nineteenth century, and even more so in later years.[8]

Despite the ban on using a grafted etrog, there were those who continued to use it over the years, and the question rose again recently as part of the process of Orthodoxization in Jewish society, in which any tendency toward strictness in *halakhah* is welcomed.[9]

20.1 The Corfu Etrog Enters the Market

Following the entry of the Corfu etrog into the market, the etrog became a popular commodity.[10] The Rabbi of Corfu, Rabbi Yehuda Bibas (1789–1852), presents

[6] The Mabit is lenient here in the law of acne and ruled that neither the acne nor the lack of a *pitam* in Safed etrogim invalidate the etrog, as he regards them as the etrog's natural elements.

[7] Simon L. Eckstein, "The Life, Work and Influence of Rabbi Chayim Palaggi on the Jewish Community of Izmir" (Ph.D. diss., Yeshiva University, New York 1970), 128.

[8] See the Rema's response in n. 3 above, and *Teshuvot Rema* (Jerusalem, 1871), 476 *siman* 117. From the question of the Sema (Rabbi Joshua Falk) to the Bach, one can infer that the issue of respecting the tradition of using a grafted etrog was raised as a reason to permit the grafted etrog: "Also, they permitted these etrogim over the years." See *Teshuvos Habach siman* 135 as mentioned above in n. 3.

[9] See also Moshe Reiner (ed.), *Arba'at Haminim* (Jerusalem, 1992), ch. 5, 14–20 *siman* 1–40. It is doubtful whether even a marginal minority of those fulfilling the *mitzvah* comply with the stringencies laid down by R. Reiner.

[10] Daniel Tirani, *Ikrei Dinim* (Vilna, 1878), 32 *se'if katan* 3.

a description from the 1840s of how Jewish merchants stayed in Corfu and the surrounding areas during the etrog harvesting and sent the harvested etrogim to Trieste where they were bought by other merchants from Eastern and Central Europe.

An earlier testimony of Rabbi Daniel Tirani, Rabbi of Florence in the last decade of the eighteenth century, some fifty years before Bibas's testimony, shows that the Corfu etrogim were marketed with the certified seals of the local rabbis, and therefore these etrogim were more acceptable to the Sephardic rabbis than the etrogim of Genoa (Yanova), that lacked such seals.[11] Corfu traders would also send etrogim to Jewish communities in Italy and in the Ottoman Empire.[12] But since the cultivation and trade of etrogim was in the hands of the locals, suspicion of fraudulent acts arose, such as the mixing of kosher etrogim with invalid ones which were difficult to identify. The rumors of such fraud caused great frustration among the Jews who paid high prices for the *mitzvah.*

Corfu etrogim were first used by the Sephardic Jews, and later, probably in the last decades of the eighteenth century, also by the Ashkenazim.[13]

When everybody started buying their own etrog and the etrog became a high-demand item and not, as in previous times, when only one or two etrogim were bought for each congregation, it became difficult to rely on the limited supply of etrogim from Italy due to the severe Italian winters that damaged many etrogim, and because some of the Italian etrogim were considered grafted.[14] Although the Ashkenazim in Central Europe were aware of the existence of the Corfu etrog, its validity was in doubt,[15] but once the Corfu etrogim were permitted, the Jews were careful to bring them only from Corfu, or from Parga, a small coastal town near Corfu. The traders in these etrogim were Jewish, or Jews with Greek partners, and

[11] Ibid.

[12] Chaim Palagi, *Lev Chaim* (Izmir, 1879), vol 2, 87a.

[13] The rabbis who permitted the Corfu etrogim in the 1875–1876 controversy (see below) claimed that these etrogim were in use for one hundred years. On the other hand, those who forbade them claimed that their use was only fifty years old, see Moshe Ra"m, *Tochechah Megulah* (Mainz, 1876, 5; Brooklyn: Photo Edition, 1894. I have therefore taken the middle approach which is also consistent with evidence of the use of the Corfu etrog by Rabbi Chaim of Volozhin in the early nineteenth century; Rabbi Shlomo Kluger, who claims in his *She'elot Uteshuvot Tuv Ta'am Vada'at* (New York: Photo Edition, 1964), vol. I, 68 *siman* 17,168, that as a child he never heard of Corfu etrogim, and Rabbi Shneur Zalman of Liadi, who published his Shulkhan Aruch at the end of the eighteenth century, and did not yet recognize the Corfu etrog (Orach Chaim, *siman* 648). The Beit Ephraim (R. Ephraim Zalman Margoliot) claims that "these etrogim come from Corfu for around thirty years or more," and since his *teshuvot* were published in the second decade of the nineteenth century, it can be assumed that he was relating to the 1790s; according to the Sephardic source Rabbi David Pardo (*Michtam Le'David*; Jerusalem: Photo Edition, 1990, vol. I *siman* 8), Corfu etrogim were routinely traded as early as the 1760s.

[14] See Tirani, *Ikarei Dinim*, 32 *se'if katan* 3, who relates that he did not permit the use of Florence etrogim that were known to be grafted, but only Genoa etrogim that grew in Genoa itself, and that there were much fraud and trickery in this regard.

[15] A responsum from the Chatam Sofer in 1831 implies that as early as 1785 etrogim were imported from Corfu and there were those who banned them, but over time they were accepted into the market, see *Teshuvot Chatam Sofer*, *Kovetz Teshuvot* (Jerusalem: Machon Chatam Sofer, 1973), *teshuvah* 25.

they probably brought the etrogim to Venice and later to Trieste, from where they were delivered to merchants from different countries.

The advantage of Corfu etrogim was their beauty, pitams, and yellow color, but their disadvantage was the fact that the Ashkenazim considered them to be grafted, and that they were sometimes expensive.[16]

It is worth noting that although the Ashkenazim considered them to be grafted, the Corfu etrog usually had the signs of a non-grafted etrog: its pedicel is sunken into the fruit, it has small bumps, it has little juice, and its seeds lie longitudinally, although according to some the Corfu etrog's seeds lie latitudinally.[17]

The Sephardic rabbis, for example Rabbi Yishmael (1722–1811) from Modina and R. Tirani, ruled that the Corfu etrogim were even more kosher than the Genoese etrogim, in contrast with the Ashkenazi approach.[18]

An early halakhic discussion of this issue among the Ashkenazim is found in the Responsa of Rabbi Meir Posner (1735–1807), author of the Beit Meir and Rabbi of Danzig from 1781.

The question was also addressed by the Rabbi of Grodno in 1803, and it gives us a clear picture in understanding the early days of the importing of Corfu etrogim into Eastern Europe. It seems that these etrogim gained prominence due to "their shape and beauty," and also because they carried some of the signs of non-grafted etrogim. Doubt was raised concerning these etrogim "that don't have enough bumps," "are not long and tall," and because their color is light yellow, and due to the lack of these signs, the rabbis tended to be suspicious of the etrogim "that are possibly grafted with other types of fruit." Those asking the question regarding the Corfu etrogim agreed that a grafted etrog is invalid.

We would like to note that Corfu etrogim were imported to Germany about a decade earlier, and it appears that there also they were prohibited from use.

Another source from this period is Maharam of Rothenburg (died 1826), who served as Rabbi in Poland in the cities of Wlodawa and Kazimierz.[19] According to his testimony, written in the 1790s, the Corfu etrogim were new to his area. He wrote that although the arrival of the new etrogim was a source of controversy over their *kashrut*, most of the Jews used them and only a minority preferred the Genoa etrogim, while the communities in Lithuania refrained from using the Corfu etrogim. The Maharam wrote that he preferred the Genoa etrogim, but due to the lack of such etrogim he had no option but to take a Corfu etrog.

His description implies that the Corfu etrogim differed in appearance from the Genoa etrogim, lacking the bumps on the outer skin and their pedicels were not sunk into the etrog. Nevertheless, he recommended the use of Corfu etrogim since the signs that validate the etrogim are not biblical or even rabbinic, and that the

[16] See Eliezer R. Malachi, *Letoldot Mischar Ha'etrogim* (Chapters in the History of the Old Yishuv) (Tel Aviv: Hakibbutz Hameuchad, 1971), 169–68.

[17] See Meir Posner, *Beit Meir* (Josefow, 1875; New York: Photo Edition, 1958), 208.

[18] See n. 10 above.

[19] See *Responsa of Mahara"m of Rothenburg* (Lemberg, 1857; New York: Photo Edition, 1990), question 19.

arguments to invalidate them stemmed mainly from the merchants of the Genoa etrogim who feared their competition.

The Maharam strengthens his position with the backing of one of the leading halakhic authorities of his time, Rabbi Mordechai Bennett (1753–1829), Rabbi of Nikolsburg and Rabbi of the whole Moravia region, who checked the Corfu etrogim and found them to be non-grafted. However, the Maharam also noted that "I fulfil the *mitzvah* with a Genoa etrog."[20]

Another testimony to the inferiority of the Corfu etrog among the Ashkenazim can be found in the ruling of Rabbi Daniel of Grodno (Horadna). In 1808, due to Napoleon's wars, the Genoa etrogim did not reach his town and, instead, only Corfu etrogim arrived. Since the Corfu etrogim were considered to be grafted, the rabbi did not permit the recital of a blessing over the etrog and instead ruled that the blessing should be recited in Aramaic, without mentioning God's name.[21]

20.2 The Controversy in the First Half of the Nineteenth Century

We have contradictory testimonies regarding the Torah leaders' use of Corfu etrogim up to the controversy that erupted in 1845. Regarding Rabbi Chaim of Volozhin (1749–1821), Rosh Yeshivah of Volozhin in Lithuania, some claim he was stringent in especially taking a Corfu etrog due to its splendid appearance, while others claim he actually invalidated them.[22] Regarding Rabbi Yisrael Lipshitz (1782–1860), author of *Tiferet Yisrael* and Rabbi of Danzig, his son declared that his father was particular to recite the blessing over a Corfu etrog.[23] There are also testimonies that Rabbi Akiva Eiger (1761–1837), one of the leading Ashkenazi halakhic authorities in the first third of the nineteenth century, and that Rabbi Yaakov of Karlin (d. 1844), one of the leading halakhic authorities in Lithuania in the generation after R. Chaim, especially sought after Corfu etrogim, while others claim that these were actually Corsica etrogim.[24]

A turning point in the halakhic dispute came from the ruling of Rabbi Ephraim Margoliot (1760–1828) of Brody, author of *Beth Ephraim* and one of the leading halakhic authorities at the end of the eighteenth century and the first third of the nineteenth century, who extended the permission to use Corfu etrogim not only in extreme circumstances when there are no other etrogim available but even in regular

[20] Ibid., 20, 2.

[21] Moshe Zlotavi, *Birkat Moshe* (Berlin, 1883), 28.

[22] See Nahum M. Kahana, "Al Devar Etrogei Corfu," *Ha-Levanon*, 1875, issue 7, 22, in a note.

[23] See *Divrei Miluim*, 452.

[24] See Yitzhak Zioni, *Responsa 'Olat Yitzchak'* (Vilna, 1885; Brooklyn: Photo Edition, 2011), 17a *siman* 44.

times when there are also other available etrogim,[25] an argument that differed from all other approaches to the issue.

According to R. Margoliot, the Corfu etrogim were grafted with cuttings from etrog trees, and these cuttings were not prohibited since they were not grafted. They therefore differed from the case of the etrogim that were forbidden by the Maharam of Padua (in the sixteenth century), who discussed etrogim from kings' and nobles' private gardens that were grafted in order to produce larger, nicer fruit. But this was not the case in in the orchards from which the etrog fruits were collected for European Jews in the early nineteenth century.

According to R. Margoliot, the Corfu etrogim were superior to the Genoese etrogim, but this contradicted the view of the Chatam Sofer who spoke in praise of the Genoese etrogim.[26] Henceforth, the ruling of the Beit Ephraim, which was based on an authoritative eyewitness (as to the origin of Corfu etrogim), served as the foundation for all those who later permitted the Corfu etrogim.[27]

R. Margoliot's brother, Rabbi Chaim Mordechai Margoliot, the head of the Dubna beit din, supported the Beit Ephraim's approach, cited his brother's view in his work *Shaarei Teshuvah*, and relied on that ruling.[28]

But two of the greatest halakhic authorities of those times, the Chatam Sofer and Rabbi Shlomo Kluger (1775–1869), Av Beit Din of Brody, the city of the Beit Ephraim, ruled stringently in this matter against the use of the Corfu etrog. Following the ruling of R. Alshich in his times, the Chatam Sofer, in a responsum, invalidated the Corfu etrog, claiming that the beauty of the etrog appeared to be a graft of two fruits, and therefore it could not be considered an etrog. Regarding the signs given to validate an etrog, the Chatam Sofer wrote that two signs were sufficient.[29] Later, in another responsum, the Chatam Sofer wrote that none of the signs were actually considered biblical signs, except for the general sign of "the taste of its bark is the same as its fruit," while the other signs did not even have rabbinical status since they were not stated by our Sages, and therefore one might only rely on them to validate the Genoa etrogim, as R. Tirani ruled in his days.

According to the Chatam Sofer, even the sign of "the taste of its bark is the same as its fruit" was not a certain sign, and therefore one could only rely on our tradition, just as we rely on tradition regarding kosher birds that do not have signs of *kashrut*, and our tradition only recognizes the *kashrut* of Yanova (Genoa) etrogim.[30]

From a letter in the responsa of the Ketav Sofer, Rabbi Avraham Shmuel Binyamin Sofer (1815–1871), son and successor of the Chatam Sofer, it appears that most of

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[25] *Beit Ephraim*, 56.

[26] See Moshe Wiener (ed.), *Arba'at Haminim* (Jerusalem: Heichal Menachem 19,944), *siman* 1818, para. 51, and especially 230. See also Chatam Sofer, *Teshuvot Chatam Sofer*, responsum 25. Regarding the identification of Calabrian etrogim from Genoa etrogim, see Mordechai Gimpel Yaffe, "Kol Sheni," *Ha-Levanon*, 1875, issue 45.

[27] See *Divrei Miluim*, 18. See the letter of Rabbi Gershom Tanchum, Ra"m and Rav in Minsk, *Ha-Levanon*, September 18, 1875.

[28] See Shulkhan Aruch, Orach Chaim 649:7.

[29] See *Teshuvot Chatam Sofer*, Orach Chaim 183 (Vienna, 1895; Jerusalem, 1970).

[30] See ibid., 207.

the Pressburg community took Corsican etrogim; those who were wealthier and sought to fulfil the *mitzvah* “elegantly” took Corfu etrogim; while those who were even more stringent used Genoa etrogim. The Chatam Sofer himself was not always able to obtain a Genoa etrog, and had to make do with a Corsican etrog. This letter implies that the members of the Chatam Sofer’s community accepted the opinion of those who permitted the Corfu etrog, while his son does not mention the prohibition against the Corfu etrog.

As mentioned above, R. Kluger, who was the *dayan* and Maggid in Brody, as well as a recognized halakhic authority in Central and Eastern Europe, was also of the opinion that one may not rely on the signs, since in the same box of etrogim one finds different types of etrogim, so one etrog in a box cannot be an indication of the *kashrut* of the other etrogim. Regarding the validity of Corsican etrogim, of which doubts were raised due to their trees being planted together with other fruits and were therefore forbidden as *kilayim*, a doubt was heard from Rabbi Yaakov Ettlinger (1798–1871), one of the leading German rabbis of the time. R. Kluger argued that since the etrog trees were grown together with one of their own species, they were not forbidden as *kilayim*.[31]

20.3 The 1846 Controversy

The term “Corfu etrog of the 1845 controversy” not only refers to etrogim from the island of Corfu but also to those from the coasts of Greece and Albania opposite Corfu, and some add Crete.[32]

In addition to Corfu, the etrogim of that period were also imported from Parga, Rapiza, Yava, and Agia, which lie on the Epirus coastal strip, an area under Ottoman rule until 1864. Until then, Corfu was ruled by the British and was later transferred to Greek rule. Marapiza, Java, and Agia began to export etrogim only from the 1840s. According to later evidence, the etrogim from the new regions were from places that specialized in growing lemons, and with the increase in demand for etrogim these orchards started to graft the trees to produce etrogim, competing with the Corfu and Parga etrogim.[33]

20.4 Those Who Banned the Corfu Etrog

The controversy over the Corfu etrogim first erupted in 1844–1845 with the publication of the letters of rabbis who forbade the use of etrogim from Corfu itself, and only

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31 Shlomo Kluger, *Kin’at Sofrim* (Lemberg, 1847; Jerusalem: Photo Edition, 1974), 16b.

32 See Kahana, “*Al Devar Etrogei Corfu*,” 51.

33 See Shlomo Marcus, *Pri Etz Hadar* (Krakow, 1900), 38.

permitted etrogim that originated from Parga[34] and, for the first time the economic interests of the disputing parties were also discussed. Behind the publication of the bans was Rabbi Alexander Ziskind Mintz, a wealthy and learned Jew from Brody who made a living from the etrog trade, and was therefore interested in preventing the competition of imported etrogim from the new Corfu areas and the Albanian coast. He circulated a letter throughout the Jewish communities publicizing his claims, based on the testimony of his former partner who joined up with Greek merchants and who he claimed collected etrogim on the Albanian coast from new orchards that had no tradition of being non-grafted.

Mintz also wrote in his letter that at the beginning of the 1840s, following the reforms in the Ottoman Empire, the Sultan allowed anybody to plant etrog orchards, unlike the previous rule when the Sultan maintained a monopoly over Parga orchards. This change in legislation resulted in the extensive planting and grafting of etrog trees in areas close to Parga along the Albanian coast. And in these places, he claims, the orchard owners grafted their etrog trees with lemons in order to improve their produce.

The rabbis in Corfu and Trieste who gave rabbinic approval to these etrogim were unaware of their origin because they had no way of distinguishing between Parga etrogim and others, and Mintz therefore argued that their endorsements should not be accepted.[35] These claims were rejected by the rabbis who certified the etrogim.

Mintz also rejected the claim of the Chatam Sofer that the Yanova (Genoa) etrogim had a kosher tradition since the Middle Ages, since these were mixed with etrogim from the lake region and etrogim from Calabria. According to Mintz, the etrogim from the lakes' region were recognized as grafted, while Calabrian etrogim grew wild and therefore were presumably not grafted, although they did not have a high standard of *kashrut*.[36]

According to Mintz, only a few orchards were presumed to be non-grafted: Parga orchards, one orchard in Corfu (Binzer), one in Morocco, and one in Israel, while in other orchards grafted etrogim grew in the proximity of non-grafted etrogim and therefore one could not rely on the signs to determine their validity.[37]

Mintz also claimed that the signs given by the halakhic authorities in previous generations to distinguish between grafted and non-grafted etrogim did not stand the test of reality, and therefore there was no choice other than to rely on the halakhic presumption that etrogim used until today are considered kosher, and also on the testimony of the local rabbis. He added that he could recruit the Rabbi of Ioannina, which is near Corfu, as well as the local governors, to testify that Christians did not have access to Parga etrogim. Mintz also launched a written attack against the Rabbi

[34] See Shlomo Kluger, *She'elot Uteshuvot Pri Etz Hadar* (Lemberg, 1846). R. Kluger later changed his opinion and emphasized that tradition should not be relied upon, for "every day gardens are renewed and orchards multiply," idem, *She'elot Uteshuvot Tuv Taam Vadaat* (New York: Photo Edition, 1964), 67b.

[35] See Palagi, *Lev Chaim*, 76b; Kluger, *She'elot Uteshuvot Pri Etz Hadar*, 11a.

[36] See ibid., 32a.

[37] Ibid., 121, 76b.

of Corfu, who assisted Mintz's competitors and permitted the use of all the etrogim called Corfu etrogim. Apparently, Mintz also recruited a protest delegation of rabbis from Poland which was sent to the Rabbi of Trieste, who relied on the Rabbi of Corfu.[38]

As the storm over Corfu etrog raged, another controversy erupted regarding Corsican etrogim. From the beginning of the nineteenth century, opinions were heard preferring Corsican etrogim over Corfu etrogim because the Corsican trees were considered uncultivated and therefore also non-grafted. However, the validity of the Corsican etrogim was questioned by R. Ettlinger, who argued that the etrogim banned by the Torah authorities in the seventeenth and eighteenth centuries for being grafted included the Corsican etrogim.[39] But R. Ettlinger's ruling was in conflict with all known rulings at the time and made the situation even more difficult, especially with the increasing trend of disqualifying Corfu etrogim except for those imported from Parga.

R. Ettlinger doubted the significance of the signs and, therefore, like his predecessors, suggested relying solely on tradition.[40] A similar, albeit more moderate line, was taken by the Rabbi of Vienna, Rabbi Elazar Halevi Ish Horowitz, who permitted relying on signs in places where there was a tradition that the etrog was non-grafted.[41]

R. Kluger sided with Mintz,[42] throwing all his weight behind the ban on Corfu etrogim, except for those from Parga. He stated that the Corfu market was open to etrogim from orchards that did not originate in Parga or Corfu,[43] while one could rely on the rabbis' endorsement regarding the etrogim grown in Corfu, which were used by rabbis from across the Ottoman Empire, since these rabbis lived close to the cultivation of those etrogim and had firsthand acquaintance with their growth. Regarding the signs to recognize a non-grafted etrog, he supported the view of the Chatam Sofer that one could not rely on these signs and instead should rely only on tradition or the testimony of a reliable rabbi.[44]

However, regarding those etrogim that were not from Parga, he argued that one could not even rely on a rabbi's endorsement, or on the word of a non-Jew despite his professional responsibility and the rule that "a professional doesn't damage his reputation." Since the non-Jew sold the etrogim to another non-Jew, the professional could always evade responsibility by claiming that he did not grow the fruit, and he therefore lost his reliability. Also, we do not have absolute proof that the etrog was

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[38] Ibid., 84a.

[39] See Yaakov Ettlinger, *Bikurei Yaakov* (Altona, 1858; 2nd ed.; New York: Mefitze Tora, 1950), *hilchot lulav*, 648:53.

[40] Ibid.

[41] Elazar Halevi Ish Horowitz, "*Yad Elazar*," 57, 32–33.

[42] From his answer on the subject of etrogim, it appears that he replied regarding this matter to the Rabbi of Schwabach in Germany, to the Rabbi of Tshernovits in Bukovina, and to the Rabbi of Machnovka in Podolia. See Kluger, *She'elot Uteshuvot Tuv Taam Vadaat*, vol. 1, 171: 67–69.

[43] Kluger, *She'elot Uteshuvot Pri Etz Hadar*, 2a, b.

[44] Ibid., 6a, 8a.

grafted, and therefore the professional non-Jew would not lose his reputation even if we reproached him by trying to prove that the fruit was grafted.[45]

R. Kluger waged a stubborn battle over his position throughout the Jewish world, and enlisted Rabbi Yisrael, the Ruzhiner Rebbe, who ordered his followers not to take Corfu etrogim that did not originate in Parga.[46] R. Kluger emphatically declared that he would not retreat from his ban against the Corfu etrog, although he was willing to accept the tradition validating the Genoa and Corsica etrogim.[47]

Later, R. Kluger extended his ban, totally disqualifying all Corfu etrogim,[48] writing that even if one only had a Corfu etrog it may not be taken, and one certainly may not recite a blessing over it.

R. Kluger testified that he examined the different types of Corfu etrogim and found them all to be grafted. However, he would take a Corsican etrog, contrary to R. Ettlinger's opinion, as he believed that they were not grafted since they grew wild.[49]

His conclusion was that the cantor should recite a blessing on a kosher etrog, and the congregation should hear the blessing from him, or they should make a blessing on a Corsican etrog and then take a Corfu etrog.

R. Kluger admitted that both Corfu etrogim and Corsican etrogim had horizontal seeds which were a sign of a grafted etrog, nevertheless he claimed that the beauty of the Corfu etrog was what boomeranged against it: "Their appearance also has what to say, as the beauty of the Corfu etrog is proof of it being grafted, while the Corsican etrog's lack of beauty shows that it wasn't grafted. If the Corfu wasn't grafted, how is it so beautiful?!".[50]

He cited another clear sign against the Corfu etrog, in the fact that it had the taste of a lemon, which was proof of it being grafted, as ruled by the Bach. He wrote that all the other signs given by the rabbis for a non-grafted etrog were null and void against this strong proof.

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[45] Ibid., 7b, 11b.

[46] See David Assaf, *Rabbi Israel of Ruzhin: His Place in the History of Hasidism in the First Half of the Nineteenth Century* (Jerusalem, 1992), 298, Sects. 24 and 125 n. 84. Among the Rebbe's close followers were the rabbis of Tchortkow, Berditchov, Iasi, Kishinev, and Belz. See also Kluger, *She'elot Uteshuvot Pri Etz Hadar*, 28b.

[47] Ibid., 37a.

[48] Kluger, *She'elot Uteshuvot Tuv Taam Vadaat*, vol. 1, 171:67–69. His answers on this matter were sent to the Rabbi of Schwabach in Germany and also to the Rabbi of Machnovka in Podolia.

[49] Some challenged this consideration on the grounds that the etrog trees that grow with other trees in Corsica should be prohibited due to *kilayim.* See Shlomo Kluger, *Kinat Sofrim* (Lemberg, 1847; Jerusalem: Photo Edition, 1974), 45, 16b–17a.

[50] See Kluger, *She'elot Uteshuvot Tuv Taam Vadaat*, *hilchot taarovot*, 171: 68a.

20.5 Those Permitting the Corfu Etrog in 1846

The rabbi of Corfu, Rabbi Yehuda Bibas, challenged the rabbis who banned the Corfu etrog, testifying that all Corfu etrogim were non-grafted and were kosher, even those from Rapiza and Agia, which were the source of the controversy.[51] R. Bibas also relied on a report by experts at the time, that in hot countries there was no need to graft—on the contrary, grafting actually harmed the fruit. He reinforced his stance with the testimonies of rabbis who lived near the growing areas of the etrogim, such as the Rabbi of Ioannina. He also used the halakhic argument that "a professional doesn't damage his reputation," and therefore there is no reason for them to disqualify their own produce.[52]

R. Bibas, who was well acquainted with reality, claimed that the whole controversy was based on commercial competition. He compared the Parga etrogim to those of Rapiza and Agia, noting that they were all picked in the presence of a halakhic supervisor. He argued that Mintz's resentment stemmed from his fear of losing the monopoly he acquired over Parga etrogim. After all, Mintz himself testified that he had previously marketed etrogim, which he later claimed were grafted.[53]

Despite the weakness in R. Bibas's claims regarding the signs, which had already been rejected by the Chatam Sofer, and despite the weakness of the argument regarding the permit of the Beit Ephraim which certainly did not relate to the etrogim of Rapiza and Agia which were relatively new, R. Bibas challenged Mintz's claims to distinguish between Parga etrogim and those from Rapiza and Agia, and he gained the support of the rabbis of Ioannina and Thessaloniki.

The Jerusalem-based emissary Israel Moshe Hazan, who served as Rabbi in Rome and also in Alexandria, also fought against Mintz's claims and argued, as R. Bibas claimed, that they stemmed solely from business motives and that Mintz's goal was to harm his competitors.[54]

R. Palagi, who accepted the Ashkenazi ruling rejecting grafted etrogim, regarded all Corfu etrogim, as well as those from Rhodes, Phoenicia, Israel, and Morocco, as non-grafted.[55] According to R. Palagi, in order to remove halakhic validity from an etrog tree we need eyewitness evidence to disqualify it, which is not the case here. Unlike the Ashkenazi rabbis, R. Palagi was of the opinion that the signs distinguishing a grafted etrog from a non-grafted one do not disqualify an etrog that is presumed to be kosher. On the contrary, the purpose of the signs is to permit those etrogim from places that do not have any former presumption, but those that are already presumed to be kosher do not need any signs.

51 Kluger, *She'elot Uteshuvot Pri Etz Hadar*, 11a; Palagi, *Lev Chaim*, 122, 83b–84a.

52 See ibid., 84a, b, 85a, 86a, b.

53 Ibid., 87a, 88a, 89a.

54 Ibid., 77a, b.

55 Ibid., 79b, 80a.

20.6 End of the 1846 Controversy

The controversy did not end with the disqualification of the Corfu etrogim, as the Sephardic halakhic authorities, the most important of them being R. Palagi, extended the presumption of etrogim being non-grafted to all the etrogim, including those of Corfu, Rapiza and Agia, Rhodes, Kos and Phoenicia, Israel, Morocco, Genoa, and Calabria. R. Palagi presented many arguments to permit these etrogim, his main claim being that the etrog's suction from the lemon root does not change the etrog's genetic traits and therefore it is not invalidated as lacking a part—a claim supported by contemporary botanists.[56]

In addition to his ruling that the Corfu etrogim were not grafted, R. Palagi added that they had a presumption of being kosher, claiming that the grafting was of a similar species which is not considered prohibited grafting, or that a tree grown from a branch of a grafted etrog tree is not considered grafted regarding the laws of the etrog. The rabbis permitting these etrogim added that the etrogim in question would be certified by an authorized person and sold only by loyal Jews, and that the trade would be under the supervision of the beit din of the town where the etrogim were grown.

Turkish Jews relied on the etrogim of Rhodes and Kos, whose presumption of validity went back many generations.[57] However, R. Palagi feared to rely on presumptions of validity where the reality and facts changed from day to day, and he therefore based his permit on other claims, as well as subjecting the etrog trade to the authority of the rabbis of the communities, supposing that they would know to choose the suitable markets.[58]

R. Palagi ruled that if one does not have a non-grafted etrog, it is permissible to take a grafted etrog without reciting a blessing, and that one may check the etrog for signs—if the signs show that the etrog is not grafted, it is permissible to recite the blessing over it, even on the first day when the *mitzvah* is biblically obligated, and we are therefore usually stricter regarding the etrog on the first day.

The support of the two Sephardic rabbis, the rabbis of Corfu and Izmir, in favor of the Corfu etrogim, together with the backing of other Sephardic rabbis, created a solid front that was difficult to break. The Sephardic rabbis were joined by many Ashkenazi rabbis who supported Mintz's rival and former partner, Mordechai Bick. Bick brought etrogim from Rapiza and Agia, and among those permitting these etrogim were some of the greatest rabbis in Galicia and Russia, including Rabbi Yosef Shaul Nathanson of Lvov, Rabbi Zvi Hirsch Chayos of Zolkiew, Rabbi Meshulam Yissachar Halevi Ish Horowitz of Stanislav, and Rabbi Yaakov Meir Padwa of Brisk.[59]

Significant support for the Corfu etrogim came from the Rabbi of Nikolsburg in Moravia Rabbi Shlomo Quetsch, who was a student of R. Bennett and his successor as Rabbi of Nikolsburg. R. Quetsch relied on the ruling of the Beit Ephraim that two

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56 Ibid., 81a; Goldschmidt, "The Problem of the Grafted Etrog Today.".

57 Palagi, *Lev Chaim*, 82a.

58 Ibid., 52b, 53a.

59 Ibid., 89b, 90a.

signs are sufficient to validate the etrog, provided it has the shape, taste and smell of kosher etrogim, in order to be used on the first day of Sukkot (Tabernacles). The Nikolsburg beit din approved R. Quetsch's ruling.[60] From the wording of the rabbi's responsum, it appears that he suspected the rabbis who banned the Corfu etrog of siding with Mintz's economic interests.[61]

For the time being, the controversy was settled in favor of the Corfu etrogim due to the testimony of the local Rabbi that they were not grafted, and the established tradition that presumed their kosher status. The facts seemed to dominate the halakhic debate, according to which it was determined that Corfu's etrogim were not grafted, and even those who feared that they were grafted could rely on the ruling of the Beit Ephraim that the Corfu etrogim were only grafted with branches of grafted trees and therefore were not considered grafted with regard to the rules of the etrog. With the support of the leading Sephardi and Ashkenazi halakhic authorities, the view of those invalidating the Corfu etrog, which included Rabbis Kluger and Ettlinger, were rejected by the majority.

20.7 In the Wake of the Controversy

Whether because of the majority decision, or because of fatigue, the controversy waned in the years after 1846, allowing the Corfu etrog trade to develop and almost completely take over the etrog market in Eastern Europe.[62] Also, the halakhic literature printed after the 1846 controversy tended to permit the Corfu etrog, and the views of those banning the etrog were totally rejected.[63] In his responsum from 1857, Rabbi Yehuda Isser of Brisk approved the use of the Corfu etrogim and even included it in the category of "Jews' customs are considered Torah."[64] A similar stance was taken by R. Meshulam Horowitz (1808–1878), one of the greatest rabbis of Galicia at the time, who refuted one by one the arguments of those banning the Corfu etrog and established that even the grafted Corfu etrogim had an assumption of being kosher, thus extending the permit even beyond that of the halakhic authorities who preceded him.[65]

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60 See Shlomo Quetsch, *Chochmat Shlomo in Har Hamor* (Vienna, 1861), 2–3, 31–32.

61 The beginning of R. Quetsch's reply clearly implies this: "And they have elaborated in invalidating them, only permitting the etrogim brought from Parga which are all under the famous Rabbi Ziskind Mintz of Brod, who has permission to bring the kosher etrogim and to pay the price he decides." Ibid., 31a.

62 Press advertisements for Corfu etrogim, see "Etrogim Mi'Corfu Be'emet," *Ha-Melitz*, October 3, 1878, 288.

63 See Isser Yehuda, *Teshuvot Ezrat Yehuda* (Warsaw, 1862), 10. Also Alexander M. Lapidot, "Bidvar Etrogei Corfu Habaim Me'Rapiza Ve'iyeha," *Kevod Ha-Levanon*, 1870, issue 27, 212–14.

64 Ibid., 14b.

65 See Meshulam Y. H. Horowitz, *Bar Levai* (Lvov, 1861; New York: Photo Edition, 1990), vol. 1, 32b, 33c.

The Ashkenazi halakhic authorities consulted with their Sephardic colleagues and accepted their position because of the proximity of the Sephardic rabbis to the growing areas of the fruit, giving them an advantage in closer recognition of how the trees there were treated. Most rabbis tended to attribute the widespread and prolonged use of the Corfu etrogim as evidence of their *kashrut* and of their being non-grafted.

As long as the facts did not change, the halakhic authorities were pleased to preserve the custom of using the Corfu etrog, as it would have been difficult to cast doubt on the observance of a *mitzvah* in the way it was observed by Jews in previous generations—including leading sages, rabbis, and righteous men—and to doubt that those Torah observers were tricked into using invalid etrogim for so many years.

It is interesting to note that the Corfu etrog controversy was resolved in contradiction to the mainstream Ashkenazi ruling at the end of the eighteenth century, yet this did not prevent the later halakhic authorities from favoring the common custom over the rabbis' rulings, especially since the Sephardi halakhic authorities never questioned the validity of the Corfu etrog.

20.8 The 1874–1878 Controversy

The controversy resurfaced in 1874–1878 following the establishment of the cartel by the Corfu farmers in preparation for the Tabernacles holiday of 1874.[66] If in the past the centers of controversy were in Galicia, the Ottoman Empire, Hungary, and the German lands, this time the focus shifted to Lithuania, even though its leadership in halakhic rulings had weakened after the passing of the Vilna Gaon (1720–1797).

According to Rabbi Yitzchak Elchanan Spector (1817–1896), the Rabbi of Kaunas (Kovna) who was considered the leading authority of his times, Corfu etrogim were banned in Lithuania as early as the first quarter of the nineteenth century, and were only permitted by one rabbinical judge in the Vilna Jewish court, a student of R. Margoliot.[67] As R. Margoliot permitted the use of the Corfu etrogim since the farmers take saplings from a grafted etrog tree and replant it in the etrog tree, but do not actually graft the kosher tree, his student therefore also permitted the Corfu etrog. Due to his ruling, only a few were careful not to use the Corfu etrogim.[68]

A new reason to disqualify the Corfu etrogim then appeared—their high price. Now, the Rabbi of Warsaw and even the Rabbi of Corfu joined those who banned

[66] See "Pest," *Ha-Levanon*, September 22, 1875, 3–4; see Yehiel M. Pines, "Al Devar Etrogei Corfu," *Ha-Levanon*, August 2, 1876, 1–4.

[67] Ra"m, *Tochechah Megulah*, 56. It seems that the reference is to Rabbi Yechezkel Halevi Landa, who was appointed Rabbi of Vilna after the death of Rabbi Abli Pasweller. See Hillel N. M. Steinschneider, *The City of Vilna* (Jerusalem: 1880; Photo Edition, 1979), 35–36. We have no direct evidence that this was his ruling.

[68] Ra"m, *Tochechah Megulah*, 56, mentions Rabbi Chaim of Volozhin, Rabbi Tebli of Minsk, and Rabbi Avraham Shmuel of Raseinka and Eishyshok. While other sources say that R. Chaim actually used Corfu etrogim, R. Chaim was no longer alive during the said period. See also Kahana, "Al Devar Etrogei Corfu," 10–11.

the etrog, testifying that it was now customary to graft the etrogim in Corfu, and that there was also other evidence that one could not rely on the rabbis' endorsement of the Trieste etrog market.[69]

The controversy was raised by the editor of the *Ha-Levanon* newspaper, Yechiel Brill, who called for a ban on Corfu etrogim because of their high price, noting[70] that the commandment of taking the Four Species on Tabernacles was exceptionally popular among the Jews of Russia and Poland, "almost more than any other commandments."

An article in the *Ha-Levanon* newspaper also provides an updated description of the trade and transportation of etrogim to European Jews. The etrogim of Italy and Corsica arrived via the port of Genoa, and those from Corfu and the Albanian coast were transported to Trieste. The rabbis endorsing the etrogim issued their letters of endorsement both in the ports of origin and in the marketing ports, and thus the Corfu etrogim received approval from the rabbis of Corfu and Trieste.

Three types of etrogim passed through the port of Genoa—etrogim from Corsica, Riviera, and Bordighera. It should be noted that the Jews in England and Germany bought Moroccan etrogim, while the Ashkenazim used etrogim from Corsica and Corfu. After R. Spector banned the Corfu etrogim, his congregation started to acquire Corsica etrogim.[71] The Orthodox Jews in Germany refrained from using Israeli etrogim on the grounds that they were not tithed as required, or because non-tithed etrogim were mixed with the kosher ones.[72]

Other marketed etrogim included those from Bordighera, Calabria Calvirza, and Naples.[73] In France and Berlin, the Corsica etrogim were preferred, in other communities in Germany they recited the blessing over Bordighera etrogim, while the *hassidim* in White Russia were meticulous to take Riviera etrogim. The Rabbi in Genoa gave wide-ranging approval to all the Italian etrogim, which questioned the reliability of his endorsements.[74]

Brill added that the Corfu etrogim were divided among those grown in Parga, those from the Albanian coast on the Adriatic Sea, or from Crete. Some of those who permitted the Corfu etrogim wanted to limit their approval to Parga etrogim alone, a restriction the Sephardic Rabbi did not agree to and, already in the 1846 controversy, they permitted all Corfu etrogim without limiting the permit to any particular location.[75] Brill testified that the Rabbi of Corfu wrote on the box of

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69 Ibid., 57, 58. See also "Al Devar Etrogei Corfu," *Ha-Levanon* 12, 1876, issue 43. For three documents on the forgeries in Corfu and Trieste, see Pines, "Al Devar Etrogei Corfu".

70 Yechiel Brill, "Milim Achadot Odot Mischar Ha'etrogim," *Ha-Levanon* 11, 1874, 35–36. It is interesting to note that reports on the eve of Rosh HaShanah 1875 actually talked about lowering etrog prices. See "Pest," *Ha-Levanon*, 4. Perhaps the high price mentioned was from a previous year.

71 See "Michtavei Sofrim," *Ha-Levanon*, August 23, 1876, 5.

72 See Yechiel Brill, "Lehashiv Cheimah," *Ha-Levanon*, November 21, 1879, 1.

73 Ra"m, *Tochechah Megulah*. He discusses Naples and Bordighera in two different places.

74 Moshe Ra"m lists the places of origin of the etrogim, but does not include the Rivieras, perhaps because Bordighera is also in the Riviera. See there.

75 See n. 65 above.

etrogim that they were grown in Parga even when they actually came from Corfu and its surrounding areas, including Crete.[76]

The shift of the Corfu etrogim from being kosher to being invalid, which took place in the 1870s, was based on the testimony of the new Rabbi of Corfu that the grafted etrogim were not separated from the non-grafted ones.[77] This contradicted the testimony of the former Rabbi of Corfu who had proclaimed that all Corfu etrogim could be assumed to be non-grafted.

Brill further argued that all European etrogim were presumably grafted, nut that in recent generations the Jews had been lenient in regard to this law.[78] (See in this book "Diseases of the Etrog Citron and Other Citrus Trees" regarding the change in growing methods and the introduction of grafting in all citrus orchards, which was forced on citrus growers in the Mediterranean countries due to the spread of gummosis in citrus orchards that had hitherto been growing ungrafted trees.)

Brill's main claim was, as mentioned earlier, the high price of Corfu etrogim, which reached an average of six rubles per etrog.[79] This expensive price was extremely difficult for the impoverished Jews of Poland, Lithuania, Austria, and Hungary.

20.9 Preferring Israeli Etrogim Over Corfu Etrogim

The discussion on the Corfu etrog was conducted at the same time as the initiative of the Moshe Montefiore Foundation's emissaries to encourage the labor of Israel's Jews. The foundation was established when Montefiore reached the age of ninety, and its goal was to improve the living conditions of the Jews in the Holy Land. The foundation's representatives visited Israel in March 1875 and recommended employing

[76] Bali B. Diamant, "Al Devar Etrogei Corfu," *Ha-Levanon*, September 22, 1875.

[77] See Horowitz, *Bar Levai*, 19; Pines, "Al Devar Etrogei Corfu"; Yosef Z. Stern, "Al Devar Etrogei Corfu," *Ha-Levanon*, September 8, 1875, 2, and also the's comment.

[78] It appears from Brill's words that etrogim were also imported from Morocco, although they were not attractive and lacked the *pitam*. R. Ettlinger and his followers preferred the Moroccan etrogim because of the high probability that they were non-grafted, as they believed that the Moroccans did not know how to graft. This assumption of R. Ettlinger was not acceptable to Rabbi Nathan Adler (1804–1890), Rabbi of London, who claimed that only the Sephardim used Moroccan etrogim, but the Ashkenazim did not for fear that they were grafted. See Yaakov Sapir, "Michtavei Sofrim," *Ha-Levanon* 13, 1876, issue 3, 20–22. Those who banned the Corfu etrog had to accept the halakhic suitability of the etrogim from Morocco, Corsica, and Israel. They claimed that the etrogim of North Africa, Yemen, and Israel never needed rabbinic endorsements since there was no fear of grafting, unlike the etrogim of Yaniva (Genoa) and Corfu, where only certain orchards were permitted for use. See ibid., 21. According to Sapir, the only orchards permitted in Corfu were those in Parga, and in Genoa only the orchards of Bordighera. The *Ha-Levanon* newspaper itself, which led the public struggle against Corfu etrogim, published ads for the sale of etrogim from all other places except Corfu. See *Ha-Levanon* 13, 1876, issue 5, 40. There, etrogim from Israel, Corsica, Morocco, and Yaniva are mentioned.

[79] See "Pest," *Ha-Levanon*, 3–4. Stern, "Al Devar Etrogei Corfu," 1.

the local Jews to produce religious articles for their brethren in the Diaspora. The writer and journalist Yechiel Michel Pines suggested growing etrogim to promote the new *yishuv's* production, and he saw it as a realistic economic opportunity.[80] He calculated that Corfu traders increased the price of etrogim to fifty times their true value. Pines not only intended to spare Jews from extra expense but also believed that the money could help support the *halukah* (the organized collection and distribution of charity funds for the Jews living in the Holy Land), which was collapsing under the growing needs. Pines added that the Corfu etrogim had never been cleared from possibly being grafted, and that the supervisors could not be relied on.

Pines advocated for the transformation of the Land of Israel into the land of the Jewish nation, and his interest in etrogim was only a small aspect of his broad agenda. Nevertheless, Pines's article touched a sensitive nerve among all Jews, as shortly before the publication of his proposal, a delegation from the Moshe Montefiore Foundation had sharply criticized the *halukah* and the locals' lack of productivity.

The foundation's criticism hurt the feelings of the leaders of the Ashkenazi *yishuv*, and *Ha-Levanon's* Brill leaped to their defense, writing that although the Jews of the country tried to grow etrogim, their income from exporting the etrogim was minimal. Also, their distance from European markets raised the price of the Israeli etrogim in comparison to the Greek etrogim.

Brill's and Pines's objection to the Corfu etrog hit its mark, and R. Spector forbade his community to use the Corfu etrog until the facts were clarified. He encouraged leading members of his community to undertake to sell Israeli etrogim in order to ensure their marketing to his people at a reasonable price. Yet R. Spector only partially responded to the charges against the validity of the Corfu etrog, restricting his ban to members of his community and only for a limited time.

Those turning to R. Spector hoped that his status as the greatest rabbi of the generation would lead to an extension of the ban on these etrogim in other communities, which indeed was the case in certain places.[81] It is not clear what the basis of R. Spector's ban on Corfu etrogim was—was it the need to lower the high price, doubts regarding their *kashrut*, the desire to support the Jews in Eretz Israel as Pines argued, or all three?

It is clear, however, that R. Spector had an interest in limiting the influence of the Corfu etrog's traders, as he put considerable effort into the matter, even enlisting his close aids. Rabbi Yaakov Lipshitz, R. Spector's secretary, published an article in the *Ha-Levanon* newspaper linking R. Spector's ruling with Pines's wishes to establish

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[80] Yechiel M. Pines, "Al Devar Yishuvah shel Eretz Yisrael," *Ha-Levanon* 12, 1875, issues 35–36. Yechiel Michal Pines (1843–1913) immigrated to Israel in 1878 as the representative of the Moshe Montefiore Testimonial Fund. He was close to the leadership of the old Ashkenazi *yishuv*, active in the establishment of new neighborhoods outside the walls, a representative of Hovevei Zion in Israel (1887), a member of the executive committee of the Odyssey Committee (1892–1890), and an early exponent of religious Zionism. See Yosef Salmon, "Yehiel Michel Pines: A Historical Figure," *Milet* 1 (1983): 262–72.

[81] "Tikkun Gadol," *Ha-Levanon* 12, 1875, issue 39; Alexander M. Lapidot, "Petach Charzuvot," *Ha-Levanon* 12, 1875, issue 46.

a new economic base for Eretz Israel's residents.[82] In the editor's comment, Brill expanded on the issue by confirming that even without Corfu etrogim there would be no shortage of etrogim for European Jews, supplied from the provinces of Italy and Morocco, and that Israeli etrogim would now enter the market. While admitting that the Israeli etrogim were not as elegant as the Corfu ones, he claimed that their internal beauty and the fact that there was no doubt regarding their *kashrut* overrode the external beauty of the Corfu etrogim.[83] These claims by *Ha-Levanon's* editor caused such storm that he was forced to admit that the few Israeli etrogim available were not able to fill the high demand of the Jewish communities in Russia and Poland.[84]

Gimpel Yaffe, Rabbi of Ruzhany in the Grodno region and Pines's rabbi and teacher, joined the discussion. R. Yaffe's remarks were quoted in *Ha-Levanon* alongside the ruling of the Mabit, one of the greatest halakhic authorities in Safed in the second half of the sixteenth century. Both minimized the importance of the etrog's beauty and favored the Israeli etrogim.[85] R. Yaffe sought to extend the ban on the Corfu etrog in order to elevate the value of the Israeli etrog due to his affection for the Land of Israel. He criticized Brill for retracting his support for the Israeli etrogim and for admitting there would not be enough Israeli etrogim to meet the high demand, writing: "Whoever loves the land will take these etrogim for the *mitzvah*… because the lovers of the land will prefer its fruits due to their holiness, and as a remembrance of Israel during the festival of Tabernacles."[86]

Yaffe's Zionist doctrine had not yet been publicized, but its first echoes were now heard in the controversy over the Israeli etrog. He based his claims on the testimony of Rabbi Yehosef Schwartz, author of *Tevuot Ha'aretz*, who wrote in his first edition that the etrogim of Eretz Yisrael were not grafted,[87] and he had no doubt that they should be preferred over etrogim from other places, which were all possibly grafted.

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82 "Tikkun Gadol".

83 "The's note," *Ha-Levanon* 12, 1875, issue 46. Brill also adhered to the teaching of the Gemarah, which derives from the word *hadar* that it "stays on the tree from year to year," a feature that in his opinion characterizes the non-grafted etrog.

84 Brill assumed that buyers would not renounce their demand for a *pitam*, which is a sign of beauty and also has a halakhic benefit, while the Israeli etrogim lacked pitams. See Ettlinger, *Bikurei Yaakov*, *hilchot lulav*, 648:23. Brill discusses the issue of pitams and claims that there were many etrogim without pitams in Israel, Morocco, and Corsica, and that in Morocco and Israel they used etrogim without a *pitam.* See the editor, "Al Devar Ha'etrogim," *Ha-Levanon* 11, 1875, issue 41.

85 "Shnei Kolot Al Devar Ha'etrogim," *Ha-Levanon* 11, 1875, issue 45.

86 "Kol Sheni," *Ha-Levanon* 11, 1875. Yaffa repeated in his remarks the concept first raised by Brill, that of "the external beauty" of the Corfu etrogim, which he also called "small beauty," versus the "internal beauty" of the Israeli etrogim, which he preferred. It is evident that Yaffa was the one who initiated these concepts. Mordechai Gimpel Yaffe, Rabbi of Rozana in the Grodno region, was one of the first Russian rabbis to advocate the settlement of Eretz Israel (even before 1881). In 1888, he immigrated to Israel, settled in Yehud and served as Rabbi of the colonies.

87 Yehosef Schwartz, *Tevuot Ha'aretz* (Jerusalem, 1845), 383. In the book's first edition, he does not mention grafted etrogim in Israel, but in the second edition (1900) Lunz admitted that there were grafted etrog trees in the country planted by Arabs, and that the rabbis of Jerusalem were careful not to buy from them. Rabbi Binyamin Bali of Passwell also mentions the obligation to buy etrogim

Another rabbi who favored the prohibition of the Corfu etrogim was Rabbi Alexander Moshe Lapidot (1819–1906), Rabbi of Raseiniai, Lithuania, one of the prominent rabbis of his time, who expressed his views on many public affairs. R. Lapidot admitted that economic considerations carried weight in halakhic decisions, and that those who permitted the Corfu etrog—including himself—did so "due to the circumstances, in order to supply cheap etrogim." Therefore, in his opinion, when the Corfu etrog became more expensive, there was no more reason to permit them.[88] According to R. Lapidot, the whole controversy was not respectable, and it should be stopped due to more serious issues facing the Jewish public.

Etrog traders from Israel, Yehudah Leib and Benjamin Beinisch Salant, made direct contact with European markets, with one of them traveling to Europe several months before Tabernacles 1875 equipped with a letter of recommendation from Rabbi Meir Auerbach, Rabbi of Jerusalem,[89] to sign a contract for the purchase of the Four Species from Israel.[90]

On the other hand, there were those who rejected the expectations that growing etrogim in the Holy Land would improve the livelihood of the country's Jews. Joseph Rivlin, secretary of the General Committee of All Kollels, argued that the proposed programs were futile, as the Kollels had already tried exporting etrogim grown in Israel, but the revenues did not cover the expenses. The problems were the distance to the destination countries, which not only increased the transportation expenses but also caused damage to the fruits that rotted on the way, as well as the poor quality of the etrogim grown in Israel.[91] Thus, Rivlin actually confirmed the doubts Brill had already aired.

The ban imposed by R. Spector on Corfu etrogim raised concerns that the other etrogim imported from Italy, Corsica, and Morocco would become more expensive as a result, meaning the ban would backfire. Therefore, a concentrated purchase was proposed so that the merchants could not raise the prices. Brill's objective was to lower the price of etrogim to the prices of lemons and oranges, which were also expensive enough in those days in European markets.[92]

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from the Land of Israel. See Binyamin Bali, "Al Devar Etrogei Corfu," *Ha-Levanon*, October 22, 1875, 1–2.

[88] Alexander M. Lapidot, "Hadrat Kodesh," *Ha-Levanon* 11, 1875, issue 45.

[89] Yehuda L. Salant and Benjamin B. Salant, "Etrogei Eretz Hakedoshah," *Ha-Levanon*, July 12, 1876, 8.

[90] Ibid.

[91] Yosef Rivlin, "Jerusalem," *Ha-Levanon* 11, 1875, issue 45.

[92] "The's note," *Ha-Levanon* 11, 1875, issue 46, and see also "The's note" *Ha-Levanon* 11, 1875, issue 40.

20.10 The Continued Controversy Over Corfu Etrogim

Pines's articles, which connected the *kashrut* of the Corfu etrogim with the productivity of Israel's Jews, provoked opposition among his colleagues in Israel and Lithuania. Brill, Rivlin and Lipshitz feared that this would prompt criticism of the old *yishuv*, and they also doubted the economic benefit of exporting etrogim from the country due to trade difficulties.[93] But beyond the economic question, some raised the issue of the ideal lifestyle in the Holy Land: those who opposed the export of Israeli etrogim preferred to preserve the ascetic character of the old *yishuv*,[94] while Pines dreamed of a modern national settlement.

R. Spector's ruling affected other communities, alarming the Corfu etrog's traders who claimed that the ban on Corfu etrogim was wholly based on economic considerations, stemming only from the high price of the etrogim. To remove doubt, R. Spector reiterated his ruling and again based the ban imposed on Corfu etrogim on two grounds—the high cost of the etrogim and the possibility that they were grafted.[95]

Ha-Levanon spearheaded the promulgation of the views doubting the *kashrut* of the Corfu etrog, and this was the newspaper's main theme throughout the controversy. The paper brought testimonies from the Rabbi of Corfu and from those involved in the marketing of etrogim, stating that they did indeed mix grafted etrogim with non-grafted ones.

An important testimony was tendered by Yaakov Sapir, one of the sages of Eretz Israel and a researcher of Jewish manuscripts, who visited Trieste, the center of the etrog trade, where he saw that all the *kashrut* certifications given there for etrogim were not worth the paper they were written on, and were primarily intended to enrich those signing the letters, i.e., the rabbis of Corfu and Trieste.[96] Sapir's testimony, and other testimonies, undermined the validity of the Corfu etrog, especially in the regions of Lithuania and Belarus.

The halakhic ramification of these testimonies was that those who blessed over Corfu etrogim committed a sin by reciting a blessing in vain. It is needless to stress the severe disappointment of the many Jews who strived to keep the commandments of the Four Species by paying high prices for their etrog, that their efforts were all in vain!

In view of the conclusive evidence not to rely on the endorsements of the rabbis of Corfu and Trieste,[97] the Corfu etrogim were banned by most halakhic authorities. The Malbim (Meir Leibush ben Yechiel Michel Weisser, 1809–1879), admitted that he had long known that the etrogim of Corfu were grafted, but "I was not able to

[93] Yechiel M. Pines, "Davar el Merivai," *Ha-Levanon* 11, 1875, issue 50.

[94] Yaakov Lipshitz, "Shaalu Shelom Yerushalayim," *Ha-Levanon* 11, 1875, issues 42–43. See also Yaakov Lipshitz, "Yehi Shalom Be'cheilech," *Ha-Levanon*, December 15, 1875, 1–2, on the need to use Corfu etrogim to cover the costs of the hospital in Jerusalem.

[95] "Moda'ah Rabbah," *Ha-Levanon* 12, 1875, issue 3.

[96] See "Al Devar Etrogei Corfu," *Ha-Levanon* 12, 1875, issue 4.

[97] Yechiel M. Pines, "Ad Kamma Yesh Lismoch al Edut Hechsherei Triest Bichlal," *Ha-Levanon* 12, 1875, issue 1.

speak, knowing that I won't be heard."[98] Now, he declared that he preferred the Israeli etrog because of the *mitzvah*, the ban on Corfu etrogim, and also to "give life to those living in the Holy Land and help the settlement of the country."[99]

Other rabbis followed R. Spector and prohibited the Corfu etrog, among them Rabbi Natan Adler, Rabbi of England and Rabbi Shmuel Zanvil Klapfish, one of the rabbinical judges of Warsaw. Other prominent rabbis who supported the ban were R. Yaffe of Ruzhany, Rabbi Yosef Zecharia Stern of Siauliai, R. Lapidot of Raseiniai, and Rabbi Baruch Halevi Epstein of Novardok.

The general ban on Corfu etrogim[100] overturned the decision reached thirty years earlier affirming their *kashrut*. Now, the only etrogim accepted as kosher were those from Israel, Morocco, Corsica, and Genoa, and the attack on Corfu etrogim compelled support for the etrogim from these places, although a number of doubts had already arisen regarding these etrogim as well.[101]

Following the tradition of the Chatam Sofer which limited the permit to Genoa etrogim could not help the situation in light of the market's expansion and diversity. There were relatively few Genoa etrogim, and these could not supply the demand of all the Jews.

The halakhic ruling that the Corfu etrogim were grafted was not accepted by many believing Jews, who could not acknowledge the fact that Jews over the generations had used invalid etrogim, and many continued to use Corfu etrogim. The halakhic solution was therefore to define the Corfu etrogim as "possibly" grafted, a definition that was consistent with the known data, and which meant that a blessing over a doubt is not a blessing in vain. Echoes of this trend can be found in the words of those who banned the Corfu etrogim such as R. Stern of Siauliai, who tried to block the breach by permitting the Corfu etrog due to the doubt.[102]

Another way to solve the difficulty was to argue that the phenomenon of grafting in Corfu was relatively new, and those who took these etrogim in previous years had indeed used non-grafted etrogim.[103] This claim, although ostensibly at odds with the long tradition of the halakhic authorities who banned Corfu etrog as early as the second half of the eighteenth century, had a basis in the new horticultural practices in the middle of the nineteenth century which required the grafting of all citrus trees, including those in Corfu and etrog orchards near the Mediterranean ports, where gummosis disease became a severe epidemic problem (see "Diseases of the Etrog Citron and Other Citrus Trees," in this book).

Obviously, Corfu etrog merchants opposed the ban and argued that R. Spector should have consulted with other rabbis on this matter. Traders also threatened to harm the interests of those who banned their etrogim and pressured them to change their

[98] Stern, "Al Devar Etrogei Corfu,"The's note.

[99] Meir L. Weisser, "Al Devar Etrogei Corfu," *Ha-Levanon* 12, 1876, issue 49.

[100] See the testimony of Alexander Moshe Lapidot and the's note, *Ha-Levanon* 11, 1875, issue 40.

[101] Baruch H. Epstein, "Kategoria Be'talmidei Chachamim," *Ha-Levanon* 12, 1876, issue 49.

[102] Stern, "Al Devar Etrogei Corfu".

[103] Pines, "Ad Kamma Yesh Lismoch," 103–02; Moshe Bar-Yosef, "Bein Hachushchash Vehabaaya Hayehudit," *Haaretz*, October10, 2001.

opinions.[104] Following the publication of R. Spector's ruling (May 1875) banning the Corfu etrogim, two rabbinical judges from Vilna, Rabbi Bezalel Katz HaCohen and Rabbi Yosef Ben Raphael, set out to gather rabbinic endorsement in support of the Corfu etrogim (August 1875).[105] Leading this initiative was R. HaCohen, one of the most prominent rabbinical judges in Vilna, a position in which he served for about thirty years. R. HaCohen was known for his many responsa in *halakhah* and his innovations printed at the back of the Gemarah under the name Mareh Cohen. He was included in the list of rabbis who had banned the Corfu etrog, but he denied this.

R. HaCohen admitted to visiting Trieste in 1864 and witnessing that the rabbinic endorsements for the etrogim of Corfu and Corsica were worthless, but despite this he ruled that they were permitted based on the ruling of R. Margoliot.[106] At the same time, Rabbi Gershom Tanchum of Minsk published an article in *Ha-Levanon* quoting the opinions of famous rabbis in favor of Corfu etrogim as published during the 1846 controversy, including the testimony of R. Eiger's son that his father, who was one of the most prominent Torah scholars, was stringent in only using a Corfu etrog.[107]

The controversy raged and split families, with reports of rabbis banning or permitting Corfu etrogim often contradicting each other. Each side tried to gather evidence for its stance, and there were also rabbis who changed their minds. But the etrog merchants continued to trade in their Corfu and Corsica etrogim.[108]

20.11 Pamphlets for and Against

The booklet *Divrei Miluim Lehachoveret Hora'at Heter* was published in September 1875, on behalf of R. HaCohen,[109] who had, interestingly, a year earlier ruled that the Corfu etrogim were invalid.[110] In the introduction to the booklet, the printers claimed that the ban on Corfu etrogim was based on their high price, which indeed is apparent from R. Spector's public letter, and they therefore argued that since the halakhic ruling was mixed with foreign considerations it could not be accepted. According to them, such a ruling undermined rabbinic rulings: "For all the words of the Torah are delivered to the rabbis of the generation alone, and if they have the

[104] Ibid., see also "Al Devar Etrogei Corfu," *Ha-Levanon* 12, 1875, issue 6.

[105] Yosef ben Raphael and Bezalel HaCohen, "Al Devar Etrogei Corfu," *Ha-Levanon*, June 15, 1876, 1.

[106] *Divrei Miluim*, 18.

[107] Kahana, "Al Devar Etrogei Corfu," 22–23, in comments. See Baruch Halevi Epstein, "Kategoria Be'talmidei Chachamim," *Ha-Levanon*, July 26, 1876, 2.

[108] See Yaakov Werber, "Lasocharim Hanichbadim," *Ivri Anochi*, October 4, 1878, 8.

[109] *Divrei Miluim.*

[110] See Stern, "*Al Devar Etrogei Corfu*," 1.

power to incline all the words of the Torah to however they desire… the whole holy Torah will collapse and expire."[111]

Those permitting the etrog realized that non-halakhic considerations, and not only in economic affairs, were included in the considerations to ban the etrog, as we will see later.[112] They also publicized that even the Jews living in Israel were diligent to take Corfu etrogim, and for this reason there was a need to call on the local Israeli Jews not to pay more than a third more than their price for a better etrog in order to prevent a price hike.[113] The permitters also argued that the Corfu etrogim had the same signs as Israeli ones, and therefore any distinctions made between them were null and void.[114]

In response, the booklet *Tochechah Meguleh* (An Open Reproach) was published at the initiative of R. Spector, under the name of Moshe Ra"m, Ra"m being the acronym of the Reish Mesivta (seminary head) in Kovna.[115] Using sharp language, the author fought to refute the arguments of the Vilna rabbis and to block their "dangerous" permission of the Corfu etrogim. Among those influencing R. Spector were Rabbi Zechariah Yosef Stern of Shavili, Rabbi Yaakov Moshe Karpas of Kovna, and others.[116]

Permitting the use of the Corfu etrog was a "scandal in the house of Israel," and a "time to act on behalf of God," the author of the pamphlet declared. According to him, a scandal so harmful to the Jewish religion had not occurred since the beginning of the Enlightenment, "since the time when infidels began to lie."[117] The author presented his reasons for disqualifying Corfu etrog and argued with those who disagreed with him. First, he criticized the Corfu traders who raised the price.[118] Second, he argued that halakhic assumptions and tradition were acceptable where there was no change in reality, but regarding trees and grafting there were constantly many changes, as also attested by the Rabbi of Corfu, so halakhic assumptions and tradition could not be relied upon.[119]

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111 *Divrei Miluim*, 3.

112 There, 5–6, according to some rabbis in Ashkenaz, if Corfu etrogim were to be banned, it would raise the price of Corsica etrogim.

113 Ibid., 17.

114 See "Al Devar Etrogei Corfu," *Ha-Levanon* 12, 1876, issue 43.

115 *Tochechah Megulah* was published at R. Spector's initiative, see Yaakov Lifshitz, *Zichron Yaacov* (Kovna, 1927; Bnei Brak: Photo Edition, 1968), 175. The author of the booklet was Zvi Hirsh Rabinowitz, R. Spector's spm. See Israel D. Beit Halevi, *Toldot Rabbi Chaim Elazar Wachs* (Tel Aviv, 1950), 73, n. 1.

116 Lifshitz, *Zichron Yaakov*, 174.

117 Ra"m, *Tochechah Megulah*, 3.

118 Ibid., 4–5. R. Margoliot's considerations in permitting Corfu etrogim because of their low price were ultimately ineffective with the increase in their price. Moreover, his permission was limited to etrogim from Parga, but in those days there was no accurate record of the origin of the fruit.

119 Ibid., 7. He rejected the claims of those permitting the etrog that "a professional doesn't damage his reputation" and therefore the orchard owners and the merchants would be careful not to graft or trade with grafted etrogim and should be trusted, a claim raised repeatedly during the controversy. Instead, he wrote that the etrog trees were mainly planted to eat its fruit, which improves with

Regarding the belief that "God does not cause the righteous to stumble," the author replied that this was similarly true in this case, as the Corfu etrogim had only now lost their *kashrut* following the testimony of the island's Rabbi and based on the evidence of the weakness of the supervision system, but this did not mean they were not kosher in the past. His halakhic argument were based on historical assumptions.[120]

In any case, the author of *Tochechah Meguleh* claimed that then, in the mid-1870s, the Corfu etrogim had neither evidence nor halakhic assumption to support their kosher status, so everyone must admit that one did not fulfill the commandment by using them. Moreover, he eliminated the fear that the ban on Corfu etrogim would prevent the observance of the *mitzvah* since, following the ban on Corfu etrogim, traders were bringing many etrogim from Morocco and Israel at reasonable prices.[121]

Although R. Spector's first ruling only banned Corfu's etrogim for his community and for his time, the ruling reappeared in the *Ha-Levanon* newspaper as a ban for all communities and forever.[122]

In *Tochechah Meguleh*, the controversy took on a new dimension, as it incorporated ideological considerations regarding the status of religious Jewry. The claims of R. HaCohen, that the forbidders opened "a way for the Reform movement" who would claim that the rabbis ruled according to their wishes, contradicted his own words.[123] In the author's terminology, R. Katz's approach to the etrog controversy was mere "contempt."[124]

The author maintained that contrary to the claims of the permitters, they were actually enacting a "desecration of God's Name," both by slandering the rabbis who forbade it and by opening a door for the Reform to claim that rabbis ruled randomly

grafting, and that the growers also managed to sell the grafted etrogim to the Jews after receiving their permits, so they had no reason not to graft the etrog trees and trade in the fruit (ibid.). The Jews of Lithuania and Belarus, the author added, were accustomed to using the etrogim of Corsica, and now the permitters of Corfu's etrogim were doubting those of Corsica in order to establish their own permits (ibid., 14). He therefore ruled that the Corfu etrogim should not be permitted by virtue of tradition, because it was clear that the entire system of supervision over them was not correctly conducted (ibid., 20).

120 "Indeed, fifty years ago, when the genius the Beit Ephraim permitted it, Italy was kept kosher [and the kosher practices of the etrogim could be relied upon, Y. S.], its rabbis were faithful to God, the number of etrogim was small and were under the control of the rabbis in the area. Therefore, this has nothing to do with slandering the earlier generations (ibid.)." How did R. Kluger ban the Corfu etrogim? The author replies that where there is a contradiction between a halakhic assumption and visual identification, visual identification prevails. R. Kluger found that Corfu etrogim were grafted, based on signs in the etrogim themselves. All the forbidders claimed that the Corfu etrogim were not kosher since they had no kosher marks, and the whole consideration of the etrog signs were to be more stringent and not lenient, and were therefore only applicable to etrogim that were known to be kosher, as in Genoa. See "Al Devar Etrogei Corfu," *Ha-Levanon* 13, 1876, issue 47.

121 Ra"m, *Tochechah Megulah*, 34.

122 See, for example, "El Socharei Ha'etrogim," *Ha-Levanon* 13, 1876, issue 42, 388.

123 Ra"m, *Tochechah Megulah*, 58–59.

124 Ibid., 60.

and arbitrarily: “It is a desecration of God’s Name, and is close to destruction of religion, and therefore no respect is due to these rabbis.”[125]

The etrog controversy, which was a halakhic controversy that lasted for many generations, now took a new turn, incorporating ideological claims from both sides while taking into consideration the reaction of the non-religious community as a halakhic consideration. It appears that this was the first expression of Orthodox ideology in halakhic rulings in Eastern Europe.

This is how Yaakov Lifshitz saw it when he wrote the Orthodox version of the history of Russian Jewry in the nineteenth century: “We, who are engaged in expanding Orthodox literature, have found an object in this matter for another purpose and intention [i.e., non-halakhic, Y. S.] to give rabbis a platform in literature on matters that concern *halakhah*, and we will also include other intentions for strengthening the religion… therefore we also made an effort to publish this prohibition.”[126]

Indeed, only external halakhic considerations could lead to such completely different halakhic rulings.

20.12 Israeli Etrogim

There is evidence of trade and exports of etrogim from Israel since the 1850swhen etrogim were grown around Umm al-Fahm, Nazareth, Safed, Tiberias, and Nablus. The first merchants were from the Ashkenazi community, and among the etrog growers and merchants was the writer and researcher Yaakov Sapir, who served as the collector of the Perushim Kollel to various countries, and Yehuda Leib and Benjamin Beinisch Salant. The Salant family established an etrog trading company as early as 1859,[127] and in that year the Sephardic traders Motro and Baruch entered the etrog trade.[128]

As previously mentioned, those who preferred Israeli etrogim over Corfu etrogim assumed that the technology of grafting was not yet known in the East.[129] As early as the 1840s, the researcher Yehosef Schwartz testified that the Israeli etrogim were not grafted.[130]

Sapir confirmed this, and after a tour of the etrog harvest in 1854 conducted by him, he reported that he had not found any grafted etrog trees in Umm al-Fahm,

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[125] Ibid., 120.

[126] Lifshitz, *Zichron Yaakov*, II, 174.

[127] See Hana Ram, “Hatchalot shel Avodat Ha’adamah Biyedei Yehudim Be’ezor Yaffo,” *Cathedra* 6 (January 1978): 20, n. 4.

[128] See Dan Porat, “Hapulmos al Etrogei Eretz Yisrael Beshanim 1875–1889,” *Cathedra* 6 (January 1978): 31. Malachi claimed the Sephardim were the first in this trade, see Malachi, *Letoldos Mischar Ha’etrogim*, 170.

[129] See Yoel M. Salomon,’*Pri Etz Hadar*’: *Judea and Jerusalem* (Jerusalem: Mossad Harav Kook, 1955), 102.

[130] See Schwartz, *Tevuot Haaretz*; Marcus, *Pri Etz Hadar*, 102.

and had seen only one grafted tree, in Jerusalem. According to Sapir, the advantage of the Israeli etrog was symbolic "to be crowned with the fruit of Jerusalem… and they will soon be privileged to see the goodness of God, to return to the Land as beforehand."[131]

The history of Corfu etrogim in Israel is not clear enough. According to one testimony, in the late 1850s and early 1860s etrog trees were imported into Israel from Corfu and were planted in Jaffa,[132] while another testimony spoke of the planting of Corfu etrog trees in Jaffa only in the late 1860s.[133] However, Israel's etrog history actually began in the 1840s, when the rabbis of Corfu sent a box of etrogim to Israel, probably from Parga, to the Rishon Letzion Rabbi Chaim Abraham Gagin. Sapir assumed that since the etrogim were sent to the Chief Rabbi, the senders must have made sure to send non-grafted etrogim.

At the same time, two Jews bought land for planting an etrog orchard in Jaffa, and they turned to R. Gagin and asked him to send them after the holiday the etrogim he had received as a gift from Corfu. They sowed the seeds of these etrogim, and after eight years the etrog trees bore fruit. In 1849, they sold their orchard to Moshe Montefiore, and branches from these trees were planted in all of Jaffa's orchards, producing etrogim with pitams.[134]

With this background, one can understand the struggle over the etrogim between the Sephardic and Ashkenazi merchants, which began in 1877. The Ashkenazim defamed the Jaffa orchards, the source of the Sephardic merchants' etrogim, claiming that they were from Corfu and were therefore grafted.[135] Although the Sephardi Rabbi Aharon Uziel permitted the etrogim after uprooting the grafted trees, the Ashkenazim were not convinced. It should be noted that the Sephardim also considered the etrog trees not inspected by R. Uziel as being grafted. The Ashkenazim were diligent in using only the etrogim of Umm al-Fahm and the Galilee, claiming that according to halakhic assumption and tradition they were not grafted. This was inaccurate, since only the orchard in Umm al-Fahm had the halakhic assumption.

In the 1877 controversy, too, business competition was at the root of the controversy, as claimed by Sapir, who supported the Sephardim in the 1846 controversy.[136] The Ashkenazi religious courts published their approval of the Umm al-Fahm and Galilee etrogim, and invalidated the Jaffa etrogim—even though the halakhic assumption only related to the Umm al-Fahm etrogim[137]—and they also testified that the

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[131] Yaakov Sapir, "Sipurim Me'eretz Nachalat Avoteinu," *Shomer Zion HaNe'eman* II, 1854, issues 178–79, 355, 357.

[132] See Abi"r's letter to Yoel M. Salomon in Salomon, '*Pri Etz Hadar*': *Judea and Jerusalem*, 61.

[133] Pamphlet, *Pri Etz Hadar* (Jerusalem, 1878), 6, discussing the five years following the growth of grafted Jaffa etrogim, i.e., 1873. Later in his description he speaks of grafted trees in Israel from the beginning of the 1860s, see there 12.

[134] "Al Devar Etrogei Eretz Hakedoshah," *Ha-Levanon* 14, 1877, issues 14–15.

[135] Salomon, '*Pri Etz Hadar': Judea and Jerusalem*, 103.

[136] See *Ha-Levanon*, "Al De*var Etrogei Ha'aretz Hakedoshah"; Malachi, Letoldos Mischar Ha'etrogim*, 173.

[137] Salomon, '*Pri Etz Hadar: Judea and Jerusalem*', 101. See also "Teudah," *Ha-Levanon*, July 12, 1878, 8.

Israeli etrogim lacked pitams from the beginning of their growth, and were therefore kosher.

The Rishon Letzion Rabbi Avraham Ashkenazi opposed this ruling, and he invalidated all etrogim that lacked pitams, since they were not complete and were lacking part of the etrog, and could therefore not be used. This ruling validated the Jaffa etrogim, which had a halakhic assumption of being non-grafted, and disqualified the etrogim from the Galilee and Samaria used by the Ashkenazim. This ruling was in contrast to all the rulings that permitted etrogim without pitams from Israel, Morocco, and Bordighera, and was against the ruling of the Mabit from the sixteenth century.[138] Therefore, the publisher of *Ha-Levanon* believed that R. Ashkenazi himself did not sign the letter, but was signed by one of his assistants, who used his seal.

In an article in *Ha-Levanon*, R. Auerbach, the Rabbi of Jerusalem, rejected the claim of those who permitted the Corfu etrog for fear of *orlah* (the prohibition to have benefit from a fruit in its first years of growth) in the Israeli etrog, proving that this fear had no basis since the Israeli etrog trees only bear fruit after five or six years after planting. He also claimed that the Israeli etrogim "are kosher without any doubt."[139] This was included in the report of a delegation of Jerusalem rabbis, which is discussed below.

20.13 Validity of Israeli Etrogim in General, and Jaffa Etrogim in Particular

With the growing controversy between the Sephardim and the Ashkenazim regarding the Jaffa etrogim, the rabbis of Jerusalem decided to send a delegation to examine the nature of the Jaffa etrogim. The delegation included the etrog merchant S. M. Zilberman, who was also a member of the Committee for All Kollels; Rabbi Shlomo Zalman Levi, a member of the Ashkenazi religious court, and the activist and journalist Yoel Moshe Salomon. All three also traded in etrogim, and it is difficult to say that this was an impartial committee. According to one testimony, they were also accompanied by Sapir, who was a partner with the Sephardi merchants.[140] The members of the delegation studied well the issue of grafting, which they published in a book, based on what they saw during August 1877.[141]

According to the testimonies of the orchard owners, the delegates reported that in the 1870s Jaffa etrogim were grafted,[142] and the Jerusalem merchants refrained from

[138] "Al Devar Etrogei Eretz Hakedoshah," *Ha-Levanon* 13, 1876, issue 47.

[139] Meir Auerbach, "Al Devar Etrogei Eretz Hakedoshah," *Ha-Levanon* 13, 1876, issue 42; "Al Devar Etrogei Eretz Hakedoshah," *Ha-Levanon*, June 1, 1877.

[140] Salomon, '*Pri Etz Hadar': Judea and Jerusalem*, 104–05.

[141] See pamphlet, *Pri Etz Hadar*.

[142] Ibid., 10–15. One cannot argue that the etrogim of the merchants and planters in Jaffa at the time of the delegation's visit were kosher because "an expert won't ruin his wares," since the plantation owners did not know the Jews' preferences.

exporting Jaffa etrogim, as they claimed that they were even on a lower halakhic level than Corfu etrogim as the Jaffa etrogim were never considered kosher.[143] The Jews of Jaffa themselves used Umm al-Fahm etrogim for the *mitzvah* and not Jaffa etrogim, buying the Jaffa etrogim after the holiday to make jam.

The Ashkenazi court ruled that the grafted etrogim should be banned, but added that there was no fear that etrogim growing on other trees came from grafted shoots, arguing that if they were the issue would be endless and all etrogim will be invalid.[144] However, R. Auerbach refused to support the court's ruling, stating that all Jaffa etrogim were presumably grafted and there was no difference between the first grafting and offshoots.[145]

The delegation was asked to also inspect the country's other orchards, and not just those of Jaffa, which it did after Tabernacles 1877, and they came to the conclusion that the orchards in Umm al-Fahm, Alma el-Shaeb, Hittin, and Tiberias were not grafted. On the basis of this testimony, the Ashkenazi court in Jerusalem permitted the etrogim from these places,[146] and Rabbi Shmuel Salant appealed to R. Spector and Rabbi Chaim Elazar Wachs (1822–1889), rabbi of Kalish and Piotrkow, to retract the ban on the etrogim from these places and to ban the etrogim of Jaffa.[147]

In the mid-1870s, the etrogim of Israel did not affect the etrogim of Corfu as the etrog orchards in Israel could not provide even a small percentage of demand abroad. Moreover, the distance of Israel from the center of demand raised the price due to transportation of the fruit, and impaired its quality.[148] But at the end of the 1870s, many etrog orchards were planted in the above places, as well as an orchard planted by Kiach (Kol Yisrael Chaverim) in Mikve Israel.[149] However, questioning the *kashrut* of the Corfu etrogim did not yet improve the priority of Israel's etrogim.

Sapir, who was an expert on etrogim after having traded in etrogim and was not dependent on the interests of the various communities in Israel, determined that there were grafted etrogim in Israel. He claimed that it was possible to distinguish between grafted and non-grafted trees, but that it was difficult to ascertain whether a fruit was from a grafted tree or not. Therefore, he argued that we must rely on the letters or attribution written by the rabbis at the place where the fruit is grown, and since this is more possible in Israel than abroad, the Israeli etrogim should be preferred.[150] These arguments were, years later, repeated by Rabbi Avraham Yitzchak Hakohen Kook (1865–1935), which concluded the dispute.

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143 Ibid., 4–7.

144 Ibid., 16–17.

145 Ibid., 17. In this judgement, he relied on R. Eiger and R. Posner.

146 Ibid., 18–20. See "Teudah," *Ha-Levanon*, July 12, 1878, 8.

147 See pamphlet, *Pri Etz Hadar*, 27–31.

148 Porat, "Hapulmos al Etrogei Eretz Yisrael," 32.

149 Ibid., 33; Malachi, *Letoldot Mischar Ha'etrogim*, 171.

150 See *Ha-Levanon*, "Al Devar Etrogei Eretz Hakedoshah," 120.

20.14 Rabbi Chaim Elazar Wachs and Israel's Etrogim

A special place in the etrog controversy and in initiatives to expand trade of Israeli etrogim is reserved for R. Wachs, an extraordinary figure in the rabbinical world of Poland in the last third of the nineteenth century. He was a wealthy man and a great Torah scholar with general education, knowledgeable about world affairs, and a public activist.[151] From 1868, R. Wachs served as president of the Warsaw Kollel in Israel, which encompassed all Polish immigrants in the country. In practice, he took upon himself the financial burden of the Kollel as early as 1862, after the imprisonment and deportation of Rabbi Dov Ber Meislish from Warsaw.

R. Wachs supported the productization of the Jewish community in Israel, although from a traditional approach rather than from a national angle.[152] His devotion to the affairs of the Jewish community in Israel stemmed from a personal recognition of the Israeli *yishuv*, and perhaps also under the influence of his Kalish community, which stood out in its close ties with the Jews of Israel.[153] The special unity of two wealthy Torah scholars who held major positions in relation to Israel's Jews—R. Wachs who headed the Warsaw Kollel and R. Auerbach, the Ashkenazic Rabbi of Jerusalem—opened the door for cooperation on various fronts, including the subject of etrogim.

R. Wachs devoted much energy to growing and selling Israeli etrogim,[154] and believed that it was a privilege to recite a blessing over an Israeli etrog, in addition to fulfilling the commandment. He saw in these etrogim a symbol of "Israel's air" and a *mitzvah* that has a connection with the coming of the Messiah.[155] R. Wachs wanted to turn the etrog trade into a lucrative industry that would support the members of the Warsaw Kollel in Israel that he headed. For this purpose, he wanted to dominate the etrog market in Poland in order to market the etrogim he grew in Israel.[156]

R. Wachs purchased land in Hittin as early as 1876 and planted etrogim, and later expanded his orchards and personally managed the sale of the etrogim, while the profits were transferred to the Warsaw Kollel. His activities were independent of the endeavors of Pines and his colleagues.

In correspondence between R. Wachs and Rabbi Eliyahu Gutmacher in 1874, printed at the beginning of the *Responsa Nefesh Chayah*, R. Guttmacher wrote that the "beginning of redemption" depended on the settling of the Land of Israel: "Let them begin to work the Holy Land," he wrote. In contrast, R. Wachs used less binding language, writing that the settlement of Israel "is the path rising to God,"[157] and he saw in the etrogim he planted in Hittin the beginning of the settlement of the land.

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[151] See Israel J. Trunk, "Polin—Zichronot Utemunot," *Merchavia* 1962, 18–19, 39–41.

[152] See Porat, "Hapulmos al Etrogei Eretz Yisrael," 37–38.

[153] See Israel Y. Eibschitz, *Toldot HaNefesh Chayah* (Jerusalem: Chorev, 1961), 31–32.

[154] Ibid., 30.

[155] See Beit Halevi, *Toldot Rabbi Chaim Elazar Wachs*, 72–74.

[156] See R. Wachs's letter to R. HaCohen, December 1877, in Eliezer Aurbach, *Chidushei Mohara"ch* (Warsaw, 1898; Antwerp: Photo Edition, 1969), 125–26.

[157] See *Teshuvot Nefesh Chayah* (Piotrkow, 1877), 10.

His initiative of planting etrog trees in Israel was also influenced by the controversy of the Diaspora etrog, and he stressed that he would be able to provide non-grafted etrogim: "And so the Jews will have clearly kosher etrogim for the *mitzvah* without any fear at all."[158]

The importance R. Wachs attributed to his enterprise is emphasized in his work *Nefesh Chayah*, which appeared in 1877. His first three entries are dedicated to the settlement of the land and the use of its etrogim, and his fourth entry bears the signatures of some 120 rabbis and rebbes who ruled that "wherever there is an etrog from the Holy Land, one shouldn't at the outset recite a blessing on Corfu etrogim."[159] This public call does not disqualify the Corfu etrogim from a halakhic point of view, but shows preference for the etrogim of Israel. Thus, R. Wachs formulated a more moderate approach than those in Lithuania who disqualified the Corfu etrog, and he left an opening to use the Corfu etrog when an Israeli etrog was not available.[160] This all appeared in a separate pamphlet that was widely distributed.[161]

Aside from distributing the pamphlet, R. Wachs corresponded with rabbis to persuade them not to use Corfu etrogim. These letters were not always consistent with his moderate approach, and he noted in them that he had no doubt that the Corfu etrogim were not kosher. He rejected all efforts to permit the grafted etrog and ruled that a grafted etrog was invalid, as it was missing the part that is not actually an etrog.[162] Moreover, he added, Israeli etrogim supported the Jewish community in Israel, which relied on the financial support of the Jewish communities abroad. Also, the Israeli etrogim influenced the price of all other etrogim and, thanks to the Israeli etrogim the Corfu etrogim were sold at a reasonable price.[163] To all this he added the special importance of the *yishuv* in Eretz Israel, and the necessity of the seal of the Court in Eretz Israel to the Hebrew calendar in the Diaspora: "That every year a

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158 Eibschitz claims that the orchards in the village of Hittin were planted as early as 1833. See Eibschitz, *Toldot HaNefesh Chayah*, 38. But, from R. Wachs's words in *Teshuvot Nefesh Chayah*, it is clear that he bought the orchards after the passing of R. Gutmacher and under his influence, see *Teshuvot Nefesh Chayah* where R. Wachs mentions the purchase of land in Hittin a year earlier. See ibid., 10. However, it is difficult to accept the statement that there was a connection between the controversy and R. Wachs's initiative since the initiatives were too close to each other, see Porat, "Hapulmos al Etrogei Eretz Yisrael," 38.

159 Ibid., 23.

160 See Avraham Bornstein, *Avnei Nezer* (New York, 1954), Orach Chaim, II, 484.

161 Marcus, *Pri Etz Hadar*, 38.

162 See a letter from R. Wachs to R. HaCohen, December 1876, in Aurbach, *Chidushei Mohara"ch.* R. Wachs dismissed the arguments of those permitting the Corfu etrog, who based their claim on the tradition that the Seer of Lublin was behind the entry of Corfu etrogim into Poland. He argued that since Corfu etrogim did not usually have clear signs of being non-grafted, their kosher status had been strongly undermined. Another source implies that Corfu etrogim were brought to Poland during the Napoleonic Wars, when it was not possible to bring etrogim from Italy, and they were only permitted to recite the blessing on a grafted etrog because of the extreme circumstances. See Ephraim Deinard, *Milchamah La'Hashem Ba'Amalek* (New York, 1892), 33. The Rabbi of Hradna ruled that a full blessing should not be made over these etrogim and, instead, one should recite the blessing in Aramaic.

163 Letter from R. Wachs to R. HaCohen, December 1876, in Aurbach, *Chidushei Mohara"ch.*

calendar will be sent from the Holy Land regarding the sanctification of the months and years, as Torah comes from Zion."[164]

R. Wachs adopted a whole range of possible arguments, from halakhic claims to ideological and pure economic arguments. It is difficult to hide that this variety of arguments undermines the basis of the ban on Corfu etrogim. Indeed, it will be seen later that R. Wachs acted contrary to his own position at the beginning of the controversy.

R. Wachs expressed his position on the subject in a letter from the beginning of 1877, in which he proved the priority of the Israeli etrogim.[165] To strengthen his assertions, he quoted the words of Rabbi Yehuda Leib Alter, the Rebbe of Gur (the Sefat Emet) and Rebbe Elimelech of Grodzisk.

The Sefat Emet wrote that the etrogim of Israel were kosher according to tradition, and that "it is a great mitzvah to bless over a kosher etrog from the Holy Land."[166] The Rebbe of Grodzisk confirmed his remarks. Rabbi Eliyahu Chaim Meisel of Lodz, one of the greatest rabbis of the time, also agreed to support the etrogim of the Land of Israel, although in weak language. "Since my way is not to say anything that won't be accepted, I cannot agree to ban the Corfu etrogim."[167]

An ardent and unequivocal supporter of R. Wachs was, of course, R. Auerbach, the Rabbi of Jerusalem, who claimed that there was never any doubt about the *kashrut* of the Israeli etrogim compared to all the others, although he acknowledged that one may only rely on certain orchards, in the Galilee and Samaria, and not the Jaffa etrogim.

Shortly after R. Auerbach's death, his two sons, who came to Israel to visit his grave, testified that one could rely on the Israeli etrogim that were under rabbinic supervision, unlike the Corfu etrogim which were not supervised. The editor of *Ha-Levanon* approved this point.[168]

20.15 Quenching the Controversy in Europe and Israel

In 1878, the sides failed to decide regarding the *kashrut* of the etrogim. Alongside the vigorous opponents of the Corfu etrogim, there were also ardent supporters of them, and each side brought strong evidence to their stance.

The simplistic sorting of moderate versus extreme rabbis, enlightened versus the conservative or modern versus traditional was not apparent here. There were also quite a few cases in which rabbis changed their minds, one of these being Rabbi Yisrael Yehoshua Trunk of Kutna, one of the greatest rabbis of Poland, who

[164] *Teshuvot Nefesh Chayah*, ibid., 9.

[165] Ibid., 4–11. R. Wachs based his ruling on the words of the Bigdei Yesha (Shmuel HaLevi) Later in the responsa, he relies on R. Kluger, who doubted Italian etrogim in general.

[166] *Teshuvot Nefesh Chayah* 24 *siman* 4.

[167] Ibid.

[168] "Hodaot," *Ha-Levanon*, July 12, 1878, 7.

consistently supported initiatives to support the *yishuv* in Israel. In a letter to the Rabbi of Sochatchov, which R. Trunk probably wrote in 1877, he objected to his own signature on the call published by R. Wachs in favor of the etrogim of Eretz Israel. In his opinion, the issue of the *kashrut* of etrogim was not clear, and therefore one should act in accordance with the majority of the public: "And since most of the Jews in these countries have the custom to use these [Corfu, Y. S.] etrogim, and great and holy Jews used them, God forbid to prohibit them."[169] However, R. Trunk also agreed that "it is proper and correct for Jews to bless on the etrogim of Israel, and the *mitzvah* is enhanced with the *mitzvah* of adoring the Land of Israel, so that many there will be able to make a living."

Elsewhere, R. Trunk stated that a blessing over the etrogim of the Land of Israel was preferable, even if they were less elegant than the Corfu etrogim: "It is a very elegant *mitzvah* when they are from Israel, which enhances the *mitzvah* of living in Israel, and also supporting the *yishuv* in Israel, as we know that our Sages were lenient in their rulings when there was a connection to the *yishuv* in Israel."[170]

He added another argument in favor of the Israeli etrogim: "So as not to be disrespectful to the earlier generations, as the great Rabbi Yitzchak Luria, Rabbi Moshe Cordoviro and Rabbi Joseph Caro, who performed the *mitzvah* with them." However, he wrote that "I didn't want to sign the proclamation, and according to *halakhah* one may use any etrog, and one should follow the majority. The problem with the Corfu etrog is their high price, but this is not a halakhic issue, and one has no reason to fear using a Corfu etrog."[171] R. Trunk's indecisive positions took into account the tradition of the former rabbis, the custom of the majority, and affection for the Land of Israel.

The etrog controversy undermined the kosher status of all etrogim, both those imported from Italy and those imported from Corfu. As mentioned, even the etrogim of Israel were not free from fear of grafting.

The Ashkenazim in Israel banned the Corfu etrogim and made sure not to use them, "As they have neither tradition nor a kosher presumption."[172] And even if some rabbis later retracted their bans, they had already given the Jaffa etrogim a bad name. Thus, the decision was left in the hands of each and every individual, who had to rely on tradition or a strong custom in his family.

A turning point in the etrog controversy in Israel occurred on the eve of Sukkot 1878, when the Sephardim published a letter from R. Auerbach, in which he permitted the etrogim of Jaffa. But the pamphlet *Pri Etz Hadar*," published in Jerusalem in 1878 at the initiative of the merchants Yehuda Leib and Benjamin Beinisch Salant, asserted that the change in R. Auerbach's position was due to his old age. They

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[169] See Israel J. Trunk, *Yeshuat Malko* (Piotrkow, 1927; Jerusalem: Photo Edition, 1988), 46. His claim was only against those who sanctified the etrog of Corfu, who would say that "even Yehoshua bin Nun ordered to take an etrog from the Corfu Islands "and did not want to take from the etrogim of Israel".

[170] See Aurbach, *Chidushei Mohara"ch*, 126.

[171] Ibid.

[172] Pamphlet, *Pri Etz Hadar*, 24.

claimed that his mind was blurred, because he contradicted the words that he had said only one year earlier.[173]

However, a letter from Brill to Pines revealed the background to the Rabbi's change of opinion: Brill wrote that R. Wachs himself grafted some of the etrog trees in Hittin with etrog trees from Jaffa, after finding that their fruits sold better.[174] It seems, therefore, that the interest in raising the revenues of the Warsaw Kollel in Israel by selling etrogim in Poland caused the two rabbis, R. Wachs and R. Auerbach, to remove their opposition to Jaffa etrogim.

This move paved the way for an end to the etrog controversy between Ashkenazim and Sephardim in Israel, and they worked together to increase the sale of etrog Eretz Israel abroad.[175] They set up a joint company to export etrogim and even set up a sales agency in Trieste.[176] Indeed, Israel etrog sales increased, and a report from the Warsaw Kollel in Israel states that in 1880 R. Wachs transferred to the Kollel 3,000 rubles in profits from the sale of etrogim, which was only part of the profits from the export of Israeli etrogim that year.[177]

Despite the impressive increase in the export of etrogim from Israel, in 1878 Pines warned of excessive enthusiasm for Israeli etrogim, as there were not yet enough to meet the demand of the Jews in the Diaspora, since an etrog tree only bears fruit after eight or nine years.[178] Therefore Pines advised that until Israel could supply the required quantities, it was appropriate to use Moroccan and Corsican etrogim, but not Corfu etrogim. And if there were not enough etrogim from these countries, he believed that it was better for communities to be content with purchasing a small number of etrogim for general use, rather than using Corfu etrogim.[179]

It seems, therefore, that the controversy veered from its halakhic territory to a totally social field. Support for the settlement of Israel for national reasons and financial aid for those living in Israel were external-halakhic issues that preferred the Israeli etrogim over the Corfu etrogim. The growth and trade of Israeli etrogim therefore shone new light on the issue, with R. Wachs developing this consideration following Brill and Pines. And even if he reduced it to the issue of productivity and economic support for the people of the country, he added a social consideration to the halakhic discussion.[180]

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173 Ibid., 28–29.

174 In the press, it was printed as if R. Wachs traded in Jaffa etrogim despite the ban. Letter from Shlomo Zalman Levin, April 1879: see *Ha-Levanon*, May 2, 1879, 6.

175 See Baruch Broide, *Ha-Levanon*, September 14, 1878, 8. See "Al Devar Ha'etrogim," *Ha-Levanon*, July 11, 1879, 8.

176 See Malachi, *Letoldot Mischar Ha'etrogim*, 176–78. Regarding R. Wachs, see Beit Halevi, *Toldot Rabbi Chaim Elazar Wachs*, 61–63.

177 See Porat, "Hapulmos al Etrogei Eretz Yisrael," 43, according to a certificate from the Zionist Archive.

178 See Pines's letter to Luis Emanuel, December 11, 1878, in Avraham Yaari, *Igrot Eretz Yisrael* (Ramat Gan, 1971), 448.

179 See Pines's letter to Ere"z, *Ha-Melitz* 19, 1883, issue 62, 991.

180 See Eliyahu Lerman, *Devar Eliyahu* (Warsaw, 1884), 41–42 *siman* 18.

Some identified the Corfu etrogim with the Greek people, since Corfu is a Greek island, and the competition between the Israeli and Corfu etrogim became a symbol of a struggle between the Jews and their oppressors: "They competed against the etrogim of their oppressors the Greeks, and overcame them."[181] The anti-Greek tone increased in the literature and served as a tool for provoking the users of the Corfu etrog.

20.16 The Controversy in the 1880s

Within a few years, the number of etrog orchards in the country had grown remarkably. In 1883, Israel exported about 30,000 etrogim,[182] and in 1887 the output rose to 42,000.[183] But other sources state that in Eastern Europe some 150,000 etrogim were needed for the Tabernacles holiday,[184] meaning that even after the increase in the number of etrogim exported from Israel, it bit into a little less than a third of Corfu's etrog exports to Eastern Europe. The struggle for the Israeli etrog was led by Pines and accompanied by R. Wachs, however while R. Wachs's interest stemmed from his desire to financially support the Warsaw Kollel,[185] of which he was president, Pines incorporated a Zionist-national slant. Pines urged the new colonies to plant etrog orchards and even encouraged Jews from Eastern Europe to purchase etrog plantations from the Arabs.

He claimed, following Sapir, that the rabbis' endorsements were not given to the fruits but to the growers, and therefore the Corfu etrogim could not be permitted as the Greeks could not be trusted not to graft the trees.[186]

However, one should not ignore the many obstacles posed by the Israeli Jews themselves to the productivity initiatives of the settlement. There were those who feared that the investment in the etrog plantations would be at the expense of the Kollel distributions,[187] and others were not pleased with the industry surrounding the rabbinic endorsement of the cultivation of etrogim.[188] The Orthodoxy of the Jewish

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[181] Yechiel M. Pines, "Me'Ohaliav," *Ha-Levanon* 14, 1877, issue 9, 69–70.

[182] See Ere"z, "Od Al Devar Etrogei Eretz Hatzevi," *Ha-Melitz* 19, 1883, issue 67, 1067. Pines mentioned 40,000, meaning that the increase in their number was less, see *Ha-Melitz*, August 6, 1883, 1.

[183] "B'eretz Hakodesh," *Ha-Melitz*, 27, 1887, issue 212, 2259.

[184] See A. Y. Slutsky, "Lish'eilat Etrogei Eretz Yisrael," *Ha-Melitz* 28, 1888, issue 117, 1238–42; "B'eretz Hakodesh," *Ha-Melitz* 28, 1888, issue 117, 2259–60.

[185] R. Wachs spoke in terms of redemption, but cited them in the names of others, such as R. Gutmacher; see R. Wachs's letter to Rabbi Elazar HaCohen, December 1876, in Aurbach, *Chidushei Mohara"ch*, 117.

[186] Ibid., Pines to Ere"z.

[187] See Israel D. Frumkin's critique of R. Wachs in Porat, "Hapulmos al Etrogei Eretz Yisrael," 41. According to Frumkin, *Havatzelet* 8, 1877–1878, issue 5.

[188] See the words of Yechiel Brill, the editor of *Ha-Levanon*, against his father-in-law Yaakov Sapir and against R. Auerbach himself in Porat, "Hapulmos al Etrogei Eretz Yisrael," 42.

society in Europe also affected the opposers, with R. Lipshitz and others criticizing the Zionists' initiative to bring about the modification of the Jewish community by growing etrogim.[189] Instead, they preferred to preserve the community in Israel as a group of scholars.

Despite all the efforts of prominent rabbis in Lithuania and Poland to ban the Corfu etrogim, their efforts had little impact as the leading rabbis and rebbes in Lithuania and Poland continued to use Corfu etrogim. R. Wachs turned to the Rebbe of Alexander, Rabbi Yitzchak Danziger, one of the most important rebbes of Poland, and asked him to add etrogim from Israel to the Corfu etrogim he and his followers used.[190] These efforts by R. Wachs were only partially successful; the claim that the etrogim brought from Corfu were grafted were unequivocally proven, or at least not agreed upon by all,[191] and the multiplicity of reasons for banning the use of Corfu etrogim only harmed their struggle as an increase of arguments indicate a lack of a main and decisive claim.[192]

R. Wachs's opposition to the Corfu etrog weakened, and he sufficed with a ruling to prefer etrogim from Israel, which was approved by many rabbis.[193] This ruling proves that most rabbis in Poland, Galicia, and Lithuania ultimately relied on the ruling of R. Margoliot to permit Corfu etrogim that were grown from offshoots of grafted trees, which are halakhically permitted. All attempts to close the Beit Ephraim's loophole do not seem to have succeeded.[194]

20.17 Hovevei Zion and Israeli Etrogim

From the beginning of the 1880s, the controversy took on an additional dimension, with the help of the press that supported the Zionist Hovevei Zion (Lovers of Zion) movement. Preference for Israeli etrogim was moved from the halakhic discussion towards the social field, with Zionist and national ideas becoming increasingly dominant. For example, Avraham Moshe Lunz, editor of the *Jerusalem* magazine,[195] wrote that although the rabbis did not halakhically succeed in banning the etrogim of Corfu,

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[189] Ibid., 34, 38.

[190] Ibid., R. Wachs's letter to R. Danziger, August 1886, in Eibschitz, *Toldot HaNefesh Chayah*, 80.

[191] Ibid., R. Wachs's letter to "the honor of tens of thousands of Jews," August 1886, 82; ibid., another letter a year later "in honor of the great rabbis of Israel," 83, 84.

[192] Zvi Y. Michaelson, *Sefer Tirosh Veyitzhar* (Bilgoraj, 1937; New York: Photo Edition, 1966), 136.

[193] Ibid., 138.

[194] Aryeh L. Broide, *Mitzpeh Aryeh* (Lvov, 1900), responsa 54, 58–59. This is theoretical as it has not been proven that this was indeed the reality in Corfu. Similarly, if there is no law of mixing with offshoots, they could still be invalid due to missing parts of the etrog. The editor of *Ha-Levanon* explained why the permit of the Beit Ephraim is based on a factual mistake. Further, the name Parga includes etrogim from various places, not all of which enjoyed halakhic kosher assumptions. See "The's note," *Ha-Levanon*, September 22, 1875, issues 2–3.

[195] Avraham M. Lunz, *Jerusalem* (Vienna, 1882), vol. 1, 245–47.

and "the rabbis do not have the power to decide such a ban due to the internal and revolutionary sides in this matter," he favored encouraging the Israeli etrogim "due to national love." Lunz suggested that the organizations involved in the Kollel distributions should take over the trade in etrogim in Israel and abroad, and impose a tax on those engaged in the trade in etrogim, and from the tax money it would be possible to plant etrog orchards in the country. Lunz saw in R. Wachs's initiative the economic potential in the etrog trade for the benefit of the country's inhabitants. Others used less powerful language than Lunz, stating that the Israeli etrog trade was "settlement of the Land of Israel."[196]

Among the supporters of the Israeli etrogim were the following newspaper editors: Peretz Smolenskin, editor of *Hashahar*; Erez (Alexander Zederbaum), editor of *Ha-Melitz*, and Nahum Sokolov, editor of *Hazefirah.* They had no interest in the halakhic side of the controversy. Erez repeated the old claim that the Greeks from Corfu, known for their hatred of the Jews, should not be helped: "They looted us then, and they continue to loot our *mitzvot* today"; "our oppressors, the destroyers of our Land and the robbers of our freedom."[197] He suggested that the owners of the orchards in Israel should unite with the rabbis to increase the sale of Israeli etrogim.[198] The idea of uniting in favor of the etrogim of the Land of Israel and banning the Corfu etrogim of Corfu was suggested over and over again in the pages of *Ha-Melitz*,[199] and was also repeated in the Galician Orthodox press, *Machzikei Hadas*.[200]

The weight of the arguments against the Corfu etrog had shifted from the halakhic literature to journalism. The editor of *HaMagid* joined the band: "And when recently the idea of the settlement of Israel began in the hearts of the people of Israel, I called to strip the etrogim of their religious form and to enclothe them with the national idea, which will find sympathetic ears in tens of thousands of hearts, and they will only use Israeli etrogim."[201]

The issue of Corfu's etrogim almost disappeared from the halakhic literature of the 1880s, despite the efforts of Zionists to attract rabbis to discuss it again.[202] *Ha-Melitz*'*s* struggle against the Corfu etrogim, which was followed by the other Zionist

[196] Chaim Y. Cramer, "'To the…," *Hashahar* 11, 1803, 262.

[197] Ere"z, "Od Al Devar Etrogei Eretz Hatzevi," *Ha-Melitz* 19, 1883, issue 67; Cramer in "Pri Etz Hadar," *Ha-Melitz* 19, July 25, 1883, issue 45, 708–10.

[198] Shlomo Z. Kaufman, "Al Devar Etrogei Eretz Yisrael," *Ha-Melitz*, June 10, 1883, 1.

[199] See Yosef C. Horowitz, "Im Ein Anachnu Lanu, Mi Lanu?" *Ha-Melitz*, August 10, 1883, 5; Chaim Yaakov Cramer, "Pri Haaretz Legaon Ultiferet Lifleitat Yisrael," *Ha-Melitz*, July 6, 1883, 1–3.

[200] See letter from Sanz to the etrog traders, *Machazikei Hadas*, September 7, 1882, 8.

[201] "'Et Sofrim,' Pri Etz Hadar," *Ha-Magid*, August 28, 1883, 2.

[202] See Zalman Epstein and Ere"z, "Al Devar Etrogei Eretz Yisrael," *Ha-Melitz* 19, 1883, issue 41; "Davar El Hovevei Zion," *Ha-Melitz* 19, 1883, issue 34.

journals,[203] apparently caused the rabbis to withdraw from the discussion on the subject, so as not to discuss political and journalistic issues in holy halakhic works.

In addition, even the Hovevei Zion members themselves were not sure that encouraging trade in etrogim would contribute to the new settlement. The main beneficiaries of the expansion of the export of etrogim from the country were the Arab farmers and merchants of the old *yishuv*. The writer Yaakov Bachrach of Hovevei Zion, who visited Israel in 1882, also raised doubts about the ability of Israel to supply the goods: "If we gather all Israel's etrogim, it will only suffice [for] two out of every thousand Jews living in Europe."[204] He added that the etrog traders were members of the old settlement, rich people who did not need the help of foreign aid, while the new settlers in the country needed immediate incomes. Therefore, in his opinion, they should not have engaged in orchards that give profit only many years after planting.

Bachrach added that the propaganda in the press in favor of the Israeli etrogim was unnecessary, since every Jew knows that in matters of *mitzvot*, fruit from the Holy Land is preferable than fruit from the Diaspora. According to him, the whole issue of etrogim was "a grain of sand relative to a high and lofty mountain," and that the issues had to be seen in the right perspective, and that we must be especially careful not to upset the Greeks in Corfu so as not "to add hatred to their hatred."[205]

Supporting Bachrach's doubts was Naftali Maskil Le'Eitan, who introduced himself as the leading etrog merchant in the Russian Empire, and who declared himself a Lover of Zion. According to him, Israel was not able to supply the quantities of etrogim required, and the ones benefiting from trade in Israel were the Arab growers and merchants of the old *yishuv*, and the Hovevei Tzion had no intention of supporting either of them.[206]

To the claim that the Hovevei Zion movement should not have cared about supporting the old *yishuv*, Eliezer Ben-Yehuda, the editor of *Hatzevi*, replied that it was appropriate to take care of all the inhabitants of the Land, and not to confuse between farming and the existence of the old *yishuv*. There was a note of enlightened criticism in Ben-Yehuda's words, suggesting that the rabbis preferred to take Corfu etrogim even when in Israel, and were indifferent to the needs of the Jewish public in the country.[207]

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203 Ibid., see articles. The rabbis seem to have recognized that the Hovevei Zion and the Maskilim were behind the effort in favor of the Israeli etrogim, and therefore they refrained from being identified with the campaign. See Porat, "Hapulmos al Etrogei Eretz Yisrael," 59. Even R. Spector, who at the time came out against the etrog of Corfu and initially supported the Hovevei Zion, kept quiet during the 1880s. In the Hovevei Zion movement, the rumor spread that the movement should take the etrog trade under its auspices as a source of subsistence for the new settlement. See "Ulekachtem Lachem Mi'pri Ha'etz," *Ha-Magid* 29, 1885, issue 24, 205–06.

204 See Yaakov Bachrach, *Sefer Hamassa Le'eretz Hakedoshah* (Warsaw, 1903), 117, in a note.

205 Ibid., 118–19, in a note.

206 Naftali Maskil Le'Eitan, "Shoalin Vedorshin Behilchot Pri Hachag," *Ha-Melitz* 19, 1883, issues 43–44. Maskil Le'Eitan (1829–1898) was a member of a family of rabbis in Belarus, a merchant, writer, scholar, and poet, and a multi-active activist in Russia. His original last name was Maskilson, but his father was already named Maskil Le'Eitan, after his book (1808).

207 Eliezer Ben-Yehuda, "Hamischar Be'etrogei Eretz Yisrael," *Hatzevi* I, 1885, issue 36, 154.

Additional articles in this spirit were published in the Jewish press. For example, there were those who claimed that the interest of Zionists and the Hebrew press in the circulation of the Israeli etrog actually caused damage, because it merged halakhic interest with the national interest.[208] Another argued that press intervention was an obstacle to the etrogim of Israel, not only because of its nationalist positions, but mainly because of the support of the radical Hebrew press (*Ha-Melitz* and *Hashahar*), which had called for changes to religion during the controversy of the late 1860s and early 1870s.[209]

Erez, the editor of *Ha-Melitz*, tried to influence the rabbis to help spread Israeli etrogim,[210] but to no avail, while the proposals of *Ha-Melitz* to do without the support of the rabbis and advance the issue with the help of the press had no chance of succeeding. Thus, the issue moved from being a halakhic controversy with clear economic and social inclinations, to an all-inclusive controversy between the Zionists and their opposers.[211]

R. Wachs tried to bridge between the positions of the sides, suggesting to the Hovevei Zion to strengthen the existing Jewish settlement in the country, and not to encourage the immigration of additional settlers.[212] But while R. Wachs supported the Jews of the old *yishuv* and wanted the income of the etrog money to boost the Kollel's income, the Zionists were only interested in building the new *yishuv* and opposed the method of Kollel distributions. The fear that the national enterprise might fall into the hands of the old *yishuv* motivated several writers, among them Yaleg (Yehuda Leib Gordon), to support immigration to America.

No alliance was formed between R. Wachs and the Hovevei Zion, and no such alliance could ever have been formed because their starting points clashed from the outset.[213]

20.18 The Corfu Etrog in Poland's Hassidic World

Despite the rabbis' refusal to support the Israeli etrog in the 1880s, and despite the non-realization of the alliance that R. Wachs wanted to form with the Hovevei Zion,

[208] Shmuel S. Strashon, *Ulekachtem Lachem Mishelachem Pri Etz Hadar*, *Ha'asif* (Warsaw, 1884), vol, 1, 186–87.

[209] Yav"o Ziv, "Shavel," *Ha-Melitz* 19, 1883, issue 52, 831. In an apologetic response, he said that it was hard to believe that the rabbis accused him of publishing *Ha-Melitz* for supporters of changes in religion, since *Ha-Melitz* opened its doors to all positions, ibid., 831–32.

[210] See Shlomo Yehoshua Mazeltz, "Lipri Haaretz," *Ha-Melitz*, September 14, 1883, 2.

[211] See Porat, "Hapulmos al Etrogei Eretz Yisrael," 57–58.

[212] See R. Wachs's letter to Pines, March 4, 1885, in Alter Y. Droyanov, *Ketavim Letoldot Chibat Zion Veyishuv Eretz Yisrael* (Tel Aviv, 1932), vol 3, no. 1331.

[213] See Mohliver's letter to Leon Pinsker, June 1885, in *Ketavim Letoldot Chibat Zion Veyishuv Eretz Yisrael*, ed Shulamit Laskov (Tel Aviv, 1982), letter 617: Mohliver's letter to Pinsker, July 1886; ibid., vol. D, 1887; ibid., 1888, letter 822.

the export of etrogim from the land expanded, which led to the uprising of the Corfu etrog' merchants.[214]

In 1886, R. Wachs visited Israel with his father-in-law Rabbi Israel Joshua Trunk and improved the cultivation of etrogim in the orchards of Hittin. Upon his return home, he renewed the fight for the entry of the Israeli etrog into European markets, publishing in the press letters sent to him by rabbis during the 1875–1876 controversy. R. Wachs based his approach on several points: the commandment to use a beautiful etrog only relates to a kosher etrog; grafted etrogim are biblically invalid; the *kashrut* of etrogim is determined by tradition; signs are not actually helpful, since the etrogim are mixed from different trees; an etrog without a *pitam* is kosher; only an Israeli etrog with R. Wachs's endorsement was kosher.[215]

The rabbis who supported R. Wachs stipulated that the etrogim he sold must be kosher, without any *safek* (doubt). Some of his supporters agreed that the Corfu etrogim were grafted, while others expounded on the issue of loving the Holy Land. But all agreed that the Israeli etrogim were only preferable on condition that they were definitely not grafted.

The Radziner Rebbe, Rabbi Gershon Hanoch Leiner, who discussed with R. Spector at the time to ban the Corfu etrogim, now changed his view, claiming that by ruling that only those etrogim with R. Wachs's certificate were kosher, weakened the position of those claiming that Israeli etrogim were not grafted, as R. Wachs only marketed a small percentage of all Israeli etrogim. The Radziner Rebbe's main claims were that he himself visited Corfu and did not find grafted etrog trees there, and that there was no need of a tradition to confirm the *kashrut* of the etrogim. But if etrogim did need a tradition, then the Corfu etrogim had a far longer tradition, from when the Jews settled there since the First Temple and used their etrogim, while the Israeli etrogim had no such tradition, as the Land had lain uninhabited for many generations.

Also, the Israeli etrogim needed a supervisor to oversee them, as R. Wachs himself claimed. Most of R. Wachs's supporters actually used Corfu etrogim, and the people of Eretz Israel also always used Corfu etrogim. Many rabbis and rebbes used Corfu etrogim, "and how can we not be ashamed to slander the great men of Israel and saints who are in the land, the Rabbi of Lublin, the holy maggid of Kozhnitz, the Holy Jew of Peshischa and all the leaders and rabbis of our generation."[216] Similar arguments were made by an etrog merchant named Lefkowitz from Warsaw.[217]

Although the economic interests of both parties were expressed in the controversy, they did not dispel the halakhic debate, which stemmed from a lack of understanding of the technicalities. Halakhic presumption and tradition stood for both sides equally, for these had no fixed levels, and each side could claim them. R. Wachs himself challenged the presumption of *kashrut* of the Israeli etrogim to the extent that he only permitted the etrogim from Hittin.

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214 "Moda'ah Rabba Lesochrei Etrogim," *Hatzefira* 13, 1886, issue 92, 4.

215 Rava, *Ha-Melitz* 27, 1887, issues 200, 206.

216 See letter from Nahum Feigenbaum, *Ha-Melitz* 27, September 30, 1887, 2204–06.

217 Letter from the etrog merchant Lefkowitz, September 15, 1887, *Hatzefira* 14, issue 201, 3–4.

The representatives of the hospital in Warsaw, who made a living from the etrogim of Corfu, correctly queried: “There is a kosher concern also in the etrogim of the Land of Israel, because in what way are the Arab garden-owners in Israel better than the Greek garden-owners in Italy?”.[218]

Once the distinguishing signs between grafted and non-grafted etrogim had been rejected, virtually the whole matter of tradition and halakhic assumption was also lost. It was clear to everyone that trees and seeds move from place to place “and who knows if the sowing was not a grafted planting from a lemon offshoot?”.[219]

The argument that attributes to the acts of great rabbis a status of binding *halakhah*, even when it is clear they were wrong, is an ideological issue and is inconsistent with the traditional view.[220] Although it was not possible to ascertain the reality, since it was not possible to know what happened in the past, it was still possible to determine whether at the time of the controversy etrog trees were being grafted in Corfu, just as this issue was clarified in Israel.

Those who supported the Corfu etrogim did not need to clarify the reality and were content with the apparent halakhic presumption, although there was also a halakhic ruling prohibiting the Corfu etrogim. It is possible that the parties despaired of clarifying the reality and therefore contented themselves with practical compromises. R. Wachs withdrew his ban on the Corfu etrog under pressure from the critics, stating that he did not ban the etrogim of Corfu, but only sought to prefer his etrogim where they were available.[221] In doing so, he shifted the focus from the halakhic debate to the social and ideological debate surrounding support for the poor of the Land of Israel. Others diverted the discussion to the national issue.[222]

Sokolov, editor of *Hatzefira*, tried to take advantage of the struggle in favor of the Israeli etrogim, and in 1888 he called on rabbis to support them. His reasoning was national and economic: “The etrog trade is a stronghold and a good source for the economy” of the Jews of Israel. He also put forward an ideological argument: “They are grown in Israel, are grown with affection of the Land, which is why we love them.”[223]

In the late 1880s, the controversy waned, and only little was left of the rabbis’ great enthusiasm to prefer the etrogim of Israel over the etrogim of Corfu, as expressed in the years 1874–1878. The erosion in support for the Israeli etrogim was due to several factors. First, it turned out that the Israeli etrogim were as kosher as the Corfu etrogim, since most of their cultivation was done by the Arabs while the people of the old *yishuv* were not enthusiastic about growing etrogim and were mainly engaged

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[218] Letter from the Committee of the Hospital in Warsaw, *Hatzefira* 14, September 16, 1887, *Ha-Melitz* 7, issue 202.

[219] Ibid.

[220] See Ze’ev Safrai and Avi Sagi (eds.), *Bein Samchut Le’atonomia BeMasoret Israel* (Tel Aviv, 1997), 11–15. Yosef Ahitov, “Temurot Bemanhigut Hadatit,” in ibid., 57–58.

[221] Letter from R. Wachs, September 16, 1887, *Hatzefira* 14, 1887, issue 203.

[222] M. L. Shapira, “Trieste,” *Hatzefira* 15, 1888, issue 167.

[223] Nahum Sokolov, “Hatzofeh Leveit Yisrael,” *Hatzefira* 15, 1888, issue 168.

in trading in them. R. Wachs also encountered opposition to his initiatives from the Warsaw Kollel he headed.

Together with the Zionists' national rationale for supporting the use of the etrog trade in order to promote the new settlement in the country, the Israeli etrog was involved in the broader question regarding the Zionists' initiatives—whether to support them or to oppose them. The support of the editors of the major Hebrew newspapers, *Hatzefira* and *HaMagid*, recommending the distribution of Israeli etrogim, was to no avail since the traditional public suspected them of having motives other than for the sake of God.

Moreover, the beginning of the *shmittah* sale permit controversy (1888–1889), which plunged the settlement into a new halakhic cyclone, raised serious doubts as to the viability of the Jewish agricultural settlement in the country, and keeping *shmittah* properly without the need for a sale permit meant that Corfu etrogim were also needed. With the death of R. Wachs (in 1889), who was the main fighter for Israeli etrogim for about fifteen years, the central figure had left the arena.

20.19 The End of the Controversy and the Corfu Blood Libel

The controversy was eventually decided by an event that did not belong to the halakhic debate—a blood libel in Corfu in 1891. A girl's body was found during Easter that year, and the authorities accused the Jews of murdering her in order to use her blood for religious purposes. A brief inquiry revealed that the victim was a Jewish girl named Rubina Sarda, the murderer was a Christian criminal, and the plot was concocted by a Greek policeman. The conspiracy took place against the background of the general election and the attempt to prevent the Jews from participating in it, but its motives are not entirely clear.[224] The plot was immediately revealed, yet the Jewish neighborhoods were besieged for a month. Out of about 7,000 of the island's Jews, about 2,500 left in a hurry, leaving behind all their belongings.[225]

The Jewish world was in turmoil. The Jewish press, in its various languages, published many reports and various assessments of what had happened. The antiquity of the Jewish community in Corfu and the island's economy's reliance on Jewish capital—which flowed through the etrog trade—added fuel to the fire. It seems that never before had such a broad Jewish coalition been formed as in the boycott now imposed on the etrogim of Corfu, which was supported by figures from the whole Jewish spectrum: Y. M. Weiss, head of the Cincinnati Reform school; Dr. M. Gidman, Rabbi of Vienna; Joseph Samuel Bloch, editor of Vienna's *Wochenschrift*; Rabbi

[224] "Corfu," *The Jewish Encyclopedia* (New York: Funk & Wagnalls, 1905), vol. 4, 271.

[225] "Chutz Le'artzeinu," *Ha-Melitz* 31, May 2, 1891, issue 112, 3–4. See also "Michtav Mi'Trieste," *Ha-Melitz*, May 27, 1891, issue 107, 1–2; "Man Demorach Etroga," *Ha-Melitz*, June 30, 1891, issue 134, 1–2.

Eliyahu Chazan, Rabbi of Alexandria[226]; and even Le'Eitan, the largest merchant of Corfu etrogim in Eastern Europe,[227] who only two years earlier had fought on behalf of Corfu etrogim in the pages of the Hebrew press, and had even managed to tilt public opinion in their favor.

Weak voices against this general mood and in favor of Corfu etrogim were heard from Rabbi Mordechai Yosef Eliezer Leiner of Radzin, son of the former Rebbe of Radzin, Rabbi Gershon Hanoch Leiner, as well as Orthodox Jews from Germany who feared that Jewish incitement against the Greeks would harm Corfu Jews. Also, Jews interested in the continuation of Corfu etrogim, such as the heads of the hospital in Warsaw. However, these voices were totally rejected.[228]

In the literature, Corfu etrogim were referred to as "bastard etrogim," "Corfu bastards," or "bloody land etrogim," and those who took Corfu etrog for their *mitzvah* were condemned as performing "a *mitzvah* together with a prohibition."[229] Corfu etrogim were presented as a symbol from which "the accursed Greeks in Corfu and elsewhere will see that the Jews have the courage to stand up for their souls and the honor of their people and faith."[230]

The views of the halakhic authorities banning the Corfu etrogim were highly featured in the press and literature.[231] The boycott of Corfu etrogim was imposed on buyers as well as sellers,[232] and rabbis in various cities published boycotts of Corfu etrogim in the local press. The rabbis in Minsk, Mir, Pinsk, and Vilna, areas where Corfu's etrog dominated for many generations and even served as trading centers for these etrogim,[233] stood out. The bans were joined by the great leaders of the generation in Lithuania, who had previously objected to the etrogim of Corfu, such as R. Spector of Kovna, the Netziv of Volozhin, Rabbi Shmuel Mohliver of Bialystok, Rabbi David Friedman of Karlin, Rabbi Chaim Berlin, and others.[234]

The press of Hovevei Zion, which in the early 1980s fought for the Israeli etrog and unintentionally tipped the scales against them, now reiterated its position with great

226 See Deinard, *Milchamah La'Hashem Ba'Amalek*, 33.

227 See Naftali Maskil Le'Eitan, "Tziduk Hadin," *Ha-Melitz* 31, 1891, issue 146.

228 "Kelal Uperat Al Devar Etrogei Corfu," *Ha-Melitz*, September 28, 1891, issue 210, 2–3; Yitzhak Subalsky, "Yishmeu Ha'Ivrim," *Ha-Melitz*, 31, June 8, 1891, issue 117, 1; *Ha-Melitz*, "Man Demorach Etroga"; Deinard, *Milchamah La'Hashem Ba'Amalek*, 17.

229 Avraham Maskil Le'Eitan, "Vehitchazaketem ulekachtem mi'pri haaretz," *Ha-Melitz*, July 22–23, 1891, issues 153–154; "Mitzvah Habaah Be'aveirah," *Ha-Melitz*, May 22, 1891, issue 103, 1–2; "Yisurei Tzadikim," *Ha-Melitz*, June 2, 1891, issue 113, 1–2.

230 *Ha-Melitz*, "Mitzvah Habaah Be'aveirah".

231 Deinard, *Milchamah La'Hashem Ba'Amalek*, 34–35. He mentions that the Rabbi of Hradna used the etrog of Corfu in 1808 because of the extreme circumstances.

232 "Kapust," *Ha-Melitz* 31, 1891, issue 222.

233 See Ephraim R. Moshowitzky, "Kavana," *Ha-Melitz*, June 4, 1891, issue 114, 2; Yehuda Yidel Zisling, "Etrogei Corfu," *Ha-Melitz*, May 31, 1891, issue 110, 1; Mordechai Ber Gimzo, "Vayishma Yeshurun," *Ha-Melitz*, May 29, 1891, 109, 2; Maskil Le'Eitan, "Tziduk Hadin".

234 Yitzhak Subalski, "Lemaan Yed'u," *Ha-Melitz*, June 1, 1891, issue 111, 1; "Haysin," *Ha-Melitz*, June 2, 1891, issue 112, 2; Deinard, *Milchamah La'Hashem Ba'Amalek*, 23–24.

fanfare.[235] Many articles were published criticizing the opponents of the national idea and the new settlement in the country, questioning the rabbis who supported the Corfu etrogim, attacking merchants who preferred personal interests over all-Israeli interests, and against the masses, who preferred the beautiful etrogim over kosher ones.[236]

The Israeli rabbis of the Sephardic and Ashkenazi communities, ruled that "The etrogim of Corfu and its neighboring cities are forbidden forever, and one who recites a blessing over them, not only did he not fulfil the commandment, but his blessing is in vain, and his *mitzvah* is fulfilled with a prohibition."[237] The writers declared: "Each of us is the one to avenge the bloodshed in Corfu."[238]

The settlement enterprise of Hovevei Zion in Israel suddenly received many words of praise from Jewish circles which did not support it before, even though only a year had passed since the exhausting *shmittah* controversy, which undermined confidence in the new settlement's ability and desire to observe *halakhah* without trickery.

Where the halakhic reasonings for rejecting the Corfu etrog did not succeed, the hatred of Jews did.

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235 *Ha-Melitz*, "Mitzvah Habaah Be'aveirah".

236 Deinard, *Milchamah La'Hashem Ba'Amalek*, 4, introduction, 2, 5, 6, 14.

237 "Al Devar Etrogei Corfu," *Ha'or*, 1891, issue 33; "Al Devar Etrogei Corfu," *Ha-Melitz* 31, July 16, 1891, issue 148, 3.

238 Gimzo, "Vayishma Yeshurun".

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Chapter 21
The Grafted Etrog Citron Controversy

Eliezer E. Goldschmidt

Abstract A serious concern arose in Italy during the sixteenth century when the grafting of the etrog citron onto another citrus variety (e.g., lemon, sour orange) became widespread. The status of a grafted etrog (i.e., fruit growing on a grafted etrog tree) was not discussed in earlier Talmudic and Rabbinic literature. It was nevertheless quite unanimously agreed that a grafted etrog fruit is unacceptable for the Sukkot/Tabernacles ritual, although the specific reason was not clear. Is it possible to identify a grafted etrog? Certain morphological traits were suggested for the identification of grafted etrog fruits, but these traits are not truly reliable. Thus, only trees from a traditionally "never-grafted" source can be used. The halakhic and scientific aspects of etrog grafting and its ramifications are discussed.

21.1 Introduction

The question of the grafted etrog [pl. etrogim] citron triggered one of the major halakhic controversies of the last few centuries, as it had crucial ramifications on etrog cultivation and consequences for etrog commerce. In this chapter, I will briefly describe the botanical-agricultural background of the grafting methods and follow the halakhic considerations that led to the now-accepted ruling to disqualify the grafted etrog. Later on in the essay I will discuss how the problem has evolved until the present day and examine the issue in light of modern scientific information.

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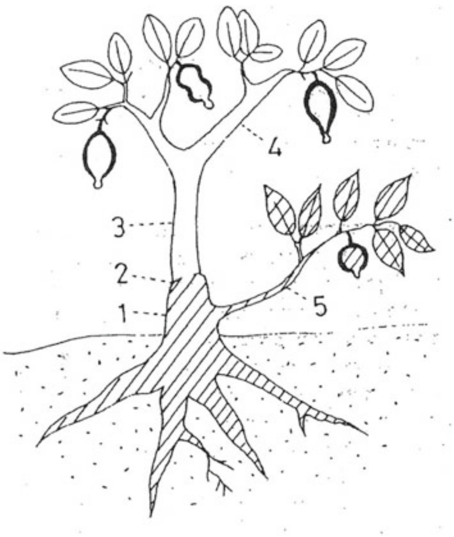

◀**Fig. 21.1** Diagram of an etrog tree grafted onto another citrus species: 1. The rootstock (marked with diagonal lines). 2. The graft union area, between the rootstock and the scion. 3. The scion (unmarked). 4. The scion canopy—branches, leaves, and etrog fruits. 5. A branch that sprouted from the rootstock, bearing rootstock leaves and fruit

21.2 What is Grafting?

Grafting is the act of combining two plants that coalesce with each other, absorb from one another and become one combined organism, one plant. In the currently accepted grafting methods, one plant, called the *rootstock*, contributes the root system, while the other plant, called the *scion*, connected as above, provides the canopy—branches, leaves, and fruit (Fig. 21.1).

It is not clear when grafting began, but it is discussed in the teachings of our sages and its techniques were already known to the Greeks and Romans.[1] Nor do we have clear knowledge as to the extent of grafting in those times, although a new study has identified grafted fruit trees (not citrus) in mosaics from the Roman and Byzantine periods.[2]

It appears that the grafting of citrus trees was customary in the late Middle Ages among the Italian aristocracy, and in the past few centuries grafting became widespread in commercial plantations of most deciduous fruit trees and citrus trees. Nowadays, grafting is commonplace, especially in fruit trees and certain ornamental

[1] On the history of grafting, see Ken Mudge, Jules Janick, Steven Scofield, and Eliezer E. Goldschmidt, "History of Grafting," *Horticultural Reviews* 35 (2009): 437–93.

[2] Anat Avital, "Propagation of Fruit Trees via Grafting: Mosaic Portrayals from the Roman and Byzantine Periods," *Cathedra* 157 (2015): 33–52.

plants and, in the past few decades, also in vegetables from the Cucurbitaceae and Solanaceae families.

Grafting creates a successful combination between the rootstock and the scion, with the rootstock conforming with soil and climate, or resisting disease, while the scion produces the desired quality fruit.

Although the rootstock and scion absorb from each other and affect one another,[3] in present-day grafting methods the rootstock and scion preserve their genetic identity.

21.3 Grafting in *Halakhah*

Grafting appears in the Mishna as one of the propagation methods of fruit trees—"planting, layering, grafting."[4] The halakhic discussion regarding grafting is mainly in two fields, *kilayim* and *orlah* (see Glossary). Inserting a young branch of a scion into the rootstock in order to graft them is considered "sowing," and is therefore discussed within the prohibition of "you shall not sow crossbreeds" (Lev. 19:19). Thus, it is forbidden to graft trees from different plant species, just as it is forbidden to sow together seeds of different species.[5] With regard to *orlah*, the ruling is that when a young tree branchlet is grafted into an adult tree which has completed its *orlah* years, the young scion is annulled in the older rootstock tree, meaning the scion fruits are not *orlah* and are not forbidden.[6] These halakhic principles are applicable today and have ramifications regarding the treatment of fruit trees according to *halakhah*.

21.4 Grafting the Etrog: A Problem Arises

A grafted etrog is the fruit of an etrog tree (scion) grafted onto another citrus species such as lemon or sour orange (rootstock).[7] The first evidence of this being a halakhic issue comes from Italy in the sixteenth century and several decades later in the Land of Israel. But the problem probably arose even earlier as grafting was introduced and

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[3] For example, influencing the citrus fruit's quality in its level of acidity and taste.

[4] M *Shevi'it* 2:6. "Grafting" is also mentioned in a different sense—"they would graft palms all day" (M *Pesachim* 4:9), but this refers to the pollination of the dates by attaching a male inflorescence into a female palm, see Judah Felix, *Plant World of the Bible* (Ramat Gan: Masada,1968), 42.

[5] Rambam, MT *Zeraim*, *Hilchot Kilayim* 1:5.

[6] BT *Sotah* 43b.

[7] There is evidence from medieval Muslim literature regarding etrog grafting, see Zohar Amar, *The Four Species* (Tel Aviv: Oren, 2009), 42–44. Rambam (MT *Zeraim*, *Hilchot Kilayim* 1:5) offers an example of the grafting of the forbidden trees "such as grafting a shoot from an apple tree into an etrog, or an etrog into an apple tree," although this grafting is actually impossible, see ibid., comment 104.

practiced long beforehand.[8] In Italy, citrus fruits were grown in the glasshouses of aristocrats (orangeries), and grafting was a common procedure (as Maharam Padua's son testifies in his responsa, see further on). A short time later we witness a heated debate between the halakhic authorities, a debate that continued for hundreds of years and is discussed in innumerable responsa and halakhic rulings.

21.5 Why is Grafting not Mentioned in Talmudic Sources?

As mentioned above, our sages were familiar with grafting techniques. So why isn't the issue of the grafted etrog mentioned in the Talmudic discourse, in the chapter discussing etrog fruits that are disqualified?[9] According to our understanding, the answer is that in the times of our Sages there were no other citrus fruit species in the Land of Israel and there was therefore no option for the grafting of etrog trees.[10]

21.6 The Main Halakhic Positions

Grafting an etrog is not mentioned in any of the Talmudic sources up to Joseph Karo's *Shulkhan Aruch*. We may ask therefore: on what basis can a grafted etrog be disqualified, and how is it related to other problems that disqualify an etrog? Although there is no clear answer to this, the vast majority of halakhic authorities have ruled to disqualify the grafted etrog.[11] But in studying their works one discovers a dilemma regarding the halakhic status of the fruit growing on a grafted tree. These are their main arguments:

1. The scion is annulled when grafted onto an older rootstock (as explained above). Therefore, the etrog scion is annulled when grafted onto a lemon rootstock, and it is no longer considered an etrog.
2. The scion absorbs from the rootstock, creating a mixture (the amount of which cannot be measured), and since part of the rootstock (lemon) is mixed into the etrog scion, the etrog is deemed "missing," which is one of the disqualifications for an etrog.[12] Assuming that the etrog and the lemon belong to different plant species, the grafted etrog has been obtained through the violation of the law of

[8] Eliezer Goldschmidt, "The Problem of the Grafted Etrog and the Present-Day Etrogim," *Techumin* 2 (1981):135–45.

[9] BT *Sukkah* 34a–36b.

[10] See Felix, *Plant World of the Bible*, 68.

[11] *Talmudic Encyclopedia*, II, Etrog; see also Goldschmidt, "The Problem of the Grafted Etrog," for the arguments of those who disqualify it, and those who permit it.

[12] These two arguments illustrate the difficulty in finding an adequate halakhic definition for the grafted tree.

kilayim (see above), and it is not fit for ritual use during the festival of Sukkot (Tabernacles).[13]

Counterarguments were raised (note 11) against each of the arguments to disqualify the grafted etrog. Nevertheless, the views of those disqualifying the grafted etrog outnumbered those who permitted it.[14]

21.7 The Mystery of Grafting

As explained above, halakhic authorities tended to disqualify a grafted etrog, although there is no agreed-upon reason to disqualify it. We believe the reason for this lack of concession in disqualifying the grafted etrog lies in the absence of a clear scientific understanding regarding the nature and functioning of the grafted plant, and the lack of halakhic definition of the grafted etrog tree. Moreover, a study of the history of grafting (note 1 above) shows that throughout the generations (up to the twentieth century!) there were repeated claims that grafting could bring about the appearance of a new species and should be treated as a kind of hybrid.[15] Thus, grafting was considered a mysterious procedure that must be treated with caution. The Rabbis were undoubtedly aware of the scientific views, and even if they did not explicitly rely on external sources, these views influenced their thoughts and judgement, causing the Rabbis to be stringent and to disqualify the grafted etrog in order to avoid doubt.

21.8 Identifying the Grafted Fruits: Distinctive Features and Credibility

The ruling to disqualify the grafted etrog spread rapidly in the Diaspora, and the question immediately arose: How can the valid, non-grafted etrog be distinguished from the disqualified grafted one? This question was especially critical for the Jews in Central and Eastern Europe who depended on the supply of etrogim from the faraway growing citron regions along the shores of the Mediterranean. The first and foremost authority to suggest signs for how to identify the grafted etrog was Rabbi Shmuel

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[13] Underlying this argument is the assumption that the etrog is a totally different species than the lemon or bitter orange, and they may not be grafted. But this assumption is not the consensus, see Goldschmidt, "The Problem of the Grafted Etrog.".

[14] Some were lenient in extreme situations; see Rema, *Moses Isserles (Responsa)* (Jerusalem: Mossad Harav Kook, 2018), 117: "So as not to cast aspersions on earlier generations whose custom was to make a blessing over such an etrog in extreme situations, nevertheless one should not make the blessing over such etrogim when not in an extreme situation." Others held that one may permit reciting the *brachah* on a questionably grafted etrog, see M *Berurah*, *Biur Halachah*, *Shulkhan Aruch* 648, s.v. *Shedomeh.*

[15] Such an idea can also be seen in the teaching of Shmuel (*Kiddushin* 39a), "Just as it is prohibited to crossbreed animals, similarly one may not graft," teaching that it is prohibited to graft plants.

Yehuda Katzenellenbogen[16] of Padua, Italy, in the first known written responsa to disqualify the grafted etrog[17]:

> I am writing to you [about] three features to identify the grafted etrogim that grow in our land, while those growing in other places won't reach you due to the far distance. The first sign is that the skin of a grafted etrog is smooth, while the genuine etrog has small bumps all over. Second, the pedicel of a grafted etrog protrudes, while that of a regular etrog is sunk into the fruit. And third, the grafted etrog is juicy, its inner part is wide and its middle peel is thin, while the original etrog is quite dry, its peel is thick and the inner part is small; these signs are considered trustworthy among us.

Another sign, cited in the Magen Avraham[18] commentary on *Shulkhan Aruch* in the name of *Olat Shabbat*[19]: "In a genuine etrog the seeds stand up straight to the length of the etrog, while in a grafted etrog they are lying down horizontally to the breadth of the etrog."

Since then, these signs are mentioned in halakhic works and have initiated countless discussions regarding their credibility, and whether one may rely on them to determine the etrog's authenticity. There were those who particularly disputed the credibility of the sign regarding the position of the seeds (Fig. 21.2).
[20]

Among the authorities who deliberated regarding these signs was the Chatam Sofer (Rabbi Moses Schreiber, 1762–1839), who wrote:

> ...all these signs are not biblical, and are not mentioned in the Talmud or elsewhere, and therefore the law of the etrog is similar to that of legally halakhic birds, which may be eaten if there is a tradition as to their validity. Those etrogim arriving from Yanova[21] have a tradition from our ancestors and masters; they are the valid etrogim, without need for any signs.[22]

[16] Rabbi Shmuel Yehudah Katzenellenbogen (1521–1597), son of Rabbi Meir Katzenellenbogen who was also known as Maharam Padua (1473–1565).

[17] Cited in Rema, *Moses Isserles (Responsa)*, 126, see "Responsa" in Eliezer E. Goldschmidt and Moshe Bar-Joseph (eds.), *The Etrog Citron: Tradition and Research* (Jerusalem: Mossad Harav Kook, 2018).

[18] Rabbi Avraham Abli Halevi Gombiner (1637–1682).

[19] The commentary of Rabbi Samuel Orgler (1645–1700) on *Shulkhan Aruch Orach Chaim.*

[20] Ya'akov Etlinger, *Bikurei Yaakov*: *Commentary of Rabbi Yaakov Etlinger (1798–1871) on Shulkhan Aruch Hilchot Sukkah Ve'lulav* (Jerusalem: Machon Devar Yerushalayim, 1958): "Also, the sign cited in the name of the *Olat Shabbat*, although he writes it is reliable, I checked the etrogim that we use and they have all the features of kosher etrogim, yet sometimes their seeds are lying to the length, sometimes to the breadth, and sometimes some of them to the length and some of them to the breadth" (648:53).

[21] "Yanova" is a distortion of Genoa, the northern Italy port from where the etrogim were sent to northern European countries. The Chatam Sofer held that these etrogim, grown in Calabria, southern Italy, are not grafted. In later years, there were those who doubted this presumption, see Avraham Yitzchak Hakohen Kook, *Igrot Hareiyah* (Jerusalem: Mossad Harav Kook, 1962), vol. I, 52:114, while others rely on this tradition up until the present day, see Moshe Bar-Yosef and Eliezer Goldschmidt, "Calabria Etrogim," *Emunat Itecha* 70 (2007): 69–70.

[22] Khatam Sofer, *Moshe Sofer (Responsa)* (Jerusalem: Hod, 1972) *Orach Chaim* 207; see "Responsa" in Goldschmidt and Bar-Joseph, *The Etrog Citron.*

◀**Fig. 21.2** Longitudinal section of a Calabrian etrog: a change in the direction of the position of the seeds and juice sacs can be noticed in different parts of the fruit. In the upper part, close to the *pitam*, the position of the seeds is horizontal, while in the lower part, close to the pedicel, the seeds and juice sacs are slanted. (Photo: Leah Goldschmidt)

Another characteristic that I (the author), remember from my youth in Jerusalem was to prefer an etrog without a *pitam* because they were considered non-grafted. But this feature seems unreasonable, as there is seemingly no connection between grafting and *pitam* retention. The argument that grafting strengthens the tree and prevents the falling of the *pitam* is wrong, as there are etrog varieties that rarely have a *pitam*, as with the Yemenite etrog, and others with a high rate of *pitam* retention. However, on second thought, this sign may be a relic from the early twentieth century when they used to graft etrog varieties which have a *pitam* onto etrog varieties with poor *pitam* retention. This kind of grafting is no longer performed today.[23]

As to the signs themselves, a few comments:

(a) Unlike other citrus fruits, such as oranges and grapefruits, etrog fruits are not uniform. The citrus research literature shows many etrog varieties that totally

[23] See further on Israeli etrogim and the question of grafting," Kook, *Igrot Hareiyah* I:114, "and especially that *baruch Hashem* the etrogim from our Holy Land are growing more attractive every year with the kosher grafting of pitam-etrogim with etrogim lacking pitams.".

differ in shape,[24] and one can find on one tree, and even on one branch, different shapes of etrog fruits.[25]

(b) The age of the tree significantly affects the shape of the fruit. The fruits of a young etrog tree are elongated and have bumps, and as the same tree matures its fruits become smoother and more lemony. In addition, the fruits of the spring and summer bloom waves also differ in shape.[26]

(c) Although the thick white peel and small amount of flesh do differentiate the etrog from the lemon, even in these features there are differences between different types of etrogim,[27] and these features may also change as the tree matures. It is therefore conceivable that signs characteristic for a particular variety or area might not be valid under different conditions.[28]

(d) And most important: To the best of our knowledge, no systematic scientific comparison has ever been made between the fruits of a grafted tree and the fruits of a non-grafted tree. Therefore, we have no experimental proof that grafting really affects these properties and signs. Such a comparison, if conducted, may have given clearer answers as to the effect of grafting on the properties of the etrog and the reliability of the traditional signs.

21.9 The Grafted Etrog Lineage

The issue of the grafted etrog dealt with so far concerns an etrog fruit growing on the grafted tree, with the etrog (the scion) grafted onto another citrus species (the rootstock). The ruling that disqualifies the grafted etrog had to deal with a reality in which most etrog growers along the shores of the Mediterranean were accustomed to grafting their etrog trees. Although experts were able to determine without difficulty whether the tree was grafted, careful supervision of the fruit was required to verify that an etrog comes from non-grafted trees. With the commercial and competitive interests involved, it was not easy to achieve complete trust among all the parties involved.[29]

Questions regarding the lineage of the grafted etrog made the issue even more complex. In view of the halakhic authorities' decision to disqualify a grafted etrog,

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[24] Johann Christoph Volkamer, *Nuernbergische Hesperides* (Nuremberg, 1708).

[25] Eliezer E. Goldschmidt. "Factors Determining the Shape of Citrons," *Israel Journal of Botany* 5 (1976): 34–40.

[26] See supplement, "Pictorial Album of Israeli Etrog Citron Cultivars" and chapter 5, "Preserving Etrog Quality After Harvest: Doctrine and Practice.".

[27] The different etrog varieties described by Volkamer, *Nuernbergische Hesperides*, differ in the size of their pulp (the juice sacs inside the fruit), and the Yemenite etrog does not have any juice sacs.

[28] Rabbi Katzenellenbogen already noted in his initial *teshuva* cited above: "… These are the signs to recognize the grafted fruits grown in our lands…," meaning these features are not consistent in all places.

[29] See in detail Chap. 20, "The Corfu Etrog Citron Polemic" and Chap. 22, "Etrog Citrons of the Land of Israel in Modern Times".

what happens with the descendants of a grafted etrog? To be specific; propagation of a grafted etrog tree can be performed either using a seed from an etrog fruit or using a cutting from the grafted tree. Should such descendants also be considered as having been "grafted?" And if we take the problem one step further and relate to any descendant (or lineage) of a grafted tree as a grafted etrog, the issue becomes irresolvable, since it is impossible—not even with modern scientific technologies––to ascertain that there was no grafting at any stage of the cultivation of the tree's predecessors.

This problem of "grafting lineage" was also subject to controversy. Rabbi Efraim Zalman Margulies in his *Beit Efraim* Responsa[30] permits the use of graft descendants, arguing that even if the grafted etrog is considered a mix of a lemon and an etrog, when a seed or cutting of the grafted tree is replanted it grows into an independent tree, and is then considered a non-grafted etrog tree.

According to *Beit Efraim*, the effect of grafting is transient, expiring when seeds or cuttings are detached from the grafted tree. When replanted, they form a new, non-grafted tree and the scion's inherent nature has not been changed by grafting. In modern language, we would say: grafting does not change the genetic properties of the scion**,** and this is indeed the accepted scientific view today. There are, however, leading halakhic authorities, including the Chazon Ish,[31] who did not accept *Beit Efraim's* approach, disqualifying even the descendants of a grafted etrog tree.

As evident from Amar's research,[32] for a long time, since the end of the nineteenth century, significant halakhic authorities in Israel permitted the use of etrog varieties that may have been descendants of grafted etrog trees. Nowadays, as well, we use etrog varieties without any means of verifying whether they are not from a lineage of grafted trees.

21.10 Etrogim of the Land of Israel and the Grafting Dilemma

The history of the cultivation of the etrog in the Land of Israel has been fascinatingly researched and described by Amar, and we will only comment briefly on the role that grafting played in this story. Israel's original etrogim, which grew in the areas of Nablus, Umm al-Fahm and the Upper Galilee, were not externally appealing, but they were strong and they were considered non-grafted. The techniques of grafting etrogim became more widespread during the nineteenth century with the import of

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[30] Beit Efrayim, *Efraim Zalman Margulios (Responsa)* (Jerusalem: Machon Lehotza'at Shut Beit Efrayim, Jerusalem, 2021), 56; "Responsa" in Goldschmidt and Bar-Joseph, *The Etrog Citron.*

[31] The Chazon Ish writes that although all the citrus fruits might be considered the same species regarding the prohibition of grafting, "regarding the *mitzva*, if the first etrog is grafted… the second generation is also disqualified" (*Kilayim* 3:7).

[32] Zohar Amar, *Etrog Citrons of the Land of Israel* (Tel Aviv: Oren, 2010). See also chapter "Etrog Citrons of the Land of Israel in Modern Times".

Corfu etrogim into the orchards of Jaffa and its surroundings. These Corfu etrogim excelled in beauty in comparison with Israel's original etrogim, and many of them also had a *pitam.* But there was considerable concern that the Corfu etrogim were grafted, and therefore there was also doubt concerning their descendant etrogim planted in Israel, which may be descendants of grafted trees.

Towards the end of the nineteenth century, etrog growers became accustomed to an etrog-on-etrog grafting method, grafting the delicate, beautiful etrog with the *pitam* onto the scion of a local etrog; Rabbi Kook permitted and encouraged this grafting method.[33] Grafting its own kind is not considered mixed breeding and is permitted, but other halakhic authorities rejected even this type of grafting, and it appears that the Chazon Ish's firm position prohibiting the use of etrogim that may have a problem of being descendants of a grafted tree[34] put an end to this etrog-on-etrog grafting.

21.11 The Search for the Original Etrog

The issue of the grafted etrog, and its extension to the lineage of grafted trees, caused a dilemma without a clear way out. Therefore, many Torah leaders have the custom of taking several varieties of etrog for the Four Species commandment, hoping that at least one of them is an authentic non-grafted etrog. The desire to find an "original" etrog without any suspicion of grafting, encouraged the search for etrogim outside the accepted agricultural growing areas. The searches reached the etrogim of Morocco and Yemen on the assumption that in these remote places the locals did not engage in grafting and their etrogim were therefore probably non-grafted.[35]

The Kivelevitz etrog variety, for example, originates from etrog trees in Wadi Kelt in the Judean Desert, and has since been grown without grafting. Also, the Chazon Ish varieties probably originated from trees that grew wild outside Safed and were identified by the Chazon Ish as being non-grafted.[36] Moroccan etrog citrons were known in Europe as early as the end of the nineteenth century,[37] and the Yemenite Jews brought with them their Yemenite etrogim which they now grow in Israel, and these are accepted by many as authentic non-grafted etrogim, as well as having other beneficial properties.

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[33] See above n. 23.

[34] The Chazon Ish's strict view regarding this issue appears in a recently publicized letter; see "Responsa" in Goldschmidt and Bar-Joseph, *The Etrog Citron.*

[35] Elisabetta Nicolosi, Stefano La Malfa, Mohamed El-Otmani, Moshe Negbi, and Eliezer E. Goldschmidt, "The Search for the Authentic Citron (Citrus medica L.): Historic and Genetic Analysis," *Horticultural Science* 40 (2005): 1963–68.

[36] See evidence in Amar, *Etrog Citrons.* But see Avraham Y. Koenig, "Chazon Ish Etrogim," *Yeshurun* 33 (2005), who cites a tradition that the Chazon Ish etrogim originate from trees that grew in the yard of one of the villages in Nachal Amud.

[37] See the *teshuvah* of Rabbi Avraham Binyamin Kluger in *Hatzefirah* 1891 and, more recently, in Elyakim Shlanger, "Regarding the Morocco Etrogs," *Halichot Sadeh* 100 (1996): 44.

It should be noted that the notion of finding etrog trees that have grown wild ever since Creation, be they in Wadi Kelt, Safed or anywhere else in Israel or in the Mediterranean countries—or even in Morocco and Yemen—is scientifically groundless. As far as we know, the etrog originated in Southeast Asia and was brought from there as a cultural crop to Persia, Israel, and the Mediterranean countries. Nevertheless, etrogim from Morocco and Yemen are also cultivated crops and did not grow wildly. And even if certain etrog trees are discovered outside the regular growing areas, they are probably "cultural refugees," remnants of neglected orchards or fruit that was discarded by a passerby.

Moreover, even the efforts to find etrog trees in the wild vegetation of mountainous areas in southwest China have so far not been successful.[38] Nevertheless, as to the grafting issue, it is quite possible that the etrogim of countries outside the Mediterranean basin, such as Yemen and Morocco, were not grafted there and they can probably be regarded as non-grafted.[39]

21.12 Etrog Hybridized with Other Citrus Species

Another aspect of the search for the authentic etrog is the fear of the natural hybridization of the etrog with another citrus species. Is it possible that some of the etrog varieties we have are not pure etrogim, but hybrids created by etrog flowers pollinated by another citrus species, such as lemon or bitter orange? This possibility did not seem to bother the halakhic masters of previous generations, who were probably unaware of the phenomenon of natural hybridization.[40] But scientifically there is room for this possibility, since all citrus species are known to behave as one species and are capable of pollinating and fertilizing each other.[41]

DNA testing of twelve different etrog varieties found in Israel (including Yemenite and Moroccan) has shown that they are all very similar to each other and distinctly differ from other citrus species, such as lemons and bitter oranges.[35] The strong resemblance among all our types of etrogim and the absence (or at least rarity) of hybrids between the etrog and other citrus species can be explained in two ways: (a) The etrog growers made careful selections and immediately uprooted any seedling that aroused suspicion as not being an etrog; and (b) as far as we know, etrog flowers undergo self-fertilization, and there is almost no foreign fertilization with the flower pollen of another citrus. This is a unique phenomenon that contributes to maintaining

[38] See Chap. 8, "The Citron and Its Uses in China.".

[39] But it must still be verified that they were not grafted after leaving their homeland.

[40] Today there are rabbis who demand that beehives be distanced from etrog orchards, and they seem to be aware of this problem.

[41] See a discussion of the question of citrus species in Goldschmidt, "The Problem of the Grafted Etrog".

the purity of the etrog species.[42] Nevertheless, citrus research literature has described some etrog-like fruits that may be hybrids of etrogim with other citrus fruits.

21.13 The Situation Today

The grafted-etrog controversy summarized here spans around 450 years, and is the subject of many hundreds of essays, rulings, responsa, and communication of Torah leaders. The controversies and doubts continue and the debate carries on; up to the present day, new books are being published discussing the subject in depth and breadth. In this chapter, we have paid primary attention to the plant-botanical basis of the grafted-etrog problem, as expressed in halakhic discussions and as seen through the eyes of contemporary scientists. But the issue of the grafted etrog also includes other important aspects—historical, economic, and social, which are extensively discussed in other chapters in this book.[43]

Map of the Mediterranean Basin—places and areas connected with the cultivation and trade of etrogim and their shipment to northern European countries (according to data from http://www.naturalearthdata.com/downloads). The editors would like to thank Mr. Saar Zini for preparing the map.

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[42] Eliezer Goldschmidt, "The Etrog*'s* Growth: Seeds or Offshoots?" *Hanotea* 63 (2009): 692–94.

[43] See Chap. 20, "The Corfu Etrog Citron Polemic" and Chap. 22, "Etrog Citrons of the Land of Israel in Modern Times".

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Chapter 22
Etrog Citrons of the Land of Israel in Modern Times

Zohar Amar

Abstract This chapter deals with milestones in the history of etrog [pl. etrogim] citrons growing in the Land of Israel from the second half of the nineteenth century until the present. It reviews several of the varieties associated with the native, traditional etrogim that grew in antiquity and their development. The etrogim found in the hills of Shechem (Nablus), Umm al-Fahm, Safed, Jerusalem, and Jericho were cultivated by Jewish growers for the purpose of fulfilling the biblical commandment of "the Four Species" (*arba minim*) and are publicly distinguished as Braverman, Kibilewitz, Shlomai, and the Chazon Ish. The cultivation of these different varieties of etrogim was largely in response to the etrog grafting controversy that preoccupied the world of *halakhah* in modern times. The traditional Land of Israel etrog was characterized by a protracted growing cycle, a large fruit with irregular contours, and generally without a *pitam* (persistent style). The introduction of other Mediterranean varieties, suspected to have arisen from a grafting lineage, had a marked effect on etrog cultivation and commerce.

22.1 Introduction

This essay will seek to trace some of the progenies of the traditional Eretz Israel (Land of Israel) etrog species over recent generations, and their present-day metamorphoses.[1] For centuries, the growing of etrogim in the Land of Israel was undertaken by Arab farmers; from the second half of the nineteenth century, the growing of etrogim for ritual purposes was taken on by Jewish growers.

[1] This article is a summary of an extensive study of the history of etrog growing in Eretz Israel since the time of the Bible, through the Mishnaic, Talmudic, and medieval periods, to the modern era. The limited scope of this article does not allow us to address different aspects such as the problem of grafting etrogim, the dispute between Rav Kook and the Chazon Ish, the kashrut of Urdang etrogim, and others. For the complete study with full footnotes, see Zohar Amar, *The Four Species* (Neve Tzuf: Z. Amar, 2009); idem, *Etrogim of the Land of Israel* (Neve Tzuf: Z. Amar, 2012).

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The rapid changes in the etrog-growing industry in the modern era presented this study with many methodological difficulties—from the introduction of new species from abroad (etrogim from Europe, Morocco, and Yemen), to the concern regarding the crossbreeding between them and an agronomic development that resulted, for example, in the appearance of fruit varieties possessing morphological traits that differed from those of their predecessors. These difficulties were compounded by additional challenges, primarily the lack of systematic documentation that could indicate with certitude a continuous and reliable "family tree" (genealogy) of the traditional etrog varieties. Moreover, written historical information is limited while some of the extant information is vague and draws on rumors that cannot always be verified.

We were greatly assisted by helpful conversations and interviews with rabbis and other Torah scholars, etrog growers and merchants, and family members and close acquaintances of people after whom etrogim were named, i.e., Braverman, Kibilewitz, Urdang, Chazon Ish, and Shlomai.

This study focused on two generations, between the years 1910 and 1960, during which these people were active. The prime motivation of the study is historical, and although it may have halakhic ramifications, we openly refrained from formulating a personal stance, neither recommending nor casting doubts on the kashrut qualification of certain etrogim varieties sold on the market today. This evolved, among other reasons, because of our view that the problem of grafted etrog trees, (for those not concerned with the lineage of grafted trees[2]), is almost non-existent in modern-day Israel.

22.2 Etrog Grafting as a Motive for Etrog Cultivation in the Modern Era

Grafting the etrog onto a lemon or another citrus species was unknown during the period of our sages and uncommon in the Middle Ages. The first mentions of grafting in halakhic literature only appear from the last third of the sixteenth century and it was both uncommon and unpopular in plantations of the Land of Israel.[3] R. Joseph Schwarz testified in 1845 that: "There are etrogim that weigh 12 pounds or more and [there are] no grafted etrogim in Eretz Israel."[4] Use of the etrog grafting technique, hitherto an accepted practice among the citrus growers of Europe, began spreading throughout the Land of Israel only from the mid-nineteenth century, initially being adopted by immigrant farmers from Europe.[5]

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2 On the problem of the grafted etrog and its history, see Amar, *Four Species*, 41–53.

3 For example, this phenomenon is not mentioned in the Shulkhan Arukh and first appears in Italy in the responsa of R. Moses Isserles (Shu"t HaRemah) §126; in Eretz Israel, see Shu"t Alshich §110.

4 Joseph Schwarz, *Tevuat Ha'aretz* (Jerusalem: Lunz Press, 1900), 383.

5 Amar, *Four Species*, 47.

Fig. 22.1 Committee of Enquiry for scrutinizing the etrogim orchards. The picture was photographed at the end of 1877, probably in Jaffa. In the picture, among others, Yoel Moshe Solomon (extreme right), R. Shmuel Moni Zilberman (standing in center), and R. Binyamin Beinish Salant (on left)

The practice of grafting in citrus orchards and the beginnings of the growing of etrog species from Greece with a *pitam* (persistent style) constituted the background for a vociferous public halakhic debate that lasted for approximately two generations and generated extensive literature, including dozens of treatises, responsa, journal articles, imprimaturs, and posters (although the halakhic discussion of this issue has never really ceased). Investigations conducted during the second half of the nineteenth century among the elders of the Jewish residents and committees that explored the etrog orchards throughout the country sought to research the ancient species of the local etrogim (see Fig. 22.1).

The accepted assumption was that only those etrogim grown historically by Arab farmers using primitive methods could be relied upon, and although these etrogim were not beautiful and halakhically preferred (*mehudar,* pl. *mehudarim*), there was no concern that they had been grafted, a method with which the Arab villagers were initially almost entirely unfamiliar. Among the places in which traditional species of etrogim were grown (the majority without a *pitam*) were the Lebanese Upper Galilee and Safed, Nazareth, Nablus (Shechem) and Umm al-Fahm, Jericho, and villages in the Jerusalem area (Lifta, Qalunya, Bait Naqquba, Suba, Al-Qabu, and Artas).[6] During that period, merchants would regularly visit the Arab villages and bring etrogim from there to the markets, whereas today etrog cultivation is exclusively in the hands of Jews, who generally market them directly.

[6] Idem, *Etrogim of the Land of Israel*, 11–12.

22.3 The Introduction of Greek Etrogim to the Land of Israel

According to different accounts, the etrogim with a *pitam* that began to be grown in Jaffa originated from seeds of etrogim grown in Greece on the island of Corfu or on the Parga Coast near the island during the first half of the nineteenth century.[7] In comparison with the traditional etrogim grown up to that time, the Greek etrogim were considered to possess a finer appearance, were smaller, and were typified by their delicate protrusions and a *pitam*. The etrogim from these trees were distributed throughout the entire Jaffa region, including Mikve Israel,[8] and later probably to Gan Shmuel and the new rural settlements (Fig. 22.2).

Aside from the halakhic debate concerning the kashrut of etrogim from abroad (chiefly those from Corfu),[9] a disagreement developed between the Ashkenazi and Sephardi communities over the qualification of the new etrogim that had begun to be grown extensively throughout the Land of Israel. Unlike the Sephardi leaders who tended to adopt a more lenient approach, some of the Ashkenazi rabbis were inclined to forbid the new etrogim since they were suspected of being grafted, preferring instead the local traditional etrogim.

This dispute should not be viewed solely in a halakhic context as other, non-halakhic considerations, such as etrog merchants' financial interests and tensions between sectors of the Old and New Jewish population, featured among the factors fanning the flames.[10] This dispute proved detrimental for all involved and ultimately abated almost entirely when many of the rabbis led by Rabbi Meir Auerbach, the most illustrious of the Ashkenazi rabbis in Jerusalem, retracted their prohibition and eventually permitted the use of some of the Jaffa etrogim.[11] This step was made possible

[7] *Kuntres Pri Etz Hadar* (Jerusalem, 1878), 6–7, presents the testimony of R. Yehuda HaLevi of Ragusa who renewed Jewish settlement in Jaffa and later sold his orchard to Moses Montefiore: "Our rabbi and teacher, the Sephardic sage R. Yehuda HaLevi testified that he planted seeds from Corfu etrogim in the garden of the minister Moses Montefiore, may God preserve him, and the garden owners took from them for their gardens"; Chaim E. Waks, *Nefesh Haya* (New York: Schlesinger Press, 1946).

[8] Yaakov Sapir, "On the Etrogim of the Holy Land," *Halevanon* 15, November 16, 1877, 119.

[9] See Gavriel Zinner, "Birur Mekomot Gedulei HaEtrogim [2]: Etrogei Corfu," *Ohr Yisrael* 30 (2003): 169–94; see also in detail the series of important essays written by R. Levi Yitzhak Sofer which have been collated in the book *Taharat HaEtrogim* (Brooklyn: L. Y. Sofer, 2016).

[10] See Eliezer R. Malachi, *Perakim BeToldot HaYishuv HaYashan* (Tel Aviv: Tel Aviv University, 1971), 168–78; Isaaq Raphael, "The Etrogim of Corfu and the Etrogim of Eretz Israel," *Shragai* 2 (1985): 84–90; David Porat, *HaPulmus al Etrogei Eretz Israel BaShanim 1875–1889* (Jerusalem, 1994); Yosef Salmon, "HaPulmus al Etrogei Corfu Ve-Etrogei Eretz Israel 1875–1891," *Zion* 65 (2000): 75–106; Melech Shapira, "Odot HaPulmus B'Inyan Etrogei Corfu," *Ohr Yisrael* 29 (2003): 205–13.

[11] Eliezer R. Malachi, *Mineged Tir'eh, Asufa M'Ma'amarei B'Inyanei Eretz Israel* (ed.), Elchanan Reiner and Haggai Ben-Shammai (Jerusalem: Yad Izhak Ben Zvi, 2001), 76.


גן האתרוגים
בשנת 1893 החליטה ועידת "חובבי ציון" על נטיעת גן אתרוגים בא"י, לכבוד יום הולדתו ה–70 של הרב שמואל מוהליבר שחל בניסן 1894.
יעקב הינדין, ניסו, ממייסדי חדרה, תרם כ–66 דונם מאדמותיו למטרה זו.
ב–25.2.1895 החל דר' מקס שפירא בהכנת השטח לנטיעה. בט"ו בשבט 1896 ניטע הגן, ובו כ–2000 עצים.
ב–1896 שווקו הפירות הראשונים ליהודים בגולה ושם גן שמואל יצא בתפוצות.
אחד מעצי הגן עד היום עמנו.

בשם ד' — עזרי מעם ד'
אתרוגי גן שמואל
אשר במושבה חדרה באה"ק תובב"א
ולקחתם לכם-משלכם-פרי עץ הדר
הנטועים ע"י ישראל:
האתרונים המונחים בתבה הזאת ובה מספר אתרוג אחד
אתרוגים ועליה חותם כזה הנה אתרוני הגן שמואל שבחדרה אשר הקרנו ודרשנו עליהם ונוכחנו שאין בהם שום חשש הרכבה כלל וכן אין בהם שום חשש מכל ושום הכשות אחרות וראוים המה לברכה להמהדרים בלי שום חשש וספק כלל ולראי באעה"ח יום ה' לחדש התרס"א פה יפו ת"ו.
NAFTALI HERZ LEWY RABBINER IN JAFFA
תעודת כשרות לאתרוגי גן שמואל, 1901

Fig. 22.2 The kashrut qualification certificate given to the "Gan Shmuel" etrogim in 5661, signed by Rabbi Naftali Hertz HaLevi, the Ashkenazi rabbi of Jaffa (courtesy of the Gan Shmuel archive)

after the orchards were scrutinized and all the grafted etrogim were uprooted.[12] The editor of the *Havatzelet* newspaper, Israel Dov Frumkin, described the restored calm: "He who makes peace between the merchants of Jaffa and Umm al-Fahm, between etrogim without a *pitam* and those with a *pitam*."[13]

As mentioned above, this changed stance evolved primarily from the rabbinical confirmation of the validity of the Jaffa etrogim and from the recognition that they were justly assumed to be non-grafted. However, this new stance appears to have been accepted by most of the relevant parties only when a suitable halakhic solution was found, enabling the combination of the advantages of both the Greek and Jaffa etrogim, an integration of old and new, as we shall see below.

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[12] *Kuntres Pri Etz Hadar*, 16–17, 28–29; Getzel Kressel (ed.), *Yehuda V'Yerushalayim* (Jerusalem: Mossad HaRav Kook, 1955), 103. R. Auerbach reversed his prohibition issued on the eve of Sukkot, 1877, approximately six months before his death.

[13] Israel D. Frumkin, "Likhvod HaEmet," *HaHavatzelet* 40, August 22, 1879, 1.

22.4 Embellishment of the Old, Traditional Etrog with Foreign Etrogim

Tension between the desire to use an etrog boasting an impeccable pedigree and the quest for a beautiful, *mehudar* etrog has been a constant feature of the etrog industry in the Land Israel in the Modern Age. Growers of the traditional, non-grafted etrogim struggled to reap a profit from their crops, largely due to their inability to produce fruit that was both and *mehudar*—while facing strong competition from etrogim from Greece and other countries—now newly grown in Israel. The halakhic solution that satisfied market demands was eventually found—the grafting of *mehudar* etrogim of Greek origin that possessed at least several generations of impeccable non-grafted pedigree onto the rootstocks of traditional Land of Israel etrogim, such as those from Nablus or Jericho.

The first to embrace this solution were apparently two people initially strongly identified with the struggle against the Corfu etrogim and those growing them in Jaffa. R. Haim Elazar Waks, the rabbi of Kalisz and Pietrokov (author of the *Nefesh Haya*), who served as the head of the "Warsaw Kollel" in the Land of Israel, was known for his opposition to etrogim from abroad and for his strenuous efforts in favor of the etrogim from the Land of Israel. In this endeavor, he joined forces with R. Meir Auerbach (author of *Imrei Bina*), rabbi of Jerusalem and former rabbi of Kalisz. R. Waks also realized his vision when he planted orchards of traditional etrog varieties in plots of land he purchased in Kfar Hittin in 1876.

When it became apparent that the fruit of the traditional etrog trees failed to compete with the Greek-like Jaffa etrogim, R. Waks decided to begin growing and selling Jaffa etrogim. These etrogim had since been qualified kosher by the Jerusalem Badatz (kashrut authority) headed by R. Meir Auerbach, and by many other rabbis who accepted the lenient view dismissing all concerns of any previous possible grafting.[14] As mentioned earlier, this occurred after it had been ascertained that those etrogim that had been examined and that were under rabbinic supervision were no longer suspected of being grafted. R. Waks adopted this view and relied on it, as he wrote explicitly in 1889.[15]

Yehiel Brill, who greatly admired R. Waks's endeavors and even corresponded with him extensively, claimed that R. Waks had big plans to purchase orchards in Jaffa (and in Nablus) and to "found there a colony that would be based solely on etrogim and for the purpose of encouraging the planting of etrog trees."[16] However, besides the orchard in Kfar Hittin, his plans remained unfulfilled. Brill described the

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[14] See Ephraim Z. Margolioth, *Shu"t Bet Efrayim* (Jerusalem, 1980), §56; Sha'arei Teshuva 649:7; Yehoshua Heschel, *Sefer Yehoshua: Psakim Ukhetavim* (Jerusalem, 1991), §155; Elazar Shapira, *Shu"t Minchat Elazar* (Munkács: Munkács Press, 1902), vol. 3, §77; Yoav Y. Weingarten, *Helkat Yoav* (Jerusalem, 2007), Orach Chaim, §32; Yisrael Z. Mintzberg, *She'erit Yisrael* (Jerusalem: Y. Z Mintzberg, 1963), Orach Chaim §29.

[15] See his letter in Shlomo A. Razachta, *Bikurei Shlomo* (Piotrków, 1894), §28:7, 1.

[16] Malachi, "Mineged Tir'eh," 74, 80.

halakhically-agreed method of grafting the Jaffa etrogim onto the traditional Land of Israel etrogim trees:

> I saw the etrog fruits that had been growing there (= in Corfu and Parga) ever since and recited a blessing: "Blessed is He who changed the etrog!" Their shape is as that of an Egyptian pyramid, broad at the base by the peduncle and gradually sloping towards the apex of the stigma. And since my eyes have never seen an etrog of such shape, I concluded that this was the original form of the etrog and that since growers had begun grafting lemon trees with etrog trees the etrog's shape had changed into that of a lemon, which is the shape of the etrog originating in Corfu and Parga!… Indeed, who can recite the blessing of the Four Species on an etrog that lacks the glorious beauty of a lemon? For this reason, the Gaon R. Waks instructed to cut down the old etrog trees from his garden and replace them with etrog trees from Alma[17]because the shape of these Alma fruits resembles to some extent the lemon-like etrogim desired by the buyers. Those buyers are meticulous about etrogim complying with the secondary meaning of the word *hadar* (glorious) and do not care for the primary meaning of *hadar*–citrus. That is to say, it should be the fruit of the tree called in Hebrew *hadar* and not from a tree the bottom of which is a lemon [tree] and whose top half is an etrog [tree]. Even those who are meticulous about specifically using a Greek etrog (from Corfu, etc.) may fulfill the Four Species commandment with an etrog from Jaffa because of its similarity to a Corfu etrog. He ordered cuttings be brought from Jaffa, and he planted and grafted them (onto an old etrog) in his gardens. Henceforth, these gardens will produce four species together: The old etrog, an etrog from Alma, the Jaffa etrog, and the grafted etrog (from Alma onto the old etrog or the Jaffa etrog onto the old etrog).[18]

Thus, R. Waks grew several varieties of etrog: The traditional etrog (the origin of which is unclear), the etrog from Jaffa (similar to that from Corfu), the etrog from Alma el Shaab (similar in form to the Jaffa variety), and an etrog that was grafted onto the stock of a traditional etrog. The solution found was based on the ruling that permits the grafting of fruit trees of the same species, i.e., one etrog species onto another, as detailed in the Jerusalem Talmud.[19]

Two varieties were chosen for this purpose: (a) the scion—producing beautiful,*mehudar* (as demanded by the consumers) etrog fruits, considered non-grafted (according to the "Beit Efraim") from the highly qualified and *mehudar* Jaffa variety,[20] similar in form to the Greek etrog; (b) the rootstock—a traditional, agriculturally uncultivated Land of Israel etrog, named in Jewish sources: *ya'ari* (honeycomb), *pra'i* (wild), *kadmoni* (ancient), or in Arabic *baladi* (local). This kind of etrog was regarded as possessing an ancient pedigree and was universally accepted. It was also considered more resilient against disease.[21]

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[17] Alma el Shaab in the Lebanese Upper Galilee. In Waks, *Nefesh Haya*, 24, it appears by the name of Almai.

[18] Yehiel Brill, *Yesod HaMa'alah* (Mayence, 1883), 191–92.

[19] The Talmud mentions the act of "sipuk etrogim," i.e., the grafting of a branch from one tree onto another tree of the same species. See JT *Orlah* 1:5, 61a. For a description of *sipuk*, see *Perush HaMishnah LaRambam*, *Orlah* 1:5.

[20] See Brill, *Yesod HaMa'alah*: "Because Jaffa etrogim are truly more beautiful than any other of the Eretz Israel etrogim, and exceedingly cheap" (Malachi, "Mineged Tir'eh," 76).

[21] See Avraham Y. HaCohen Kook, *Etz Hadar HaShalem*, Yehuda Zoldan edition (Jerusalem: Mossad HaRav Kook, 1986), vol. 8, 47, on the "resilience of the etrogim growing wild that are entirely non-grafted.".

Fig. 22.3 HaRav Avraham Yitzchak HaCohen Kook

22.5 Rav Kook and Etrog Growing in Eretz Israel

Another well-known proponent of the use of this kind of grafted etrogim, indisputably kosher with a *mehudar* appearance, capable of competing with etrogim from abroad, was HaRav Avraham Yitzchak HaCohen Kook (1865–1935, Fig. 22.3).[22]

Rav Kook's endeavors in this regard gained momentum after he settled in the Land of Israel in 1904 and following his appointment as rabbi of Jaffa and the *moshavot* (the new agricultural settlements). He became highly influential in the growing of non-grafted etrogim. In 1907, he published the *Etz Hadar* booklet that received widespread acclaim from Torah scholars both in the Land of Israel and abroad.

Rav Kook provided assistance and kashrut qualification certificates to many etrog growers and various citrus growers' associations, his only condition being that they complied with the stringent halakhic criteria: "…with utmost supervision and endeavor to guard against the suspicion of grafting, and be supervised to comply with all issues relating to the special commandments of the Land of Israel, such as *orlah* and tithing of the fruits, as prescribed by the holy Torah."[23]

Rav Kook advocated the cultivating of non-grafted etrogim that would compete in their *mehudar* beauty with etrogim from abroad, and adopted the precedential halakhic method of R. Waks and R. Meir Auerbach in such a manner so that "grafting is done specifically from an etrog onto an etrog."[24] He clarified explicitly, however, that he was referring to the grafting of kosher etrogim with a *pitam* onto the rootstock

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[22] Bezalel Landau, "HaMa'avak Lema'an Etrogei Ha'aretz," *Mahanayim* 50 (1961): 32–39; Hagai Ben Artzi, *HaRav Avraham Yitzchak HaKohen Kook KePosek: Yesodot Hadshani'im BePsikato shel HaRav Kook* (Jerusalem: The Hebrew University of Jerusalem, 2003).

[23] Avraham Y. HaCohen Kook, *Igrot HaRaya* (Jerusalem: Mossad HaRav Kook, 1962), vol. 1, 83. See also Yehuda Zoldan's introduction to his edition of *Etz Hadar HaShalem* (f. 21), 30–34; Zvi Kaplan, *B'Shipulei Glimato* (Jerusalem, 2009), 59–69; Yohanan M. Yismach, *Kruzei Ha*Raya (Jerusalem: Yismach Family, 2000), 11–16, 24.

[24] Kook, *Pri Etz Hadar*, §86, 39; §88, 45.

of etrogim without a *pitam*,[25] apparently referring to grafting kosher Jaffa etrogim possessing a *pitam* onto the ancient etrogim.

In another letter, he explained that in the Land of Israel, "non-grafted are only a small minority found in Nablus and some other Arab villages, but they grow wild and have no attributes of being mehudar, and he therefore supported the cultivation and distribution of these kosher etrogim that, by means of mutual grafting, would attain the status of " etrogim *mehudarim*."[26] This grafting method was adopted in practice in the new agricultural settlements where they used rootstocks of "wild" etrogim from Jericho as described and advocated by R. Mordechai Diskin who was closely affiliated with the followers of Maharil Diskin (R. Yehoshua Yehuda Leib Diskin) and of Rav Kook.[27]

22.6 Growing Traditional Land of Israel Etrogim

Not everyone accepted the solution of graft-embellished etrogim, as described above, and ultimately, many rabbis, including Rav Kook himself, ideally preferred the traditional Land of Israel etrogim that grew without any grafting or special treatments, even though these were not considered *mehudar*.[28] Etrog varieties named after the first growers, who identified and selected them from the Arab orchards deemed to have a grafting-free pedigree, can still be found in the Four Species markets prior to Sukkot (Tabernacles). Several of these types are described in detail below. (See also Pictorial Album of Israeli Etrog Citron Cultivars)

22.7 Maharil Diskin—Braverman Etrog

This etrog is a well-known traditional Land of Israel type, known simply as "Maharil Diskin," i.e., attributed to R. Moshe Yehoshua Yehuda Leib Diskin (also known as the Rabbi from Brisk, 1817–1898, Fig. 22.4). The evolution of this species and its origins is the subject of many accounts and testimonies. According to the Braverman family tradition, Maharil Diskin recommended a specific cultivar of etrog on which

[25] Kook, *Igrot HaRaya* 1, §114, 144–145.

[26] Ibid., §52, 61. At the same time, he was a natural partner in the planting of the traditional etrog varieties and, in a letter from 1909, he was asked by R. Aharon HaCohen Orlansky from Petah Tikva to support this activity: "Consult Y. Hanoch Slar from Petah Tikva and Y. H. Fein from Rishon Lezion, and travel around Jerusalem where the etrogim are known to be non-grafted, and buy from there etrogim and seeds, which can be used as is the custom" (*Etz Hadar HaShalem*, 31 n. 1).

[27] Mordechai Diskin, *Ma'amar Mordechai* (Jerusalem: Frumkin Press, 1912), 23b–24a.

[28] See Yosef Briner, *Otzar HaHadar* (Jerusalem: Otzar Hatorah Press, 2016), 165–78, who maintained that Rav Kook adopted a stringent approach and limited the dispensation of the "Beit Efraim".

he recited the blessing to R. Zerach Reuven Braverman (d. 1938, Fig. 22.5), one of his most prominent students, as guaranteed to be non-grafted. Seeds from this variety of etrog were the original source of the Braverman etrogim. R. Zerach's descendants settled in Petah Tikva and founded an agricultural farm that, among other crops, grew etrogim.

According to a childhood memory of R. Yitzchak Braverman (1904–1991), the son of R. Yisrael David Braverman (Fig. 22.6), the etrog originated from seeds sown by R. Zerach Braverman in Petah Tikva, taken from Maharil Diskin's own etrog. However, a more credible testimony claims no direct connection between this species and Maharil Diskin. The etrogim were brought from Nablus (and according to other unsubstantiated reports), also from Umm al-Fahm and from Wadi Kelt), just like R. Pinchas Globman's etrogim (Fig. 22.7, see below). When these etrog trees dried up, etrog planting was renewed with seeds brought by R. Yehiel Michel Kibilewitz, Globman's son-in-law.

Braverman etrogim were highly regarded because of their pedigree and the "tradition" associated with Maharil Diskin. To this day, the Braverman variety remains the preferred variety among Brisker disciples, and the one they consider the most

Fig. 22.4 Maharil Diskin

Fig. 22.5 R. Zerach Reuven Braverman

Fig. 22.6 R. Yisrael David Braverman

Fig. 22.7 R. Pinchas Globman

reliable. The Braverman-Diskin variety is not as refined as the Chazon Ish variety and is not considered *mehudar* in appearance: It is generally of rectangular (barrel-like) shape and devoid of a *pitam*, is coarse in texture, bumpy, and may reach 1 kg or more. This variety conforms to the description of the "baladi" etrog mentioned in Jewish sources. It is relatively difficult to grow and prone to insect infestation. Today we have progeny of the first Braverman and second Braverman (Kibilewitz) etrogim. The current low market demand for this species has led to a sharp decline in its cultivation and efforts should be made to protect it from extinction.

22.8 Globman-Kibilewitz and Wadi Kelt Etrogim

R. Pinchas Globman was born in Pinsk (Russia) in 1870 and came to Jerusalem in 1877. In 1888, he married the oldest daughter of R. Yehoshua Stampfer, one of the founders of Petah Tikva, where the couple made their home and lived the rest of their lives. He was a Torah scholar and publicly active in the city's charity and welfare institutions.[29] He died in 1951.

There is speculation that the idea of growing non-grafted etrogim first arose in approximately 1910 during one of R. Meir Hirsch Hershler's trips to Transjordan to import wheat for Passover matzot (unleavened bread).[30] This enterprise was also taken up by his friends R. Dov Ber Halevi Epstein, R. Ze'ev Shachor, R. Yaakov Meir Sonnenfeld, and R. Pinchas Globman. The decision to grow the etrogim in the new agricultural settlement of Petah Tikva was a natural one, and it is reasonable to assume that the seedlings were brought from Jericho fruit, probably from Wadi Kelt.[31]

R. Hershler used to bring his etrogim from the orchards in Wadi Kelt which he had leased from local Arabs. Seedlings from these etrog seeds were in demand, and they were apparently planted in several orchards. In any case, it can be asserted with certitude that these etrogim were planted in R. Pinchas Globman's orchard and in the yard of his home in Petah Tikva. In 2010, Mrs. Hanna Talmi, Globman's granddaughter, related her recollections:

> It was common at that time to plant orchards and vineyards in Petah Tikva. My grandfather planted a small orchard with some mandarin trees that I remember well. I assume that it was in this orchard that the idea of planting indisputably kosher, non-grafted etrog trees was born. I recall from stories of my childhood that the trees were brought by Arabs from Wadi Kelt… I don't know which year the first etrog trees were brought… It certainly took several years after my grandfather's settling in Petah Tikva until the Etrog orchard bore fruit. I would say a cautious estimate of when this happened would be many years—approximately a hundred years.[32]

After Rachel, Globman's daughter, married R. Yehiel Michel Kibilewitz (in 1914), her husband took it upon himself to grow the trees. Kibilewitz was born in 1895 in the Belarussian town of Lubča and came to Jerusalem with his parents and sister in

[29] David Tidhar, *Encyclopedia of the Founders and Builders of Israel* (Tel Aviv: Rishonim Library, 1947), vol. 1, 223–24.

[30] R. Meir Zvi (Hirsch) Hershler, son of R. Shmuel Yosef Hershler, head of the Ungarin Kolel in Jerusalem. Living initially in Hebron, he later moved to Jerusalem where he traded in grains and legumes. When he saw the large etrogim that the Arabs were growing for food in Wadi Kelt, he decided to lease several orchards from them. He subsequently renewed the contract every year. Initially, he was satisfied with the etrogim grown by the Arabs, but later began to plant new seedlings. Together, R. Meir and his son, R. Yona-Zev became the biggest etrog merchants in Jerusalem (taken from Menahem Barash's essay in *Yediot Aharonot*, September 30, 1974.

[31] According to a document titled "An Explanation of the Kibilewitz Etrogim's Pedigree," written by Yitzchak Kelly in November 1987. A note found in Kelly's archive said: "The 'Kosher Etrog' Company. The seedlings were brought about 70 years ago from Transjordan (Wadi Al-Qelt) near Amman by HaRav HaGaon Yosef Chaim Sonnenfeld, of blessed memory." The source of this information is unclear. The "Kosher Etrog" Association was mentioned by Rav Kook in 1914. See Kook, *Igrot HaRaya* 2, §608 237. This would appear to be the "Association of Kosher Etrogim" that was founded in Petah Tikva in 1913 as a branch of the Shevach Ha'aretz Association. See ibid. 2, 341.

[32] A letter to the author from April 8, 2010.

1907. He was among the students of Rav Kook while at the "Central Yeshiva" in Jaffa (which operated continuously until World War One), in whose name he published several articles.[33] During his time at the yeshiva, he delved deeper into the study of the special commandments associated with the Land of Israel, and especially those of non-grafted etrogim.[34] Kibilewitz regarded the preservation of his father-in-law's high pedigree etrogim as a lofty ideal rather than as a commercial enterprise. The first step towards cultivating these etrogim took place in Petah Tikva.

When Kibilewitz moved to Bayit Vegan (the name initially given to Bat Yam) in the mid-1930s, he took with him the etrog seedlings, continuing to cultivate and distribute them. He grew three or four trees in his own home garden at Bat Yam, while at the same time operating a kind of etrog nursery with seedlings in small cans,[35] distributing them to people specifically seeking this distinguished variety.

Kibilewitz apparently decided to cease his endeavor in the etrog field in 1953 after most of his etrog trees died, and he was looking for a suitable location, both agriculturally and religiously, for the "remnant leftovers." Among others, he approached Kibbutz Hafetz Haim which followed the halakhic rulings of the Chazon Ish (R. Avraham Yeshaya Karelitz, 1878–1953). As kibbutz member R. Shraga Stiffel recalls:

> In 1953, we were approached by an etrog grower from Bat Yam—Yehiel Michel Kibilewitz. He supplied etrogim to the Chazon Ish and his followers. Kibilewitz visited us and offered us his remaining etrog trees after most of his trees had died because of their proximity to the ocean (sea air contains a high level of salt), and we transferred the small trees to our kibbutz and planted them in a separate plot.[36]

At some point during the same year, Yitzchak Kelly (d. 2009), one of the founders of Moshav Beit Meir, took three seedlings from Kibilewitz. He related how R. Kibilewitz subsequently came himself to check on the seedlings. In a document entitled "An Explanation of the Pedigree of the Kibilewitz Etrog," he describes, among others, the shapes of his etrog fruits:

After several years, I planted seeds from these etrogim, and they produced four varieties:

A. A tower shape; some with a 'belt'
B. A tower that assumes an orange color during its ripening
C. More rounded etrogim (some completely round, i.e., disqualified for use); many with a *pitam* and not considered *mehudar*

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[33] See Moshe-Zvi Neria *Chayei HaRe'iyah* (Tel Aviv: Moriah Press,1983), 274; idem, *Moadei HaRe'iyah* (Jerusalem: Machon Hatora Veharetz, 2015), 271.

[34] See S. Meisel, "HaRaya Kook Ve'HaYeshiva HaMerkazit' BeYaffo," *HaTzofeh*, September 12, 1986.

[35] As described by Mrs. Esther Kelly (nee Oppenheimer), his neighbor in Bat Yam, and later at Moshav Beit Meir, in an interview on March 23, 2010.

[36] Nechama Marcus, *Le'ovdah u-Le'shomrah: Sippuro shel Kibbutz Hafetz Haim*, ed. Asher Wasserteil (Kibbutz Hafetz Haim, 1992), 193–94. This etrog plantation was damaged in 1957 by a fungus that spread throughout the country and decimated many plantations of non-grafted etrogim. My thanks to Rabbi Motti Immanuel who sent me the interview he conducted with R. Shraga Stiffel.

D. Etrog fruits (wrongly) called Yemenite etrogim, possessing little inner fruit content, each weighing up to 4 kg and generally considered *mehudar*

It should be mentioned that the Kibilewitz etrogim are not usually comparable in beauty to other cultivars, especially since their base is usually partly brown. It is noteworthy that this year, the Sabbatical year, almost all of them had a clean base.

According to our information, the lifespan of a non-grafted etrog tree is approximately fifteen years. After renewal, the first two trees, which are thirty-five years old, look like young saplings.[37] The direct progeny of some of R. Kibilewitz's etrog trees grew until recently in Moshav Beit Meir (and several other places) and are the most authentic source of these etrogim.

Another etrog grower was Noah Margali (d.1982) from Kfar Saba, to whom Kibilewitz gave three seedlings from which Margali planted an orchard. It is noteworthy that these were also called Braverman and were "barrel"-shaped. It is possible that this was yet another etrog variety grown by Kibilewitz.[38]

Kibilewitz etrogim have always been regarded as possessing high pedigree, and Kibilewitz's daughter, Hanna Talmi, recounted how her father would send a beautiful etrog to the Chazon Ish every year.[39] Among the rabbis who would use etrogim of this variety were R. Shlomo Zalman Auerbach and R. Yehoshua Yeshaya Neuwirth.[40] Kibilewitz etrogim were not considered *mehudar* and could be termed "wild," being characterized by large protrusions and indentations. Completely clean etrogim of this variety were a rarity. Etrogim left unpicked for several months after Sukkot grew to an extremely large size and resembled the Yemenite etrogim. Most of the etrogim had no *pitam* and some had a "belt" (*gartel*).[41] The glory of this cultivar was in its pedigree. R. Kibilewitz died in 1961.

22.9 Jericho Etrogim

Jericho was one of the main sources of etrogim for the Jerusalem community. A plan (ultimately unimplemented) for purchasing land in Jericho for growing etrogim

[37] The document was written in November 1987, immediately following the *shemita* year. The description of the etrog's pedigree is based primarily on a letter of R. Kibilewitz's widow.

[38] After Margali's death, his family continued to sell etrogim and the plantation continued to exist until the end of 1985 (My thanks to Mrs. Menuha Margali, Noah's daughter, for providing me with this information during an interview on June 1, 2010). On the eve of the *shemita* year 5747 (1987), Mordechai Antman successfully saved several seedlings before the Kfar Saba orchard was destroyed and grows a small stand of etrogim trees from them to this day.

[39] In a conversation on March 5, 2010.

[40] The etrogim were initially taken from Kibilewitz himself and later from Yitzchak Kelly from Beit Meir, as emerges from correspondence in the possession of the Kelly family.

[41] According to Menuha Margali and Hanna Talmi, and in accordance with the fruit seen on the tree at the Kelly family home at Beit Meir (March 2010).

had existed since 1876.[42] According to an 1896 report by the agronomist Menashe Meirovitch, the Jericho etrogim were more beautiful than those in the villages near Jerusalem and its trees yielded approximately 3,000–5,000 etrogim a year.[43] These may have been the etrogim of R. Hershler, who grew them in orchards he leased from Arabs in the Wadi Kelt area and which were considered to be of the highest quality.[44]

Evidence of the Jericho etrogim's importance and the fact that they were preferred over others by the Jerusalemites can be seen in R. Diskin's book *Ma'amar Mordechai*. R. Diskin asserted that the farmers of the new Jewish settlements who were concerned about grafting took seeds from nice-looking Jericho etrogim assumed to be non-grafted and grafted the resultant saplings onto high pedigree "wild" etrogim trees:

> So, they went to Jericho where etrogim are planted but not grafted (since some Jerusalemites are meticulous about specifically using Jericho etrogim) even though they are not beautiful in appearance and do not give fruit every year, and they brought Jericho seeds and planted them in the new settlements, but the initial grafting had to be taken from a tree owned by a non-Jew, because for grafting one needs to take from a tree that was itself grafted and Jericho trees could not be used for grafting, because they are called "wild" and are not good for grafting, and the following year the farmers could therefore graft the saplings they grew onto new trees.[45]

R. Mordechai ben Yitzchak Diskin (Fig. 22.8) was born in Grodno (Russia) in 1839 and came to the Land of Israel in 1882. He was among the founders of Petah Tikva and engaged in agriculture. Although he describes in his book the growing of non-grafted etrogim in Petah Tikva, many of those etrogim were invalid for ritual use and were not considered *mehudar*. Diskin himself grew etrogim, but neglected the plantation in view of the negligible demand for them and the trees dried up.[46] In 1913, he published another book[47] with endorsements from rabbis including R. Kook, R. Yisrael Abba Tzitron, and R. Zerach Reuven Braverman, who testified that he had known R. Mordechai Diskin since his youth.[48] R. Diskin died in 1914.

[42] See a report in *Halevanon*, vol. 12, July 1876, 376: "And a respectable company is already being established to purchase the whole Jericho plain for it is well watered and good for citrus trees, just for this endeavor," Porat, *HaPulmus al Etrogei Eretz Israel*, 39.

[43] See Menashe Meirovitch, "Hoveret Ha'Ikar," in *Chevlei Techiya*, ed. Itzhak Avineri (Tel Aviv, 1931), 68, published by the friends of Menashe Meirovitch in honor of his seventieth birthday.

[44] See Menahem Barash's essay in *Yediot Aharonot*, September 30, 1974.

[45] Diskin, *Ma'amar Mordechai*, 23b–24a.

[46] Ibid., 24a.

[47] Mordechai Diskin, *Settlement of the Land of Israel: Discussing Tree Plantations in General and Particularly Etrogim* (Jerusalem: Frumkin Press, 1913).

[48] Ibid.

Fig. 22.8 R. Mordechai Diskin

22.10 Urdang (Hadera) Etrogim

Shraga Feibusch Urdang was born in 1871 in Liepāja, Latvia. He came to the Land of Israel after World War One and settled in Hadera where he engaged in horticulture. He was known as a Torah scholar and grew Land of Israel etrogim that had a tradition as being non-grafted. One of his sons, Tuvia Urdang, was an agricultural engineer who specialized in citrus farming and, according to his daughter, was the person who cultivated the etrogim in the orchard.[49] Another son, R. Eliezer Eliner (1904–1980), a writer, teacher, public figure, and a frequent visitor to Rav Kook's home, adopted the custom of bringing Rav Kook a gift every year—a glorious etrog from his father's orchard.[50]

Some claim that the Urdang etrogim, also known as "Hadera etrogim," originated from traditional species that were originally from Nablus. According to several accounts, the person responsible for bringing them from Nablus to Hadera was Yehoshua Hankin's brother, Tanchum. He planted a small stand of etrogim trees in his orchard and these grew to produce the Urdang etrogim.[51] Tanchum Hankin (1875–1964) was born in Ukraine and after immigrating to Israel with his family, attended the Hebrew school in Jaffa after which he studied agriculture at Mikveh

[49] From a conversation with Mrs. Marie Laufer on April 15, 2010.

[50] R. Eliezer Eliner (who, on Rav Kook's advice, Hebraized his family name) was a member of the Mizrachi (Religious Zionist) movement and was a prominent activist for religious observance. As a student, he was active in the Mishmeret Shabbat movement in Jerusalem and used to pray each Saturday night at the Western Wall in the special minyan led by R. Zerach Braverman. This information appeared in Neria, *Moadei HaRe'iyah*, 422, and in the introduction to his *Sichot HaRe'iyah* (Jerusalem: Moreshet Press, 1983), 2–3.

[51] R. Zvulun Gerz and Sarah Brit in a recorded interview from 1987; R. Yehuda Brit in a conversation on April 6, 2010.

Israel. In 1892, he joined the founders of Hadera, planted its first orchard, and was regarded as an expert in the citrus field.[52]

In 1900, the Hankin brothers owned five acres of citrus trees, a small portion of which were etrog trees. Avitzur wrote:

> There is no way of ascertaining whether the etrogim that grew in the Hankin orchard were grown for ritual use on Sukkot and were non-grafted, but we do know that the fruit itself attained extremely large dimensions, each weighing up to two kilograms. The etrogim were primarily used for preparing tasty jam and were even displayed in a special exhibition of various citrus fruit at Mikveh Israel.[53]

According to this account, Hankin may have grown some species for ornamentation, including those bearing extremely large fruit, that match descriptions of the Land of Israel varieties, and which possibly served as rootstocks for the grafting of Jaffa etrogim.

R. Levy Yitzchak Sofer, who conducted a comprehensive study of etrog grafting and pedigree, suggests that the etrogim marketed today as Urdang are, in fact, progeny of the etrogim imported from Greece (Corfu or Parga) to Jaffa in the mid-nineteenth century. One palpable piece of evidence supporting this claim is the typically beautiful form of the Urdang etrog which differs in its appearance from the traditional wild etrogim of the Land of Israel. This variety is characterized by a relatively small fruit with beautiful protrusions and indentations, a sharpened tom (*hotem*) and a *pitam* at its end (Fig. 22.9).[54] The mature fruit reaches a weight of up to 1 kg and thereafter assumes a rounder shape.

Unlike other varieties, the original shape of this variety has been preserved almost unaltered. According to this narrative, Tanchum Hankin may have brought some of his etrogim from Jaffa which, as mentioned above, was also the origin of "the Gan Shmuel" etrogim. These etrogim, some of which were grafted onto the rootstocks of local etrogim, were common among different growers and it was from one of these (or, as suggested, by Hankin himself) that Urdang took trees to establish his orchard. It is possible that he also grew etrogim from the seeds of a Nablus etrog for a rootstock.

The Hadera etrogim were grown by residents in private gardens or small plots by a small group of locals, among them R. Menahem Arieli, R. Yitzchak Lifshitz,

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[52] See Tidhar, *Encyclopedia of the Founders and Builders of Israel*, 2, 695. His brother, Menachem Mendel Hankin (1868–1937) was also connected to citrus growing. He was one of the founders of Hadera (1891), and although he left the city due to malaria, he maintained ownership of his land there. Already in 1892 he planted an orchard in Hadera and occasionally visited it to supervise the crops. He was also among the founders of the Pardes company and served for years on its management.

[53] See ibid., 3, 1283–284; Shmuel Avitzur, "LeKorot Hitpatchuta HaMishot shel Hadera," *Ariel* 95–96 (2003): 84–87.

[54] The fruit is similar to the Pigolo variety of etrog. An illustration of this etrog appears in Volkamer's work, in which he called it "the Jewish etrog." See Johann C. Volkamer, *Nürbergisches Hesperides oder gründliche Beschreibung der edlen Citronat, Citronen - und Pomeranzen - Früchte, wie solche in selbiger und benachbarten Gegend, recht mögen eingesetzt, gewartet, erhalten und fortgebracht wedren, samt einer Ausführlichen* (Nuremberg, 1708), 121.

Fig. 22.9 "Jewish Etrog" varieties (according to Johann Volkamer, 1708), similar in form to the Urdang etrogim

R. Zvulun Graz (later head of the Rehovot Rabbinical Court), R. Yitzchak Brit, and others. Another etrog grower was R. Avraham Gross, a Holocaust survivor born in a town near Munkács, who came to Israel in 1946. After settling in Hadera, he began large-scale growing of Urdang etrog progeny. These are, in essence, the "Hadera etrogim" still grown today.[55]

Other citrus farmers grow the Urdang etrog progeny as indisputably kosher but under other brand names because of the doubts that subsequently arose among the followers of the Chazon Ish concerning their validity.[56] By contrast, the Urdang etrog is still accepted today by the Orthodox Council of Jerusalem (Badatz-Ha'Edah Hakharedit) as non-grafted.[57] This variety is also accepted in different chassidic circles which have always preferred etrogim similar in appearance to the Corfu etrogim.[58] In practice, Urdang etrogim are still considered the most common variety in the Sukkot Four Species markets.

22.11 Chazon Ish Etrogim

The questions surrounding the purity of traditional etrogim on which the rabbis of the Land Israel relied in previous generations lingered during the first half of the twentieth century. However, this problem was of particular concern to the Chazon

[55] My thanks to R. Avraham Gross for this information (in an interview on March 17, 2010).

[56] For example, the Sokolovsky etrogim sold today, etrogim taken from the tree grown in Jerusalem by Dov Sokolovsky, who was known as a chassid and someone meticulous about religious observance. In 1952, he went with R. Tzvi Kopschitz to visit R. Yitzchak Brit and received a seedling from him (according to R. Zvulun Graz in a recorded interview from 1987).

[57] Moshe Sternbuch, *Moadim Uzmanim* (Jerusalem: Yeshivat Hamatmidim, 1992), 6, §60. Shlomai, a resident of Kfar Haroeh, mentioned an orchard in the neighboring settlement, probably Hadera, where there were etrogim considered doubtful as being non-grafted. These may have been Urdang etrogim which he specifically states were awarded kashrut status by the Jerusalem Badatz. However, as he heard himself from the Chazon Ish, the latter disqualified them from being used for the *mitzvah*.

[58] See Itzhak Alfasi, *HaHasidut VeShivat Tzion* (Tel Aviv: Sifriat Maariv, 1986), 15–16.

Fig. 22.10 R. Avraham Yeshaya Karelitz (the "Chazon Ish")

Ish (Fig. 22.10), who settled in Bnei Brak in 1933. He was the one who reignited with great vehemence the debate over the validity of the common Land of Israel etrogim and the concern regarding grafting. These concerns cast doubts even on the best-known etrog brands regarded by most religious circles as non-grafted.

The Chazon Ish adopted the most stringent approach and, due to his concern, favored the use of certain pedigreed species propagated using seeds rather than cuttings. The halakhic authority of the Chazon Ish and, chiefly, his initiative to propagate the etrog species he deemed to be non-grafted, in effect transformed the modern Israeli etrog industry and decisively influenced the etrog trade. Most tangible expression of this development is the "Chazon Ish" etrog cultivar which, according to various estimates, constitutes the predominant commercial segment among Lithuanian circles.

Which species did the Chazon Ish consider to be qualified as indisputably kosher? Here, too, answers vary, in part because he would periodically issue his opinion on different etrog species he was asked about. Different etrog growers seeking his approval would present him with their prime specimens. According to one account, eight or nine different species of etrog would be laid on his table, including Yemenite and Moroccan etrogim.[59] The Chazon Ish nevertheless ascribed special importance to two species which he investigated personally—these also being the only two upon which he himself would recite the ritual blessing during the last years of his life.

A. Chazon Ish Halperin Variety

According to popular accounts, the Chazon Ish would customarily travel to vacation in Safed for his health, a custom he adopted in 1934–1935, soon after his arrival in Eretz Israel. He used these opportunities to travel around the surrounding villages, searching for etrog trees and evaluating their authenticity.[60] He found trees

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[59] Avraham HaLevi Horowitz, *Orchot Rabbeinu* (Bnei Brak: Yeshayahu Horowitz, 1991), vol. 2, 261.

[60] Shlomo Cohen, *Pe'er HaDor*, vol. 2 (Bnei Brak, 1967), 131; Zvi Yavrov, *Ma'aseh Ish* (Bnei Brak, 2005 vol. 1, 39–40.

he believed to be growing "wild" without human intervention and any possible grafting.[61] He identified these etrogim as part of the ancient tradition of the Land of Israel etrogim. From one tree which he examined himself (according to him, one can visibly discern the lemon's influence on the grafted etrog), he took an etrog and instructed that it be propagated using its seeds in order to ensure a line of identical fruit.

He gave some of this species to the founder of the Zichron Meir neighborhood, R. Yaakov Halperin (1888–1964),[62] who in turn distributed it further,[63] lending his name to the Chazon Ish etrog known today as the Halperin variety. R. Halperin grew approximately twenty trees in a small plot in Bnei Brak called the Halperin Orchard. Some of the progeny of these trees grow today in the courtyard of the Ohel Yaakov Yeshiva (named after R. Yaakov Halperin) in Bnei Brak.

2 Chazon Ish R. Michel Yehuda Lefkowitz Variety

On another occasion, the Chazon Ish gave etrog seeds to his close follower and student R. Michel Yehuda Lefkowitz (1913–2011) who planted them in Bnei Brak. The Chazon Ish followed the tree's progress as it grew and urged R. Lefkowitz to water them well.[64] This etrog tree, which grew in a small orchard in the courtyard of R. Lefkowitz's Bnei Brak home (where its progeny still grows today), served as the origin of the variety of Chazon Ish etrogim known as Lefkowitz.

It is possible that R. Lefkowitz may have been unaware of the etrog's origin when receiving the seeds from the Chazon Ish, and various conjectures and opinions have subsequently emerged. According to the most common narrative, the initial source of this etrog was in Nablus,[65] although a different hypothesis claims that it may have been from Umm al-Fahm.[66]

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[61] These would seem to be formerly agricultural etrogim trees found in the remnants of abandoned plantations.

[62] Yavrov, *Ma'aseh Ish*, 1, 40; Horowitz, *Orchot Rabbeinu* 2, 258, 261, 263–64.

[63] However, according to another account, R. Yaakov Halperin was the one to bring the Chazon Ish an etrog from the forested area around Safed for him to determine its status. Because this study is based on various accounts, it must be mentioned that there are also claims that the Halperin etrog's origin is not from Safed, but rather from Nablus, and there are even those who believe that its precise origin is unknown.

[64] A letter from R. Michel Yehuda Lefkowitz from 1990; Horowitz, *Orchot Rabbeinu* 2, 258; Yavrov, *Ma'aseh Ish* 3, 139.

[65] Shlomo Schwartz, another grandson of R. Lefkowitz, is today responsible for growing the trees. He told me that his grandfather had said that the origin of this variety of etrog was from Nablus. Cf. R. Sternbuch, Moadim Uzmanim, §60: "There are seedlings originating in Nablus which the Chazon Ish of blessed memory authorized, etc." This is also mentioned in a letter from 1997 written by R. Yehuda Shapira (who died in 2009).

[66] Moshe M. Karp, *Hilkhot Chag B'Chag* (Jerusalem, 1993), 93, wrote about the Chazon Ish etrogim: "He checked one seedling from the Umm al-Fahm species and recognized it as being free of suspicion of having been grafted, and he took from it for the etrog, and this is the species accepted today as the Chazon Ish etrog. And there are others that he recognized as kosher when he was in Safed and scrutinized the accepted Safed species and found it too to be kosher and this is recognized today as the Halperin species".

There are additional "Chazon Ish species"—etrogim on which the Chazon Ish recited the ritual blessing. Each year, at the end of the Simchat Torah festival, people would visit his home hoping to receive an etrog he had blessed to plant in their courtyards. The Chazon Ish would distribute as many seeds as possible in order to increase their dissemination and prevalence.[67] Propagation using seeds enables the reproduction of etrogim that possess a range of genetic traits which differ slightly from that of the original fruit.

The etrog fruit of the Lefkowitz variety is elongated and has a cone-shaped, somewhat "tower-like," pointed top, while the Halperin variety is broader at its top.[68] In light of the different Chazon Ish etrog variants that exist today, we have refrained from providing a more precise description. Both main varieties can reach a hefty size and weight in excess of 1 kg. In any case, intensive cultivation of these species has led to a state of affairs whereby many etrogim bearing these names can be found today, even though they are of a completely different shape than that of their progenitors. By means of a hormonal growth regulator, it is possible to prevent detachment of the *pitam*,[69] and fertilizing the orchard with substances such as potassium may influence the texture of the outer peel.[70]

Several questions are still open in spite of this wealth of information: What was the exact origin and "pedigree" of the tree from which the Chazon Ish took his etrog species? And how did he know with certitude that the progenitors of these etrogim had never been grafted? When asked the latter question by his students, the Chazon Ish replied with full confidence that these species' level of kashrut qualification is "as attained by tradition."[71]

22.12 Shlomai Etrogim

Shraga Feivel Shlomai (Shlomowitz) (Fig. 22.11) was born in 1898 in Czechoslovakia. He emigrated to Israel in 1933 and became a student of R. Yosef Tzvi Dushinsky. He first became familiar with beekeeping and the challenge of growing etrogim while working as a laborer in Rishon LeZion. In 1936, he joined the settlers of Kfar Haroeh, working for his livelihood in various branches of agriculture. He

[67] Yitzhak Frenkel, *Zechor LeDavid* (Sefer Zikaron LaRav David Frenkel) (Jerusalem, 2000), 166.

[68] And I have seen growers who swap them.

[69] Eliezer Goldschmidt, "Sikkuyim L'Meniat Neshirat HaPitam B'Etrogim al Yedei Rissus B'Picloram," *HaSadeh* 50 (1970): 740–43. Fruit with a *pitam* grow today in R. Lefkowitz's courtyard, apparently due to the influence of pesticides.

[70] The use of potassium is accepted in all citrus crops and can lead to a peel that is up to 15 percent thicker. The thickened peel makes the external texture rougher. Use of potassium may also result in an increased level of citric acid. My thanks to the agronomist Assaf Avtabi for this information.

[71] See R. Michel Yehuda Lefkowitz's letter from 1990; Yavrov, *Ma'aseh Ish*, 139; vol. 6, 116; Frenkel, *Zechor LeDavid*, 167–69.

Fig. 22.11 R. Shraga Feivel Shlomai

owned a beehive and gained expertise in growing various species of etrogim.[72] He became especially well known as a grower of untainted Land of Israel etrogim, devoid of any suspicion that they had been grafted.

Shlomai (or Kfar Haroeh) etrogim gained widespread approval from the leading rabbis of his generation, including R. Avraham Chaim Naeh and R. Shmuel Wosner and, according to some, even from the Chazon Ish himself.[73] Shlomai took pride in species of etrogim originating from Nablus about which he claimed to have received a tradition and signs from “important and trustworthy pious people in the Old Jerusalem community.”[74] According to Shlomai, these etrogim originated from remnants of trees in the plot belonging to R. Yosef Haim Orenstein in Hadera who took them from R. Shneor Schneerson who had, in turn, brought them from Nablus.[75]

However, the crowning glory as far as Shlomai was concerned was the discovery of a traditional variety of etrog in an Umm al-Fahm orchard in the *shmitah* year of 1965–1966). Afterwards, in 1967, he took cuttings from these trees and planted them in his back yard. He highly valued this discovery. Whereas he had received the Nablus etrog tradition from others, “but I myself discovered the origin of the Umm

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72 The information was obtained in various interviews he gave to the press, for example, to G. Sharoni, *Ma’ariv*, September 19, 1956, 2; ibid., September 30, 1963; H. Fikrash, *HaTzofeh*, October 16, 1959; O. Kapeliuk, *Davar LeHaklaut*, October 31, 1967. See also the anthology, Haggai Huberman and Abraham Naveh (eds.), *Yichudu shel Kfar: Toldotav VeKorotav shel Kfar Haroeh al shem Maran HaRav Avraham Yitzchak HaCohen Kook* (Tel Aviv, 2003), 125–26, 279.

73 See a copy of all the rabbinic imprimaturs in Shraga Shlomai, *Etrog M’Artzeinu HaKedoshah* (Kfar Haroeh, 1955); Frenkel, *Zechor LeDavid*, 168; Eliyahu Weisfish, *Sefer Arba’at HaMinim L’Mehadrin Hashalem* (Jerusalem, 2007), 278–80; See also the letter of R. Akiva Sofer (last of the Pressburg rabbis dynasty and a descendant of the Chatam Sofer) from July 1953 (he died in December 1959) regarding the kashrut status of the Shlomai etrogim, from *Otzrot HaSofer* 3, 24.

74 Shraga Shlomai, *Kuntres Pri Etz Hadar with ‘Readers’ Introduction*’ (Kfar Haroeh, 1997), 37–38.

75 In various press interviews: G. Sharoni, *Ma’ariv*, September 19, 2; ibid., September 30, 1963; ibid., October 18, 1967, According to one source, the etrogim from Nablus were received from R. Meir Hirsch Hershler, a Jerusalem etrog merchant, see Oded Kapeliuk, *Davar LeHaklaut*, October 31, 1967.

al-Fahm etrogim and could prove this unequivocally to any person of expertise who understands this matter."[76]

Shlomai died in 1974. Yosef Eigner, who had purchased the plantation from Shlomai, continued to grow some of the Umm al-Fahm etrog trees for several years and testified that the mature etrogim were similar in their large size to the Yemenite etrogim he had seen in Moshav Geulei Teiman.[77] In practice, according to Shlomai's testimony, he positioned his beehives in close proximity to the etrog trees and succeeded, via the bees' cross-pollination of the various etrog varieties, to produce beautifully symmetrical fruit from the traditional etrogim, with a stronger *pitam* that would not be easily detached.[78]

However, in most cases, Shlomai's etrogim were of a round shape with a slightly sharpened top, almost completely smooth, and generally lacking a *pitam*, even after spraying. Although today's market demand calls for cultivation of slender, elongated varieties, some demand still remains for the rounded etrogim.[79]

22.13 Features of the Original Land of Israel Etrog

Some of the etrog cultivars in existence in modern-day Israel—such as the Braverman and the Kibilewitz types which appear to have originated in Nablus, Umm al-Fahm, Jericho and others—are the progeny of the traditional etrogim species that were grown by Arabs prior to the emergence of the grafting problem in the mid-nineteenth century. It is, however, impossible today to precisely characterize each species according to its initial origin, i.e., the Safed variety, the Nablus variety, the Jerusalem Hills variety etc. (except perhaps the Kibilewitz-Jericho variety) due to various cultivation techniques employed by the growers. Nonetheless, some typical characteristics in prominent field signs can be determined for most of the recognized traditional etrogim if allowed to grow on the tree until reaching full maturity.

Land of Israel etrogim attain their peak size after a growing cycle of 9–10 months and can remain on the tree for a year or even more. At full maturity, the fruit reaches a large size (1–4 kgs and even more) and are generally devoid of a *pitam*. The etrog is ball-shaped like a watermelon or elongated, and is usually asymmetrical, sometimes rough, with protrusions or deep indentations.[80] The mature etrog is yellow, the peel

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[76] Shlomai, *Kuntres Pri Etz Hadar*, 41–42, 47.

[77] In a conversation with me on February 5, 2010.

[78] In various newspaper interviews, G. Sharoni, *Ma'ariv*, September 30, 1963; ibid., October 18, 1967.

[79] This information was given to me by Yaakov Tzipilewitz (Kfar Maimon). If this is indeed the authentic Nablus variety, it is the only one characterized by such a rounded shape. According to this, the Talmudic statement according to which "an etrog that is [round like] a ball—is invalid" (B. Sukkah 36a) is defined as such when devoid of the sharpened *hotem*. My thanks to Yedidya ben Zimra for this clarification.

[80] Schwarz, *Tevuat Ha'aretz*, 383; Menahem Reischer, *Sha'arei Yerushalayim* (Jerusalem, 1871), 71; Abraham Yaari, *Igrot Eretz Yisrael* (Tel Aviv: Gazit, 1943), 427; Sapir, "On the Etrogim of the

is generally pitted and occasionally smooth. In a few of the varieties, its external appearance resembles a large etrog of the Yemenite type however differs in its internal structure.

The fruit has a juicy, sour pulp, and when mature, the fleshy white peel can be eaten. In general, the edible white peel is significantly larger than the inner sour section. In ancient Hebrew and traditional Arab agriculture, the etrog was undoubtedly grown for eating and probably also for its pleasant fragrance, leading the growers to prefer the large, mature specimens while no use was found for the small, non-mature fruit.[81]

22.14 Summary

Varieties of etrog that are progeny of the traditional etrog trees that grew in the Land of Israel in previous generations can still be found today. It is possible that certain changes in their traits occurred over time, thereby making it impossible to identify "pure" species of etrogim identical to those that grew here centuries ago. Nevertheless, some of these varieties preserve characteristic traits that match the descriptions mentioned in early rabbinic literature and in later sources up to the modern era.

Many of these etrogim can be found in the traditional Four Species markets and are referred to by the names of those who were the first to grow them and deemed them to be non-grafted (some of the famous ones have been mentioned above). Today, these species are sold for performing the Sukkot festival commandment before reaching full maturity and are therefore still inedible. R. Yaakov Sapir (Fig. 22.12) referred to this phenomenon already in the mid-nineteenth century: "Only then, when the etrog has attained its full size and maturity, can the signs mentioned by the halakhic authorities regarding its appearance, interior, and exterior be discerned, and not while still small and not fully developed, when it cannot be evaluated."[82]

As already stated, most of the Land of Israel varieties lacked a *pitam*. When the European varieties of etrog began to be grown in the Land of Israel (initially in Jaffa), they were distinguished from the local ones in that most of them possessed a *pitam*, they were generally smaller in size even when fully grown, and by their small protrusions. Naturally, there is no reason to undermine the validity of other etrog varieties we have today, some of which are small and have a *pitam*, and which

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Holy Land," 119. He also wrote in the first section of the article published in *Halevanon* 14, August 11, 1877, 12: "As the etrogim for the festival *mitzvah* are harvested from the tree while still unripe in size and green as the grass… and it can remain on the tree throughout the year and does not spoil. And I saw etrogim in the month of Av that were as large as watermelons, still hanging on the tree from the previous year".

[81] Yaakov Sapir, "On the Etrogim of the Holy Land," *Halevanon* 14, August 11, 1877: 12; Diskin, *Settlement of the Land of Israel*, 3; Cf. to what R. Yosef Kapach wrote in his commentary on the Rambam's *Mishneh Torah*, *Hilkhot Shofar V'Sukkah V'Lulav* (Jerusalem: Machon Mishnat Harambam, 1992), ch. 7, 587.

[82] Yaari, *Igrot Eretz Yisrael*, 429.

Fig. 22.12 R. Yaakov Sapir

existed already in the time of sages. It has become apparent that modern agricultural treatments (spraying, fertilizing, and others) have spawned a range of variants with changing traits, even from the local etrogim with the highest pedigree, in order to meet market demand.

The progeny of the ancient Land of Israel etrogim is worthy of further investigation, in order to single out those with the purest pedigree and those that most clearly preserve the traits described in ancient sources. These etrogim should be planted in specially designated conservation plots at different locations, and the process should be accompanied by a rigorous and professional supervisory system that will maintain a precise record for each tree (including its "family tree") throughout the entire growing process. The trees should be marked with a metal seal or have a computerized identification chip inserted in their trunks. A genetic germ plasm bank of etrog varieties should be established in order to preserve their lineage for the future.

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Pictorial Album of Israeli *Etrog* Citron Cultivars

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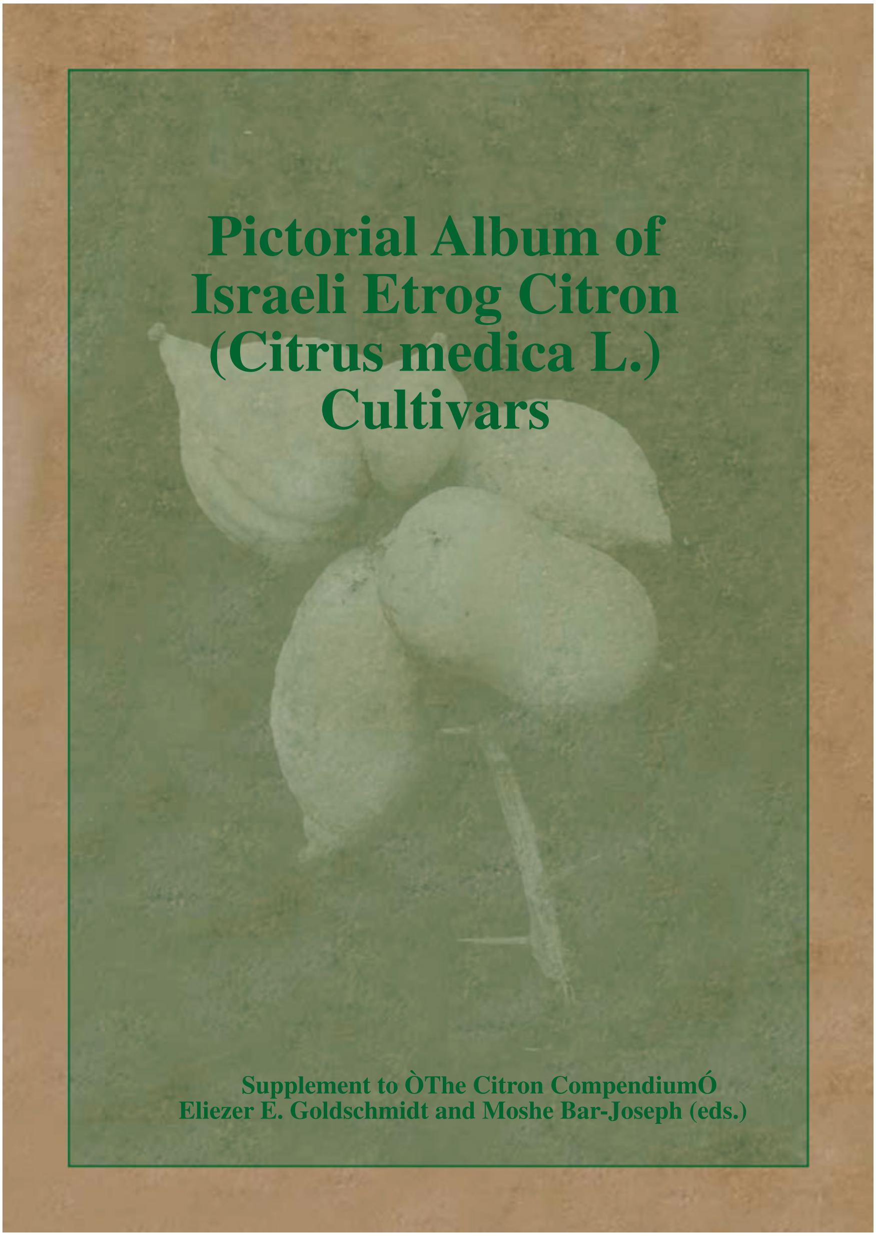
Pictorial Album of
Israeli Etrog Citron
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Cultivars
Supplement to ÒThe Citron CompendiumÓ
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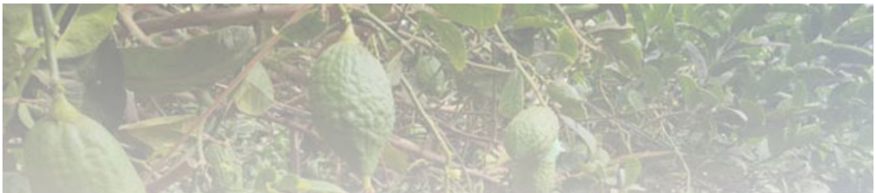

Pictorial Album of Israeli Etrog Citron Cultivars*

This album contains photographs of fruits from some of the etrog citron cultivars currently grown in Israel.

Depicting the typical shape of etrog cultivars is not an easy task. Etrog fruits of most cultivars are not uniform, and even on the same branch one can find fruits with different shapes. Variations in fruit shape and size also reflect preferences of communities for a specific fruit type recommended by their religious authorities.

Among the physiological reasons for this variability are season and tree age. The season of fruit development affects shape significantly. Spring etrogs (“bicher») are more robust than summer etrogs (“water etrogs”). Tree age and disease also affect fruit shape. While fruits of young trees are elongated and bumpy, fruits from mature trees are roundish and lemon-smooth. And yet, growers, traders, and buyers familiar with etrogs can visually identify the characteristic shape of their desired cultivar.

From a genetic standpoint, two major sources of variability need to be considered: a) somatic mutations; and b) sexual recombination. The latter is presumably rare because of cleistogamy, i.e., self-fertilization that occurs within the closed flowers. Among the many citrus genotypes for which citron was a parent, citron was always the male (pollen) parent, never the female (seed) parent. Cleistogamy appears to be the rule for citron, and certainly for etrog citron cultivars, but possibly it is not absolute in cases of seed propagation (1, 2,). So to account for the differences among current etrog citron cultivars somatic mutation seems to be the most likely explanation, but sexual recombination may take place occasionally. Epigenetic hereditary effects, although not well defined, cannot be ruled out. And yet, in spite of the remarkable phenotypic variability in fruit shape, molecular analysis demonstrates close genetic similarity between the major etrog citron cultivars (3).

The descriptions rely mainly on the work of Amar (4). For a more comprehensive list of etrog citron cultivars see Goldschmidt and Bar-Joseph, The Etrog Citron, 2018.

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* This Album was prepared by the Eliezer E. Goldschmidt, Moshe Bar-Joseph and David Karp. Etrog Citron fruits were provided by R. Yeshaya Kirszenbaum and R. Elimelech Retman. The photos were taken by Dr. Yoel Fixler and the Graphic arrangement by Mrs.Yiphat Kedem. The presence of a Pitam in some of the photos might be the result of a hormonal treatment, see Avtabi and Klein "Selected Aspects of Commercial Production in Etrog Orchards" (this volume).

Braverman

Fruit Shape: Large, coarse, barrel-like fruit, without a pitam.

Origin: Not clear. Named after R. Zerach Braverman, who received seeds from Rabbi Yehoshua Leib Diskin, towards the end of the 19th Century. According to a family tradition those etrogs originated from old Um-El Fahem Etrog trees.
Due to their rather coarse form Braverman etrogs are assumed to be descendants of the ancient Land of Israel etrogs.

Ordang

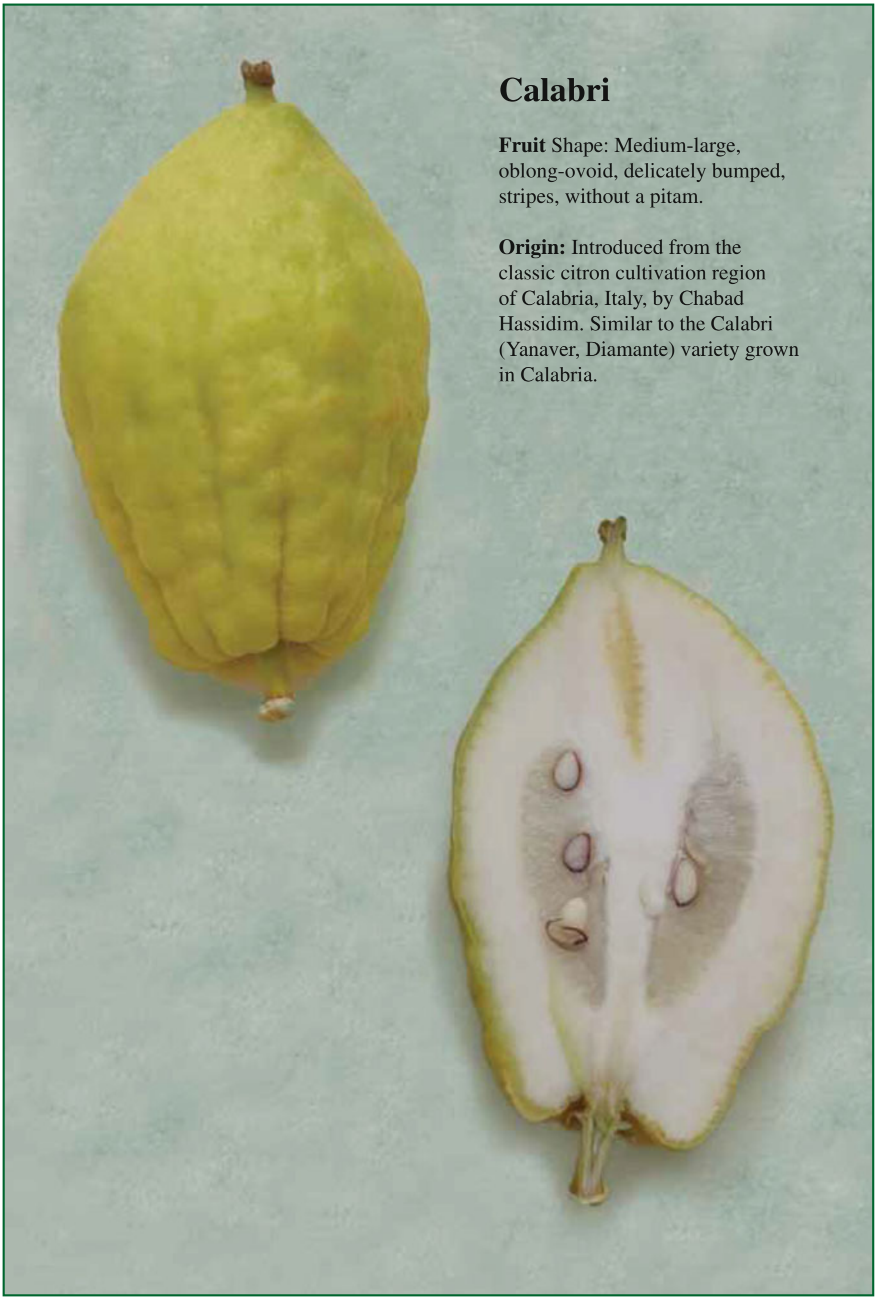
Fruit Shape: Medium size, uniform, beautiful oblong shape with one flattened, curved end and a tapered, pointed end. Smooth, delicately bumped. High rates of pitam retention.

Origin: Doubtful. Named after Feivush Ordang from Hadera, who started its cultivation at about the turn of the 20th Century. While some claim that it originated in Shechem, others speculate that it is a descendant of the Corfu etrogs seeds of which were introduced to Jaffa by the middle of the 19th Century.

Chazon-ish Halperin

Fruit Shape: Medium-large, oblong, with a broad, flattened base, bump stripes, without a pitam.

Origin: The Chazon-Ish (Rabbi Avraham Yeshayahu Karelits, made Aliyah 1933) identified Etrogs near Safed which he trusted to have never been grafted. He gave the seeds to his disciples and encouraged them to cultivate this variety. "Chazon-Ish Michal Yehuda Lefkovitch" is another, closely related variety.



Calabri

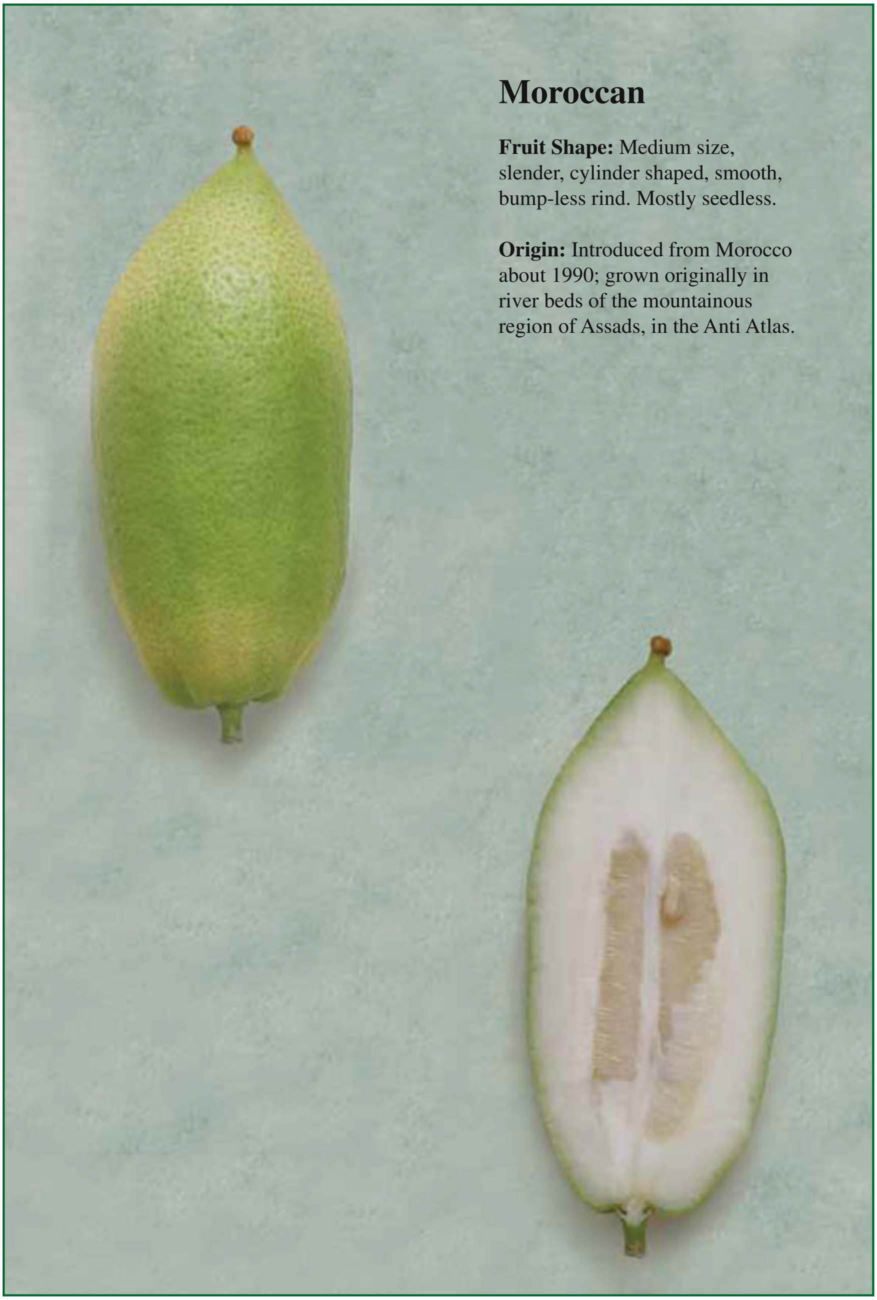
Fruit Shape: Medium-large, oblong-ovoid, delicately bumped, stripes, without a pitam.

Origin: Introduced from the classic citron cultivation region of Calabria, Italy, by Chabad Hassidim. Similar to the Calabri (Yanaver, Diamante) variety grown in Calabria.

Yemenite (Temoni)

Fruit Shape: Large, ovoid, egg-shaped. Chubby rind slightly bumped. Highly variable shape. May attain 5 Kg or more if left intact on trees. Pitams rare. Internal Structure: Very thick white peel (albedo). Segments, divided by thick partitions, contain seeds but no juice sacs.

Origin: Introduced by the Yemenite Aliyah, on several occasions, since 1882.



Moroccan

Fruit Shape: Medium size, slender, cylinder shaped, smooth, bump-less rind. Mostly seedless.

Origin: Introduced from Morocco about 1990; grown originally in river beds of the mountainous region of Assads, in the Anti Atlas.

Rejoicing with the Four Species – etrog citron fruit, date palm fronds, myrtle, and willow branchlets – during the Sukkot (Tabernacles) festival.

צילום: משה בר-יוסף

Glossary*

Abiotic factors Non-living causes that may damage plants

Albedo The inner, white layer of citrus fruit peel

Amino acids The building blocks of the proteins present in living tissues

Anamorph An asexual reproductive stage of a fungus, often mold-like

Anatomy The study of the form and shape of plant tissues

Angiosperms A major division of plants which produce flowers with seeds encased in "fruits"

Anthocyanins Phenylpropanoid plant pigments involved in the pink/blue coloration of flowers and fruits

Antibody A specialized defense protein of vertebrates, which is also applied as a diagnostic tool for the specific detection of plant pathogens

Aphids Small sap-sucking insects and members of the super family aphidoidea in the order Hemiptera; feed on soft stems, branches, buds, and fruit, preferring tender new growth to mature foliage

Apical dominance The phenomenon whereby the main, central stem of the plant is dominant over (i.e., grows more strongly than) other side stems; presumably regulated by auxin, a plant hormone

Archaeobotany Botanical findings in archaeological excavations

Ascospores Sexually produced haploid fungal spore of ascomycetes

Asexual (vegetative) plant reproduction Propagation from cuttings or other vegetative plant organs

Auxins Group of natural plant hormones involved in regulation of developmental processes such as rooting, fruit drop, and apical dominance; synthetic auxins act similarly when applied to plants

Bacteria Single-celled micro-organisms that lack organelles or a true nucleus; bacteria, archaea, and eukaryota form the three major domains of all living organisms

Base pairs The sets of hydrogen-linked nucleobases that make up nucleic acids DNA and RNA

E. E. Goldschmidt and M. Bar-Joseph (eds.), *The Citron Compendium*,
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Biological balance The dynamic equilibrium in nature achieved by interrelationships among organisms of any stable natural community in a certain habitat and food web

Biological control An approach of controlling pests such as insects, mites, weeds, and plant diseases using other organisms; often involves an active human management role

Carotenoids Isoprenoid plant pigments involved in the yellow/red coloration of flowers and fruits

Cell cycle Cycle of stages that cells pass through, allowing them to divide and produce new cells

Chemotaxonomy Sorting of plants' taxonomy according to their chemical components

Chimera A plant in which the tissues are of varied genetic origin, e.g., variegated plants, with green, chlorophyllous leaves and white, chlorophyll-less leaves

Chitin A large, structural polysaccharide found in the exoskeletons of anthropods and the cell walls of fungi; derived from chains of modified glucose

Chlamydospores Thick-walled, large resting spores of fungi that allow their survival in unfavorable climatic conditions

Chlorophyll The green pigment of plant leaves; stored in chloroplasts and plays a key role in photosynthesis

Chloroplast A subcellular organelle of plant cells that produces energy through photosynthesis

Chromosomes Subcellular structures consisting of a string of DNA wrapped by associated proteins

Cleistogamy Self-pollination within unopened flowers

Corfu (Kerkira) An island near the western coast of Greece; used to be a center of etrog citron growth and commerce

Cultivars Plant types selected by humans for certain particular traits

Cuticle A delicate, waxy layer over the outer surface of the epidermis in plants; contains cutin and protects against water loss and parasitic infections

Cutting A shoot or leaf section used for vegetative plant propagation

Cytoplasma Complex of intracellular component consisting of fluids immersed with filaments, proteins, ions, and organelles, suspended in the cytosol

Damping-off A disease caused by different fungi and fungus-like organisms resulting in the collapse of emerging seedlings

Diploids Organism with cells that contain two sets of similar chromosomes

DNA sequencing The process of determining the sequence of the nucleotides in the DNA string

DNA A string of deoxyribonucleotide molecules, coding for the hereditary traits of cellular organisms and for some viruses

Ecology The study of the interaction of different organisms with other organisms and the environment

ELISA (Enzyme-linked immunoassay); a laboratory test to detect and quantify a range of pathogenic viruses and bacteria

Embryo The plant compartment resulting from the pollination of the ovule; results in zygotic cells accompanied by endosperm tissues of seeds

Endophytes Endosymbiotic microorganisms colonizing within plants, causing no symptoms to the plant

Epidermis The external, dense cell layer covering plant organs—leaves, shoots, and fruit

Epiphytic Organisms living on the surface of plant tissue

Eschatology Theological expectations for the coming of the Messiah and the Last Days

Esroger An official, licensed etrog citron dealer

Essential oils Volatile oils stored in sub-epidermal glands that give citrus fruits their distinctive odor

Ethylene A volatile gaseous compound acting as a plant hormone; promotes fruit ripening and coloration, leaf drop, and senescence

Eukaryotes Organisms that contain a nucleus and organelles, enclosed by a membrane

Fecundity A measure of the number of offspring produced by a given insect over time

Flagella Microscopic, hair-like structures involved in the locomotion of a cell

Flavedo The outer, colored layer of citrus fruit peel

Flavonoids Phenylpropanoid compounds present in citrus fruits; assumed to act as antioxidants

Gartel Belt (in Yiddish); a phenomenon occurring frequently in etrog citrons—a narrowing around the middle of the fruit resembling a belt

Gel electrophoresis The method for separating and estimating the sizes of proteins and other biological molecules

GenBank® The NIH genetic sequence database

Gene A chain of DNA or RNA nucleotides coding for a biological trait or function

Genoa (Genova) A port city in North-Western Italy; once a center for export of citrons to North European countries

Genome The genetic make-up of a biological organism

Genomics Investigating the genome of a biological organism

Genotype The genetic information coded by the chains of DNA within a particular organism

Genus A taxonomic definition of a group of closely genetically related species

Germ tubes The outgrowth produced by fungal spores during germination

Gibberellins Group of natural plant hormones involved in regulation of developmental processes such as germination, stem elongation, flowering, and senescence

Graft compatibility The success of grafting depends upon the genetic kinship between scion and rootstock within the same plant species or, at least, the same botanical family

Grafted citron Citron fruit grown on a tree grafted onto another kind of citrus (e.g., lemon)

Grafting A plant propagation technique; a shoot or bud of one plant or tree inserted into the stem or the trunk of another where the two organs unite; the combined, grafted plant consists of the top, above graft union organs (shoots, leaves, and fruit—scion) and, below, the graft union organs (trunk, roots—rootstock); grafting is widespread among trees, fruit trees in particular

Gram staining A method that differentiates bacterial species into gram-positive and gram-negative

Haploids Organisms or reproductive stage cells with a single set of chromosomes

Hesperidium The unique anatomical structure of citrus fruit

Holomorph The whole fungus, including anamorphs and teleomorph

HoshaNa Liturgical poems recited during the Feast of Tabernacles (Sukkot) while holding the Four Species

Iconography The artistic representation of symbols and images in a historic or religious context

Integrated pest management A broad-based approach that integrates practices for economic control of pests, with the intention of keeping the use of pesticides at a minimum level and relying as much as possible on biological and physical control

Kilayim Mixing; sowing a mix of seed from different plant species or grafting of two plant species is forbidden according to Jewish law (Lev 19:19)

LD50 (median lethal dose) The dose at which a chemical substance used for plant protection is lethal for 50% of tested subjects

Leafhoppers Small sap-sucking insects belonging to the Cicadellidae family; adults are excellent short-distance jumpers when disturbed; they associate with yellows diseases by vectoring phytoplasma; can be direct pests when found in high numbers

Meristem The plant tissue location of new growths; constituted with undifferentiated cells that are continually proliferating

Messenger ribonucleic acids (mRNAs) Molecules transcribed in plant cells from DNA carrying information that is translated to proteins by cell machinery

Middle Ages The period of European history between ancient and modern times, 476–1450CE

Mites Tiny arthropods of the subclass Acari in the Arachnida class displaying various nutrition and feeding strategies that live in a wide range of habitats; their mouthparts (chelicerae) allow them to chew with a vertical, scissor-like action

Mitochondria Organelles within plants and other Eukaryotes that produce adenosine triphosphate (ATP), the main molecular energy source of cells

Mollicutes A class of very small and wall-less bacteria

Mutation A change of a living organism's hereditary material (DNA or RNA); mutations can occur spontaneously or are induced by external factors such as irradiation

Necropolis An ancient, city-like cemetery

Nucleic acid A chain of DNA or RNA nucleotides which store the genetic information of an organism

Nucleotides Molecules that form the building blocks of DNA and RNA strings

Oil glands Cellular cavities beneath the epidermis containing essential oils present in citrus fruits and other vegetative organs; visible on fruit surface as round dots in pits

Oospores Thick-walled sexual spores of fungi and oomycetes
Organic matter Substances based upon carbon compounds made by living organisms
Orla Fruit of the first three years of a fruit tree, the eating of which is forbidden according to Jewish law (Lev 19:23)
Ovary Part of the female reproductive organ of the flower, from which the fruit develops
Parasitism The relationship between two different species, where one gains benefits at the expense of the companion
Parenchyma The main cellular tissue of plant organs
Particle size The diameter, in millimeters, of suspended soil particle compositions Particle-size classifications are:
[1] Clay—0.00024–0.004 mm (mm)
[2] Silt—0.004–0.062 mm
[3] Sand—0.062–2.0 mm
[4] Gravel—2.0–64.0 mm
Pathotype Strains of a single pathogen species differing in their ability to attack different varieties of the same host species
PDA (Potato dextrose agar); a culture medium of pathogenic microorganism
Pedicel The stalk that connects the fruit to the mother tree; the fruit obtains all of its water and nutritional supply via the pedicel
Persistent style The top of the style (*pitam*) normally drops from the ovary by the end of flowering; in certain citron varieties the style is retained at the top of the developing fruit
Ph A measure of the relative acidity or alkalinity of water; water with a pH of 7 is neutral; lower than pH 7 levels indicate increasing acidity, while higher than pH 7 levels indicate increasingly basic solutions
Phenology The description of the relationships between environmental conditions and biological processes such as insect or tree development; defines the timing of recurring biological events and weather factors
Phenotype The physical expression (shape and form) of genetic traits embedded within the DNA (genotype) of a living organism
Phialide A conidiogenous fungus cell in which the meristematic remains unchanged as successive conidia forming chains are extruded
Phialoconidia A conidium produced from a phialide
Phloem restricted bacteria A population of walled and/or wall-less intracellular pathogenic bacteria, transmitted by phloem feeding insects
Phloem The vascular system of plants that transports the products of photosynthesis from the leaves to the roots, fruits, and other plant organs
Photosynthesis The central biochemical process of plant cells that uses the energy of sunlight to form from carbon dioxide and water the energy storing sugar molecules from which all plant dry matter is derived
Phylogenesis The course of formation of living or extinct plant or animal genera based on genetic evidence
Phylogeny The genetic hierarchical relationship between groups of organisms

Physiology The study of the chemical and physical processes of a living organism

Phytotoxic glycopeptide Sugar combined molecules that are poisonous or toxic to plants

Pitam The top of the style, in citron flowers, which in certain varieties is retained at the top of the developing and mature fruit

Plant hormone A biological compound used by plants to control the development and functions of their cells and tissues

Plant propagation The reproduction of plant organisms (sexual/asexual)

Planthoppers Are placed among twenty families of the order Hemiptera, in the infraorder Fulgoromorpha; they feed by sucking sap from plants and the nymphs produce copious quantities of honeydew

Pleiomorphic Cellular organism showing distinct size and shapes

Pollen Mostly yellow grains formed in the stamens of the flower containing the male sex cells

Presumptively non-grafted Citron trees with reliable evidence that neither they nor their predecessor trees were ever grafted

Psyllids Small plant-feeding insects that tend to be very host-specific; belong to several families in the superfamily Psylloidea of the order Hemiptera; in some species the adults vector bacterial plant pathogen

Pycnidium (plural pycnidia) An asexual fruiting body produced by certain fungi

Quarantine pest A noxious organism, a plant, an arthropod, or a vertebrate of potential economic importance to agricultural settings or forests; refers to a species not yet present in a country where it could establish itself

Responsa Collection of the halakhic correspondence of a rabbinic figure

Revaii Fruit of the fourth year after planting which, according to Jewish law (Lev 19:24), must be redeemed prior to eating

Ribosomal ribonucleic acid (rRNA) The RNA component of ribosomes

Ribosome A complex cellular structure used to translate RNA molecules transcribed from the genotype of an organism into its cellular proteins

RNA polymerase (RNAP) or ribonucleic acid polymerase A multi sub-unit enzyme that catalyzes the process of transcription of a DNA template into an RNA polymer

Saprophyte An organism that feeds on non-living tissues or organisms that feed and grow on dead organisms

Scale insects Small insects of the infraorder Coccomorpha; they pierce plant tissues with their mouthparts and remain in one place; adult females retain the larval juvenile features together with sexual maturity

Secondary metabolites Organic compounds not directly involved in plant metabolism

Sexual (reproductive) plant propagation Propagation from seed

Shmitah The seventh year, in which, according to Jewish law (Lev 25:4) agricultural activity is forbidden

Specific conductance A measure of electrical current conductance used for approximating the total salt content of a water source

Sporangia Oomycote structures within which spores are produced

Spores Dormant bodies that carry all the genetic material of certain bacteria or fungi

Stomates Pores found in the epidermis of leaves that regulate the exchange of water vapor and carbon dioxide with the atmosphere

Style The top part of the female reproductive organ of the flower, protruding from the ovary

Synanamorphs A single fungus that produces multiple morphologically distinct anamorphs

Taxonomy The system of classification of all past and presently living biological entities

Teleomorphs The sexual reproductive stage typically a fruiting body of a fungus

Tradition (With regard to citron); citron trees with reliable evidence regarding the source of seeds or cuttings from which they were propagated

Vacuole A subcellular compartment surrounded by a membrane, which holds various solutions or materials

Viroids Small (240–400 base length) single-stranded, circular RNAs that are infectious pathogens of plants

Virus An autonomous chain of nucleic acids (DNA or RNA), which lives within a cellular organism and uses the cellular machinery to reproduce and function

Water potential The potential energy of water in a system compared to pure water, under constant temperature and pressure conditions

Water quality The chemical, physical, and biological characteristics of water, with respect to its suitability for irrigation

White flies Sap feeders producing honeydew of one family in the superfamily Aleyrodoidea; are abundant in warm climates; the adults are tiny with a pale yellow or white body; the nymphs are flat, oval, and usually covered with a white waxy substance

Xylem The Vascular system of plants that transports water and mineral nutrients from the roots to the canopy

* Arranged by M. Bar-Joseph, Z. Mendel and E.E. Goldschmidt